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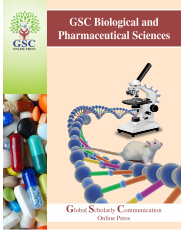

(RESEARCH ARTICLE)

Evolving effective irrigating schedule for potted maize crop

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Abstract

The trial, a 2 x 7 Factorial experiment evaluates two watering regimes: 25 ml of irrigation applied full dose in the Morning (M), or Afternoon (A) or Evening (E), as well as two equal-split applications applied either in the Morning + Afternoon (MA), or Morning + Evening (ME) or Afternoon + Evening (AE), in addition to three equal-split application applied Morning + Afternoon + Evening (MAE). A second irrigation regime was application of 50 ml of irrigation water applied in the same sequence as for 25 ml. A 4-day application schedule was maintained for both watering regimes. Analysis of data reveal that final crop heights were significantly ($p \leq 0.05$) influenced by irrigation schedule as well as by volume of irrigation applied in both 2017 and 2018 trials. 50 ml of irrigation applied consistently gave better crop heights in both trials. Stem girth however did not respond significantly ($p \geq 0.05$) to irrigation schedule and to volume of irrigation applied. In 2017 trial leaf number and leaf area were also not significantly ($p \geq 0.05$) influenced by irrigation schedule investigated as well as the volume of water given. However trials conducted in 2018 indicates significant response of leave area to irrigation schedule as well as rate. Yield parameters responded significantly ($p \leq 0.05$) to irrigation application, with 50 ml irrigation given better grain yield than 25 ml. Application of water in the Morning gave the best yield responses, thus recommended. The least yield responses were observed when irrigation water was delivered in the Afternoon.

Keywords: Climate change; Water application; Morning; Afternoon; Evening and Subsistence agriculture

1. Introduction

It has been frequently reported that the earth surface is made up of ¾ waters yet obtaining water in the required quantity as well as quality has eluded many African nations.

Water is critical for human development - for his domestic uses, the crop he planted (either for irrigation or in crop processing) as well as in his animal husbandry enterprise. Recent years have witnessed a great intensification of land and water use in an effort to increase agricultural production in many parts of the world. This involved application of modern techniques leading to an increased farming efficiency. As a consequence great attention has been paid to irrigation. According to the International Water Management Institute, agricultural activities account for about 70 per cent of global water withdrawals cited in [1].

Oyewole and Alemeru [1] had observed that, a world where water is becoming a scarce resource, complicated by population growth with its expanding demands for water, dwindling financial capacity to meet water demands and competition for available finance, balancing domestic water requirements against agricultural needs would be an important policy decision in decades ahead.

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Foundation for Arable Research (FAR) [2] observed that drought is one of the main causes in seasonal yield variation. Stressing that crop response to drought can be calculated in terms of potential soil moisture deficit (PSMD), the cumulative difference between crop demand and water supply.

Assessing irrigation performance plays an important role in improving irrigation efficiency and water resource management. The need to establish just how much water crops require would be an important task; as the great challenge for the coming decades would be the task of increasing food production with less water. The task is complicated, observing that recent climate change activities have been impacting on rainfalls with often negative implications for the available water bodies [1]. To mitigate these effects, efforts must be made to effectively manage water utilization in agricultural production as a mean to cushioning its effect on the dwindling resource; this would not be an easy task for policy makers in the agricultural sectors, observing the regular absence of political will among monitoring agencies to enforce policy decisions.

Observing that the main approach in water schedule is to save water, labour and energy, by eliminating those irrigations with minimal effects on yield, this trial set out to investigate the following objectives: (i) To determine the response of maize growth to different water scheduling, (ii) to determine the response of maize development to different water scheduling, (iii) to determine the response of maize yield to different water scheduling and (iv) to determine the most effective water schedule for maize performance: growth, development and yield components and yield and economic implications.

2. Material and methods

2.1. Experimental Location

The experiment, a pot trial, was conducted in Kogi State University, Anyigba (Latitude $7^0.6^1$ N and Longitude $7^0.43^1$ E) (under constructed corrugated roof pavilion with cemented floor) between May and August 2017 and repeated in 2018.

