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RESEARCH ARTICLE

WATER USE AND MAIZE GROWTH IN A UNIVERSITY FARM

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ABSTRACT

An experiment was conducted at the University of Nigeria Nsukka Experimental Farm to determine the water use by maize (Zea mays L.) from its early period of growth to maturity at three (3), nitrogen levels of 100kgN/ha, 130kgN/ha and 160kgN/ha. A modified field water balance equation was employed to approximate the water use. This was compared with the Blaney and Criddle formula. Result findings showed that with the modified field water balance equation 365.63mm was the water use. The water use by maize crop at different N levels were relatively the same. With the Blaney and Criddle formula the calculated consumptive use was 307.34mm, thus approximately 19% difference was noted in the two methods. With the result one can estimate the amount of water need and farm water application efficiency for maximum maize production in southeastern soils of Nigeria.

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INTRODUCTION

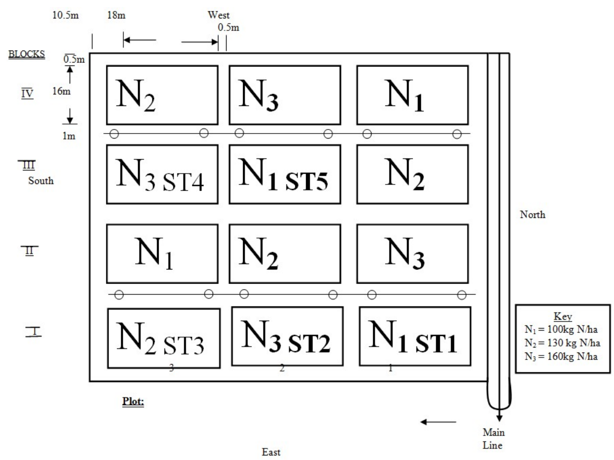
Crop production in humid tropical area like Nigeria and south east in particular is largely dependent on rain fall because irrigation water is cost and farmers cannot afford the technology. The area witnesses high rain fall and temperature that influence the soil ecological system of which may be positive or negative. That water is needed for crop production is not an over statement as water is required for plant growth, seed germination, transport of nutrients from the soil to the plant, cooling the plants atmosphere, acting as solvent for plant nutrients, as cellular constituents, help maintain turgidity of the tissue. Also,an essential ingredient in combination with solar energy and chlorophyll in the manufacture of carbohydrates by green plants. For a given crop there is water above which optimum yields are obtained but below which yields are less than the optimum (Wilson, 1968). However, to have a successful rain fed crop production in humid tropical environments depends on a lot of factors that include but not limited to soil bulk density, porosity, infiltration rate, water holding capacity, hydraulic conductivity, soil surface sealing and crusting (as a result of periodic wetting and drying), surface roughness/hard pans, solar radiation, tillage, soil type, crop species and root system and land use management. These factors greatly influence the quality and quantity of available water and nutrients very critical and major importance in crop production. Some of them determine the hydrological properties of soil. In compacted soil, water infiltration is reduced, increased penetration resistance, low porosity and hence limited root growth that will influence water use efficiency and yield. Ismail and Ozawa (2007) observed an increased water use efficiency of 45 – 64% in crop grown on clayey soil than sandy soil, while Dou *et al*. (2016) in their own work reported 25% increase in water use efficiency for rice grown on clayey than sandy loam soils. In another work crop root system was found to influence water use efficiency in winter wheat and its capacity to absorb water and pick up plant nutrients (Hochholdinger, 2016;Guan *et al*., 2015; Bengough *et al*., 2011; White and Kirkegaard, 2010; Yadav *et al*., 2009). Also, the flow of heat is being noted to be higher in a wet soil than in a dry soil. According to Ochsnor *et al*. (2001) and Onwuka and Mang (2018) dissipation of soil heat increases with soil water content. Broad bent (2015) noted that more water is allowed to penetrate the soil profile, when increased soil temperature decreased water viscosity. Increased viscosity decreases water absorption and uptake by plants at low temperature (Toseli *et al*., 1999). The implication is that the rate of photosynthesis is reduced, hence low food production and yield. Soils of low water holding capacity is also a big challenge to crop production and water use as they usually fail to provide enough moisture during the plant growing season due to dry weather conditions and erratic distribution of rain fall. On the other hand, tillage can improve soil hydro-physical properties and organic matter (OM) decomposition, thereby increase rain water penetration and transmission of all that dissolve therein within the soil profile. This increase root penetration and proliferation, water use efficiency and yields. Nonetheless, the use of wooden hoe as a common tillage equipment tool used by most farmers in Nigeria encourages crust and hard pan formation. This constitute a major problem in water infiltration, transmission and use by crop plants. That in such soil deep tillage is needed in other to improve the hydrological conditions and properties of the soil that will lead to increased water use efficiency of the crop and yield. In as much as water is very important in crop production, it produces undesirable effects when mismanaged. When it is supplied extensively to plants, soil aeration is hindered, a condition which is unfavourable to plants. On the other hand, when supplied insufficiently it causes the plant to wilt away or the seed not to germinate. For optimum crop growth and performance, the water supplied must be the required amount. In fact, water its availability in quality and quantity is a major influencer in the plant – soil – ecosystem (Xu *et al*., 2016; Wang *et al*., 2014; Zhang *et al*., 2009).