2.2. Experimental Treatments and Design

The trial, which was a 2 x 7 Factorial experiment evaluates two watering regimes: 25 ml of irrigation applied full dose in the Morning (M), or Afternoon (A) or Evening (E), as well as two equal-split applications applied either in the Morning + Afternoon (MA), or Morning + Evening (ME) or Afternoon + Evening (AE), in addition to three equal-split application applied Morning + Afternoon + Evening (MAE). A second irrigation rate was application of 50 ml of irrigation water applied in the same sequence as for 25 ml. A 4-day application schedule was maintained for both watering volumes.

2.3. Cultural Practice

Two maize seeds were sown into an un-perforated black plastic bucket holding 10 kg of sandy-loam soil obtained from a fallowed farm land. The maize stands were later thinned to one vigorous plant per stand two weeks after sowing (2 WAS). The crop was kept weed free by hand pulling weeds regularly, while watering was done as in the treatment when the crops were two weeks old. The soil was also regularly pulverized to ensure water infiltration and aeration. Spot application of compound fertilizer NPK (15:15:15) 2 WAS and at tassel stage at the rate of 2g per pot was conducted. Crop stands received a total of 25 irrigations before harvest.

2.4. Data Collection

Growth and development data were collected at 2, 4, 6 8 WAS and at crop harvest, while data on yield components and yield were determined at the termination of the trial. Data were collected on plant height, being a measure of plant height from ground level to the pick of the longest leaf (before tassel) or the tassel (after tassel); Number of leaves per plant, numerical counting of all fully unfolded leaves. Other parameters collected were leaf area**,** and stem girth in accordance with [3]. While data on yield and yield components, such as cob yield, cob weight and grain yield were also obtained over a Metler weighing scale to two decimal places.

2.4.1. Productivity of total applied water (PAW)

According to Molden [4] the productivity of total applied water (PAW) is defined as crop yield per unit of volume of water supplied to the crop, being estimated by dividing crop yield by the total applied water (rainfall + irrigation).

2.5. Statistical Analysis

All data collected was subjected to Analysis of Variance (ANOVA) using the Statistical Analysis System (SAS) 1998 Package for Factorial Experiment [5].

3. Results and Discussion

3.1. Effect of irrigation scheduling and volume on crop height

Final crop heights were significantly ($p \leq 0.05$) influenced by irrigation schedule (Table 1) as well as by volume of irrigation applied in 2017 and 2018 trials. 50 ml of irrigation applied consistently gave better crop heights in both trials relative to other treatments. While the effect of

volume applied was evident at 2WAS mode of application either as time applied or single / split dosage was only evident as from 8WAS; an indication that as the crop grows its water requirement increases requiring an increase in frequency and volume of irrigation application. That cell growth is considered one of the most drought-sensitive physiological processes due to the reduction in turgor pressure [6]; with drought causing impaired mitosis resulting in reduced growth [7], may have accounted for the observed height response to irrigation application, with noticeable reduction in plant height with reduced water level.

The observed outcome in this trial was in line with previous observations that maize is relatively insensitive to soil moisture deficits imposed during early vegetative stage [8, 9, 1]; as the response to water stress only became noticable at 8WAS. As the crop grew and water requirements probably increases, under severe water deficiencies imposed by either scheduling or volume, cell elongation can be inhibited by interruption of water flow from the xylem to the surrounding elongating cells [6], with negative impact on height - usually, a common adverse effect of water stress on crop plants is the reduction in fresh and dry biomass production [10]. Generally, better height performances were observed when irrigation was given in the morning as a single dose compared with other treatments, with the least height responses observed when

irrigation was given in the afternoon; an indication that temperature increase may have effect on water uptake in maize crop. Increase in temperature is expected to negatively influence stomata opening [11], which should have a negative effect on transpiration pull, thus affecting uptake of irrigation water applied during heated weather such as in the afternoon.

3.2. Effect of irrigation scheduling and volume on crop girth

In 2017 and 2018 trials crop girth did not significantly ($p \geq 0.05$) respond to irrigation schedule and to volume of irrigation applied (Table 2). Though not statistically significant, crops treated to morning irrigation gave the best performance in 2018 trial. Stem girth, which is a measure of a plant's stem width, is an indication of the stem ability to resist lodging resulting from wind or cob bearing [1]. The thicker the girth, the less breakable the stem would be [1].

3.3. Effect of irrigation scheduling and rate of water application on leaf number and leaf area

In 2017 trial leaf number (Table 3) and leaf area (Table 4) were not significantly ($p \geq 0.05$) influenced by irrigation schedule investigated as well as the volume of water given. However trials conducted in 2018 indicates significant response of leave area to irrigation schedule as well as water volume delivered (Tables 3 and 4). This latter observation is in line with previous reports that leaf area expansion depends on leaf turgor, temperature, and assimilating supply for growth; stating that drought-induced reduction in leaf area [12] as a result of suppression of leaf expansion through reduction in photosynthesis. Such expected response may however be limited to drought situation [12], or where the crop water thirst far exceeds irrigation delivered, which may have accounted for the observation obtained in 2018. The probable absence of such water deficit in 2017 may have resulted in the observed non-significant influence of the treatment on leaf area particularly.

Table 1 Effect of irrigation time and rate of water application on maize height

Irrigation Schedule	Plant Height (cm)									
	2017					2018				
	2WAS	4WAS	6WAS	8WAS	Final height	2WAS	4WAS	6WAS	8WAS	Final height
	Application of 25 ml of water every 4-days									
M	22.00	46.90	71.55	80.23	134.00	53.33	63.55	96.31	141.07	241.07
A	10.87	25.75	40.10	61.17	110.00	50.11	61.01	91.45	121.40	221.40
E	15.37	35.97	51.17	75.27	98.00	53.22	61.39	94.66	119.10	229.10
MA	12.50	30.80	51.17	67.80	103.00	51.33	60.81	90.71	125.30	235.30
ME	14.73	35.37	57.80	70.43	122.00	51.66	62.56	92.22	134.50	234.50
AE	10.93	26.67	41.70	68.80	114.00	50.12	61.10	90.33	103.07	203.07
MAE	21.37	40.60	68.80	77.27	120.00	51.33	62.30	92.60	127.01	230.01
Mean	15.40	34.58	54.61	71.57	114.43	51.59	61.82	92.61	124.49	227.78
	Application of 50 ml of water every 4-days									
M	29.93	53.30	112.00	123.57	241.07	55.33	64.87	94.34	141.07	247.63
A	17.23	33.43	62.90	93.50	221.40	53.00	61.00	90.66	121.40	231.14
E	28.33	33.40	73.67	88.67	219.10	55.11	64.20	98.22	119.10	239.71
MA	29.00	42.53	89.13	99.83	225.30	57.12	63.56	93.20	125.30	232.56
ME	27.37	39.33	84.60	99.63	234.50	53.01	62.20	92.47	134.50	231.78
AE	16.17	31.10	51.60	71.67	203.07	52.33	64.01	91.36	103.07	197.37
MAE	32.47	52.20	90.00	107.00	240.01	53.33	62.01	92.22	140.01	226.57
Mean	25.79	40.76	80.56	97.70	226.35	54.18	63.12	93.21	126.35	229.54
LSD	Ns	Ns	Ns	3.678	6.452	Ns	Ns	Ns	3.081	6.563

MAE: Three equal split given morning, afternoon and evening; MA: Two equal split given morning and afternoon
ME: Two equal split given morning and evening; M: Single irrigation given morning
A: Single irrigation given afternoon; E: Single irrigation given evening

Table 2 Effect of irrigation time and rate of water application on maize stem girth