Water use by crops studied by some workers has established that water needs of various crops differ significantly as both the vegetative and reproductive stages of the crops are greatly affected by the available water content of the soil. Kowal and Kassam (1973) in their study of energy and water budget of maize crop grown in a dry sub-humid climate of northern Nigeria assessed and related crop performance, the pattern of crop water requirement during the growing season. They found out that the period of maximum water requirement by the crop occur when the leaf area index was greater than 2:1 and coincide with the period when the amount and frequency of rainfall was greatest. The rate of crop growth was drastically reduced when soil water potential decreased below – 0.5bar, total water used by the maize plant during 117days from sowing to harvest was 486mm of which 345mm was transpired through the plants while crop water use efficiency was 355g of water per grain of dry matter. Dimitrov (1970) observed that the greatest yield increase in maize was obtained when the soil moisture content was above 80 percent of field capacity, throughout the vegetative period. Mbagwu (1985) worked on three soils of different locations, Onne, IKnne and Ilora southern Nigeria, noted that the dry season crop water requirement could be estimated from crop evapotranspiration (ET crop). The water budget of each location was computed using mean monthly rainfall, temperature and potential evapotranspiration and average profile water holding capacity of the soil. The water budget showed that during the dry season months there are soil moisture utilization of net deficits 147mm at Onne, 344mm at Ikenne and 347mm at Ilora, his results showed that supplementary irrigation will be needed. The crop evapotranspiration varied from 5.0-6.0mmday^{-1}, rooting depths from 30-100cm and irrigation intervals from 4-15days. Lawson and Blatt (2014) however, argued that crops perform more effectively and reduce water use through transpiration when they balance atmospheric gas exchanges to increase the uptake of CO_2 for photosynthesis. Maize is one of the grains used presently today in many families in preparing many kinds of food and dishes. It is used in breweries and as silage in animal production, therefore, maximizing its production is very important. This can be done by growing it in season and off season. Thus, it is necessary to acquire a good knowledge of water use and growth of the maize. Water input could be through the rainfall during the season or through irrigationwater during the off season. To get the most out of each unit of water we must know how much water to apply, when to apply it, where to apply it and how to design and manage an irrigation system. Hence the objective of this present work is to determine the water used by maize crop (Zea mays L.) from early growth to the point of maturity at the University of Nigeria Nsukka campus farm.

MATERIALS AND METHODS

Site description: This study was conducted at the University of Nigeria Nsukka Agricultural Farm. The soil is classified as Ultisol and belong to the sub-group Oxic Paleustult. Generally, the soils have high percentage of sand and granular structure at the top and the top soil is characterized by rapid to very rapid permeability (Obi and Asiegbu, 1980). The climate is characterized by a near uniformly high temperature and seasonal distribution of precipitation. The average annual rainfall is about 1800mm.The area witnessa bimodal distribution of rainfall generally; a minor dry season occurs in August. The area witnesses a minimal change between day and night temperature and little change in temperature from one season to another. The areas fall between Latitude 06 52^{I}, 07 24^{I} E (Jungerius, 1964). Humidity is generally low duringharmattanwhich is always very desiccating with the accompanying high speed of wind. The vegetative cover of the soils was the common savannah regrowth.

Field Methods: Randomization of treatments and field layout in university cereals research farm.



The area measuring 0.39ha was ploughed and ridged and marked out into plots as in Figure 1. The experiment which was a randomized block design has four blocks and three treatments of Nitrogen fertilizer levels of 100kgNha^{-1}, 130kgNha^{-1} and 160kgNha^{-1} as N1, N2 and N3 treatment respectively. Each plot has the dimension of 16m x 18m (288m^2) and space of 1m between blocks and 0.5m between treatments. A space of 0.5m was allowed from the treatments to the edges of the field and 1m space for the main line irrigation pipe lines.