Irrigation Schedule	Stem Girth (cm)									
	2017					2018				
	2WAS	4WAS	6WAS	8WAS	Final girth	2WAS	4WAS	6WAS	8WAS	Final girth
	Application of 25 ml of water every 4-days									
M	0.33	0.60	0.67	0.71	0.91	1.21	1.52	1.91	2.47	5.71
A	0.43	0.49	0.61	0.79	0.90	1.20	1.22	1.60	2.13	3.23
E	0.85	1.02	1.06	1.10	1.20	1.21	1.32	1.76	2.17	4.43
MA	0.67	0.80	1.00	1.03	1.33	1.20	1.27	1.33	2.52	4.52
ME	0.83	0.91	0.97	1.03	1.63	1.21	1.23	1.63	2.07	4.67
AE	0.40	0.49	0.70	0.74	1.01	1.20	1.39	1.41	2.17	3.17
MAE	0.77	0.83	0.97	1.02	1.40	1.22	1.33	1.40	2.46	4.66
Mean	0.61	0.73	0.85	0.92	1.20	1.21	1.33	1.58	2.28	4.34
	Application of 50 ml of water every 4-days									
M	1.13	1.20	1.27	1.28	1.47	1.28	1.91	2.65	3.71	6.47
A	0.70	0.72	0.79	0.82	1.23	1.24	1.90	2.23	2.23	3.78
E	0.61	0.83	1.08	1.10	1.17	1.31	1.96	2.65	3.33	5.72
MA	0.93	1.07	1.20	1.30	1.52	1.17	1.33	1.52	2.52	3.52
ME	0.97	1.13	1.67	1.79	2.07	1.13	1.63	2.07	2.47	4.07
AE	0.70	0.73	0.76	0.91	1.17	1.30	1.41	1.76	2.17	4.17
MAE	1.10	1.33	1.55	1.56	1.66	1.33	1.96	2.56	4.66	5.66
Mean	0.88	1.00	1.19	1.25	1.47	1.25	1.73	2.21	3.01	4.77
LSD	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

MAE: Three equal split given morning, afternoon and evening; MA: Two equal split given morning and afternoon
ME: Two equal split given morning and evening; M: Single irrigation given morning
A: Single irrigation given afternoon; E: Single irrigation given evening

Table 3 Effect of irrigation time and rate of water application on maize leaf number

Irrigation Schedule	Leaf Number (LN) 2017					2018				
	2WAS	4WAS	6WAS	8WAS	Final LN	2WAS	4WAS	6WAS	8WAS	Final LN
Application of 25 ml of water every 4-days										
M	4	5	6	9	10	3	4	5	9	11
A	3	5	8	10	11	3	5	7	10	11
E	3	5	8	9	10	3	5	7	9	10
MA	3	5	7	9	11	3	5	7	9	11
ME	3	5	6	8	10	3	4	6	8	10
AE	4	5	7	9	11	4	5	7	9	11
MAE	3	5	8	9	10	3	5	7	9	11
Mean	3	5	8	9	10	3	5	7	9	11
Application of 50 ml of water every 4-days										
M	3	5	8	9	11	4	5	6	9	11
A	3	4	6	8	10	3	5	8	10	11
E	3	3	6	8	11	3	5	8	9	10
MA	3	4	6	6	10	3	4	7	9	11
ME	2	4	8	10	11	3	5	6	8	10
AE	2	3	5	8	10	4	5	7	9	11
MAE	2	3	6	7	11	3	4	8	9	11
Mean	3	4	6	8	11	3	5	7	9	11
LSD	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

MAE: Three equal split given morning, afternoon and evening; MA: Two equal split given morning and afternoon; ME: Two equal split given morning and evening; M: Single irrigation given morning; A: Single irrigation given afternoon; E: Single irrigation given evening.LSD at 0.05 percent probability

Table 4 Effect of irrigation time and rate of water application on maize leaf area