Installation and reading of the Tensiometers: Tensiometers were installed at 30cm and 60cm depth at representative points ST1, ST2, ST3, ST4 and ST5 as shown in the sketch Figure 1 above.There were together five points. The tensiometers were used to monitor changes in soil metric potential on weakly bases. Before installation each tensiometer was filled with distilled water and corked. The porous cups of the tensiometers were soaked for 24hours to have them saturated after which suction pump was used to suck out air that must have been entrapped within the system. Auger was used in excavating the spots where the tensiometers were installed. The soil was packed back firmly at each installation to minimize the possibility of excess water flow through the disturbed soil (Marshall and Strick, 1949) close contact between the cup and soil was ensured. Reasonable quantity of water was ponded after installation to ensure moisture penetration to at least 200cm. Tensiometer readings were taken at the same time every week at 11'0 clock so as to follow a period of slow temperature change because according to Richards (1949) tensiometer readings generally increase during the afternoon. The weekly tensiometer readings were taken throughout the period of the maize crop growth and development.

Samples for soil characterization: Core samplers of height 5.6cm by 5.0cm diameter were used in collecting some soil samples. Undisturbed cores of soils were obtained by pushing metal cylinders vertically into moist soil to obtain the samples at a required depth. Auger samples were also obtained from each plot before and after the study.

Infiltration measurements: Double ring infiltrometer was used to determine water infiltration at representative location in the experimental field. Water was provided by the aid of a siphon from the tap to the points. Readings were taken at 5 months' interval and water was poured when needed until the reading go to a steady at about three hours in each point.

Crop Establishment: The tensiometer readings and other measurements/readings commenced a month after maize establishment or planting. The maize height was measured with a ruler calibrated in centimeters. The plant height for 5 plants in each point was taken. The measurement was taken weakly starting from a month after planting until the maize was due for harvesting. Water was supplied through rainfall and sprinkler irrigation.

Laboratory Methods

Particle size: The particle size analysis of the soil was carried out at the beginning and at the end of the study. The textural class was determined using Bouyoucos (1951) hydrometer method.

Bulk density: this was determined by core method

Determination of crop water use: Modified field water balance equation was used in calculating the water used by the maize within these periods. The modified field water balance equation is

$$W = I + P - R - \Delta DE$$

Where;

W= water use
I= Irrigation water supplied
P= rainfall in the growing season
R = runoff
ΔDE= change in soil moisture content.
Below expressions are used to convert water use in inches to mm
1 inch = 2.54cm; 1cm = 10mm

Organic matter content: This was determined by Walkley and Black oxidation method (Walkley and Black, 1934).

Data Analysis: Data collected from the study were subjected to analysis of variance (ANOVA) and significant difference among treatment means were separated using least significant difference (LSD) at 5%

RESULTS AND DISCUSSION

The result presented in Table 1 showed the soil texture, organic matter (OM) content and bulk density of the soil before and after the study. The result showed that the texture of the soil is loamy sand (LS) both before and after the study. The sand fraction and bulk density of the soil decreased after the study, while the silt and clay fraction and OM content of the soil increased. Texture is an attribute of the nature of parent material which in this case is false bedded sand stone (Jungerius, 1964). The low OM and increased bulk density (BD) observed before the experiment may be due to intense weathering on the soil due to high temperature and rainfall prevailing in the area. According to Nweke and Chime (2021) most soils in Nigeria especially the southeastern soils are highly weathered, degraded, high bulk density and erosion as a result of continuous cultivation, high rainfall and temperature.The low quantity of OM simple suggests low influence on water retention and use by the maize plant. The increased OM and decreased bulk density simply apply improved porosity, structure, water retention and transmission. This probable may be due to increased activities of soil microbes as a result of N addition and root exudates of maize plant. Thus, different N levels treatments influence the result of the study. Root exudation is a major source of SOCreleased by plant roots (Nguyen, 2003)

Plant Height: The result in Table 2 showed maize heights at different dates. The highest maize height of 238cm was obtained from the plot treated with highest N level of N3, this was followed by N2 with 178cm and N1 170cm. Since all plant received equal amount of irrigation water, it is of evident that the quantity of N levels applied has effect on the growth of the plant. Thus, those plots with higher N application recorded higher maize height. After tasseling the maize did not grow any further in height. This probably may be the reason for the same maize height recorded for N1, N2 and N3 in 6-8weeeks. Mineral fertilizer exerts strong influence on the vegetative growth development of plants according to the studies of Nnabude *et al*. (2015), Nweke and Nsoanya (2015, 2013).

Soil moisture tension at 30cm and 60cm depth under different N levels: The mean corrected tensiometer readings are shown in Table 3. There was a sharp increase in tension during the 4th and 5th weeks of the maize growth to 370cm, 320cm and 510cm for N1, N2, and N3 respectively at 30cm depth. The increase in tension simple suggest higher soil water utilization by the maize plants during their tasseling stage and perhaps indicates higher water loss through evaporation during the same period. All decreased as weeks under study increased though the decrease did not follow a particular order. The reading value however, increased in the 8th weeks with N3 recording the highest value of 470cm and least value of 310cm obtained from N2. At 60cm depth the tensiometer reading recorded highest reading of 150cm at 8th weeks for N1 and 380cm at 4th week for N2 and 240cm at 8th week for N3 levels respectively. It was observed from the result that the tensiometer reading at 60cm depth is lesser in value to 30cm

Table 1. Soil particle size, organic carbon and bulk density of the soil before and after the experiment

	Before the study						After the study					
Treatment	Sand %	Silt %	Clay %	TC	OC %	BD g/cm3	Sand %	Silt %	Clay %	TC	OC %	BD g/cm3
N1(100kgNha1)	87.o	2.6	10.4	LS	1.4	1.42	85.0	2.4	12.6	LS	1.45	1.43
N2(130kgNha1)	86.5	2.7	10.8	LS	1.4	1.52	84.3	2.8	12.9	LS	1.47	1,44
N3(160kgNha1)	86.8	2.7	10.5	LS	1.4	1.55	84.4	3.7	11.9	LS	1.50	1.40
Mean	86.77	2.67	10.57		1.4	1.50	84.57	2.97	12.47		1.47	1.42
LSD 0.05	NS	NS	NS		NS	0.023	NS	0.463	0.591		NS	NS

Table 2. Average plant height (cm)

Week measured	N1	N2	N3
Month after establ.	37	33	52
One week	59	55	75
2 weeks	85	74	100
3weeks	115	113	157
4weeks	137	137	188
5weeks	163	170	202
6weeks	170	178	238
7weeks	170	178	238
8weeks	170	178	238
Mean	122.889	124	165.333

N1 = 100kgNha^{-1}, N2 = 130kgNha^{-1}, N3 = 160kgNha^{-1}

Table 3 Mean corrected tensiometer reading at 30 and 60 cm depth under different N levels

week/depth	30cm	30cm	30cm	60cm	60cm	60cm
	N1	N2	N3	N1	N2	N3
Month after establ.	120	120	130	95	130	60
One week	130	150	150	120	140	80
2 weeks	55	70	100	40	105	60
3weeks	85	110	110	70	90	40
4weeks	370	270	420	95	380	180
5weeks	270	320	510	100	200	190
6weeks	60	130	210	40	165	90
7weeks	175	200	240	90	270	120
8weeks	320	310	470	150	150	240
Mean	176.111	187.779	260	88.889	181.111	117.778

N1 = 100kgNha^{-1}, N2 = 130kgNha^{-1}, N3 = 160kgNha^{-1}

Table 4. Weekly change in soil moisture and the water use

Week	Treatment	Change in soil moisture	W = P+I-R-ΔDE
One week	N1	-1.4527	15.78
	N2	-1.3795	15.70
	N3	-2.8681	11.46
Mean		-1.8015	14.8133
2 weeks	N1	2.8076	3.82
	N2	2.6962	3.93
	N3	2.3342	4.30
Mean		2.6127	4.0167
3weeks	N1	-1.1987	147.78
	N2	-0.063	146.52
	N3	-1.8037	148.38
Mean		-1.0218	147.56
4weeks	N1	-1.8847	60.96
	N2	-0.4274	59.50
	N3	-9.0455	68.11
Mean		-3.7859	62.8567
5weeks	N1	0.7300	5.90
	N2	6.0037	0.63
	N3	8.2165	-1.59
Mean		4.9834	1.6467
6weeks	N1	-2.1250	66.14
	N2	-5.1620	69.17
	N3	-15.3980	79.41
Mean		-7.5617	71.5733
7weeks	N1	5.6960	31.33
	N2	6.3950	30.64
	N3	7.7038	29.33
Mean		6.5983	30.4333
8weeks	N1	-1.7038	33.70
	N2	-4.3220	36.32
	N3	1.5386	30.46
Mean		-1.4957	33.433