Irrigation Schedule	Leaf Area (LA) 2017					2018				
	2WAS	4WAS	6WAS	8WAS	Final LN	2WAS	4WAS	6WAS	8WAS	Final LN
Application of 25 ml of water every 4-days										
M	11.33	40.72	164.20	285.00	654.00	13.53	71.77	275.30	779.24	1658.40
A	10.33	41.26	135.80	192.00	490.00	13.34	60.63	272.67	734.62	1496.80
E	11.34	42.19	175.70	244.00	515.00	13.54	71.42	264.52	767.29	1558.23
MA	11.34	61.72	171.80	255.00	543.00	13.44	59.01	265.91	773.19	1649.10
ME	10.33	50.13	157.10	252.00	510.00	13.43	59.66	272.87	739.24	1597.21
AE	11.00	62.42	175.50	293.00	559.00	13.00	59.26	253.76	747.83	1551.67
MAE	10.43	41.61	155.50	292.00	381.00	13.11	59.36	272.54	777.36	1654.52
Application of 50 ml of water every 4-days										
M	10.33	56.70	142.80	275.86	517.68	13.72	77.45	283.11	987.67	2852.88
A	11.33	49.01	139.06	216.70	383.30	13.22	66.83	262.34	978.41	1950.62
E	10.30	46.99	173.37	253.14	510.55	13.46	72.10	264.01	962.16	2822.64
MA	10.00	60.33	142.54	232.30	465.55	13.34	63.33	261.67	928.11	1811.21
ME	11.00	52.08	182.39	226.48	441.40	13.63	63.67	263.98	979.62	1779.12
AE	10.33	49.06	137.24	168.68	360.53	13.12	63.89	263.12	842.34	1734.32
MAE	11.33	49.56	151.06	216.41	401.80	13.41	63.34	262.56	923.29	1767.15
LSD	Ns	Ns	Ns	Ns	Ns	Ns	Ns	12.673	87.179	134.341

MAE: Three equal split given morning, afternoon and evening; MA: Two equal split given morning and afternoon; ME: Two equal split given morning and evening; M: Single irrigation given morning; A: Single irrigation given afternoon; E: Single irrigation given evening.
LSD at 0.05 percent probability

Plant leaves play crucial role in crop photosynthesis, any effect of imposed treatment on either leaf number or leaf area which may impact on photosynthesis should probably be expected to affect crop yield. Worthy of note, however is the fact that the process of yield formation involves complex interplays of various yield determining factors [13], besides leaf number and leaf area [11] with usually unpredictable outcomes. Such varying factors which may affact sink-source relation may moderate expectations away from basic principles.

3.4. Effect of irrigation scheduling and rate of water application on maize yield parameters

Yield of cobs and grains responded significantly (p≤ 0.05) to irrigation application (Table 5). When 25 ml of irrigation was applied, the highest grain yield (4.80 t/ha) was observed in a single application of water in the morning, while treatment that received 25 ml irrigation in the afternoon gave the least grain yield, though at par with Morning + Afternoon, Morning + Evening as well as Evening application. Similar outcome was observed when 50 ml of irrigation was applied, the highest grain yield (5.33 t/ha) was observed in single application of water given in the morning. The least grain response was observed when 50 ml irrigation water was given in the afternoon. Generally, application of 50 ml of irrigation water gave better grain yield that when 25 ml irrigation was given. Yield responses to water stress have been reported by [12], [8], [13], noting that prevailing water stress reduces plant growth and development, leading to hampered flower production and grain filling and thus smaller and fewer grains. With reduction in grain filling occurring due to a reduction in the assimilate partitioning and activities of sucrose and starch synthesis enzymes.

Table 5 Effect of irrigation time and rate on maize development and yield

Irrigation Schedule	Tassel branches	Yield Parameters (mean of two trials)				
		Un-dehusked Cob weight/ plant (kg)	Weight of de-husked cob/plant (Kg)	Grain yield (kg) / plant	Grain yield/ha (ton) at 53,333 plants / ha	PAW
Application of 25 ml of water every 4-days						
M	10	0.74	0.49	0.09	4.80	0.008
A	10	0.42	0.28	0.05	2.67	0.004
E	10	0.51	0.34	0.05	2.67	0.004
MA	13	0.56	0.37	0.05	2.67	0.004
ME	12	0.72	0.48	0.05	2.67	0.004
AE	13	0.53	0.34	0.05	2.67	0.004
MAE	10	0.70	0.47	0.06	2.67	0.004
Application of 50 ml of water every 4-days						
M	16	0.89	0.59	0.10	5.33	0.004
A	18	0.61	0.41	0.06	3.20	0.003
E	17	0.61	0.41	0.08	4.27	0.003
MA	19	0.71	0.48	0.09	4.80	0.004
ME	14	0.81	0.54	0.09	4.80	0.004
AE	13	0.60	0.41	0.08	4.27	0.003
MAE	14	0.79	0.52	0.09	4.80	0.004
LSD	Ns	0.013	0.019	0.005	0.167	

MAE: Three equal split given morning, afternoon and evening; MA: Two equal split given morning and afternoon; ME: Two equal split given morning and evening; M: Single irrigation given morning; A: Single irrigation given afternoon; E: Single irrigation given evening.
LSD at 0.05 percent probability

Table 6 Effect of irrigation time and rate of water application on maize economics, 2017

Irrigation Schedule	Mean grain yield/ha (ton)	Economics Derivatives			
		Gross percent returns (₦)	Total number of irrigations	Labour cost per irrigation (₦ 2,500/ha)	Cost / Benefit ratio (₦)
Application of 25 ml of water: Irrigation given for 100 days at 25 ml / every 4-days = 625 ml total irrigation					
A	2.67	213,600	25	62,500	151,100
E	2.67	213,600	25	62,500	151,100
MA	2.67	213,600	50	125,000	88,600
ME	2.67	213,600	50	125,000	88,600
AE	2.67	213,600	50	125,000	88,600
MAE	2.67	213,600	75	187,500	88,600
Application of 50 ml of water: Irrigation given 100 days at 50 ml / every 4 days = 1250 ml total irrigation					
M	5.33	426, 400	25	62,500	363,900
A	3.20	256,000	25	62,500	193,500
E	4.27	341,600	25	62,500	279,100
MA	4.80	384,400	50	125,000	259,400
ME	4.80	384,400	50	125,000	259,400
AE	4.27	341,600	50	125,000	216,600
MAE	4.80	384,400	75	187,500	196,900

Maize at ₦ 80,000/ton (corn maize Report, official CBN Reports, Commodity Prices, 2012-2013; ₦365 to $1
MAE: Three equal split given morning, afternoon and evening; MA: Two equal split given morning and afternoon; ME: Two equal split given morning and evening; M: Single irrigation given morning; A: Single irrigation given afternoon; E: Single irrigation given evening.

3.5. Productivity of total applied water (PAW)

PAW (Table 5) was highest when irrigation was given as single application in the morning either at the rate of 25 (0.008). Yield producing efficiencies of irrigation water were mostly higher in those crops treated to 25 ml irrigation as against those treated to 50 ml irrigation water; implying that applied irrigation was better utilized in the former than in the latter. This observation is in line with previous reports which indicated that many irrigation experiments involving different irrigations levels showed that deficit irrigation usually has higher PAW than full irrigation [1] and [14].

3.6. Cost-benefit ratio of irrigation

Considering the cost-benefit ratio of the applied irrigation (Table 6), single application of irrigation in the morning gave the highest monetary returns when 25 ml irrigation water was applied every 4-day (₦321, 500) as well as when 50 ml irrigation was given (₦ 363, 900). For the 25 ml treatment, returns on investment were at par for Afternoon and Evening water application, which were higher than the split dosage, which also stood at par (₦88, 600) for all the split irrigation. In the application of 50 ml irrigation, water applied in the morning also recorded the highest returns on investment (₦ 363, 900) while application of a single dose irrigation in the Afternoon recorded the least return on investment (₦193, 500).

4. Conclusion

Africa's agriculture is highly climate (particularly rainfall) dependent, with crops mostly grown under natural environment. The implication is that, rainfall directly or indirectly impact on food the least yield responses were observed when irrigation water were delivered in the morning. The best PAW was however obtained when 25 ml irrigation was given in the morning and in most instances PAW was better or compared with the application of 25 ml of irrigation than in 50 ml treatment. Cost-benefit analysis also reveals that application of single dose irrigation either as 25 ml or 50 ml gave the highest returns on investment, with 50 ml performing better than 25 ml irrigation (₦363, 900 and ₦321,500, respectively), thus recommended for the study area as a result of having the highest return on investment.

Compliance with ethical standards

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Disclosure of conflict of interest

The author may wish to state categorically that there is no observed conflict of interest as regard this publication.

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