Run off - Rainfall 50%, Irrigation 20%

Table 5. Water use by modified field water balance equation (W = I + P-R-ΔDE) mm

Week measured	N1	N2	N3
One week	15.78	15.70	11.46
2 weeks	3.82	3.93	4.3
3weeks	147.78	146.52	148.38
4weeks	60.96	59.50	68.11
5weeks	5.9	0.63	-1.59
6weeks	66.14	69.17	79.41
7weeks	31.33	30.64	29.33
8weeks	33.70	36.32	30.46
Total	364.63	362.41	369.86

Mean of the three (3) total = 365.63mm N1 = 100kgNha^{-1}, N2 = 130kgNha^{-1}, N3 = 160kgNha^{-1}

Table 6. Blaney and Criddle method

Month	Mean monthly Temperature (^{O}f)	Day time hours %	Consumptive use factor	Coefficient K	Consumptive use in inches
February	51	7.47	3.81	0.89	3.39
March	50	8.45	4.23	1.28	5.41
April	50	6.98	3.50	1.91	6.69
Mean	50.33	7.633	3.847	1.38	5.163

depth reading at different N levels with the least of all at 60cm depth N1 (88.89) when N1 – N3 and both 30cm/60cm depths are compared. Also observed is that recorded readings of the tensiometer is independent of increase in weeks but close observation showed that the reading value increased with the increase in N levels though more pronounced in 30cm depth relative to 60cm depth. This result scenario agrees with the work of IITA (1975), conducted at Ibadan, Nigeria and FAO/UNESCO, (1973). The observed rise and fall in tensiometer reading could be associated with temperature variations. Broad bent, (2015) noted that soil moisture decreased with increased soil temperature of which allow more water to pass through the soil.

Weekly change in soil moisture and the water use: The water uses by the maize plant recorded in Table 4 indicated that the maize plant used more water at 3, 4 and 6th weeks but the least of all was the water use at 5th week. Maize is the best crop material for silage in animal production and the most preferred feed ingredients in other home and industrial products because of its high-quality digestible energy and greater portion of the grain (Bhattarai *et al.*, 2019), but high water demand and inability to cope with water stress and heat under limited water supply according to Steward *et al.* (2013) is big a challenge to maize production. Thus, many variables have been noted to limit the availability of water resources for efficient crop production activities (Kumar *et al.*, 2024; Zhiqiang *et al.*, 2023; Kilemo, 2022; Celerino, 2021; Muhammad *et al.*, 2021; Mbavaa *et al.*, 2020; Bishwoyog *et al.*, 2020; Suwei *et al.*, 2017).

Water use efficiency by modified water balance equation (W = I + P-R-ΔDE): The result in Table 5 showed maize water consumptive use by modified method, while Table 6 showed water consumptive use by Blaney and Criddle method. The modified water consumptive use showed no relative difference for the water use at the various N levels. The average water used was 365.63mm to the time the maize matured. The Blaney and Criddle method gave a total water used within the period as 307.34mm as against 365.63mm by modified field water balance equation. The result simple suggest that with climatological data using Blaney and Criddle method recorded 19% lesser than the value recorded with modified field water balance equation. This study to an extent agrees with the work of Gumbs and Shastry (1978) at Trinidad. The climatological data measured in Trinidad was 6%lesser than the value measured with Lysimeters in Trinidad. The consumptive use of water by maize plant within the period under study = 307.34mm.Comparison between Blaney and Criddle formula and modified field water balances equation (W = I + P-R-ΔDE): W = I + P-R-ΔDE = 365.63 mm. Blaney and Criddle formula = 307.34mm, Difference between the two = 58.29mm;% difference = 18.97%, Approximately 19%

CONCLUSION

The result findings of the study have indicated that there was no major difference in water use by maize plant at the different levels of N application. But the difference of 58.29mm or 19% is got when comparing the two methods that were applied in the study. The modified field water balance equation has 365.63mm as water use during the period, while Blaney and Criddle formula has 307.34mm as the water use during the period. With this one can estimate the amount of water needed for effective maize production even in dry season at various N levels and enhance farm water application efficiency and maximize maize production in the studied area.

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