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Influence of Watering Regime on Growth, Yield and Bulb Nutritional Composition of *Alium cepa* L. (Onion) under sreenhouse Conditions

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Abstract Scarcity and high cost of onions in Nigeria might be connected to production still largely limited to the field in the north where weather condition is most favorable to it. Its cultivation under screenhouse conditions requires knowledge of optimal watering regime; hence, watering frequency was investigated on onion. Plants were raised in polyethylene pots filled with 9 kg top soil and exposed to wet conditions: watering daily (W_0), 3 times/week (W_1) and once/week (W_2); drought conditions: watering once/1½ weeks (W_3) and once/2 weeks (W_4); or waterlogged condition: planted in water-saturated soil (W_5). Except waterlogging, soil was watered to field capacity in perforated pots. Plant height and number of leaves were reduced by 68.53% and 70.15% respectively at W_5. W_5 also reduced shoot fresh weight, root fresh weight, shoot dry weight and root dry weight from 38.42 g to 19.41 g, 14.00 g to 2.60 g, 6.01 g to 1.31 g, and 3.56 g to 0.73 g respectively relative to W_0. Growth reduction considering plant height with fresh and dry weights of plant parts increased with increasing severity of drought, with the highest at W_4. Yield in terms of number of bulbs and bulb size were optimal at W_1 and W_2 relative to other treatments. Except nitrogen free extract, bulb proximate composition was highest under W_1. Except Ca and Mg, nutrients were highest under W_1. Relative to W_0, W_5 reduced bulb nutritional and proximate compositions. Onions' optimal production can be achieved under wet conditions, partially in drought but poorly under waterlogging.
Keywords Onion; Water stress; Irrigation; Yield

1 Introduction

Onion (*Allium cepa* L.) has been valued as a food and medicinal plant since ancient times (Ahmad et al., 2021). It is widely cultivated and is a vegetable bulb crop known by most cultures and consumed worldwide (Barret and Lloyd, 2012; Friedmann et al., 2014). It is a short duration horticultural crop (Brewster, 2012). It is commonly known as "Queen of the kitchen," due to its highly valued flavor, aroma, and unique taste, and the medicinal properties of its flavor compounds (Selvaraj, 2017; Griffiths et al., 2018). Onion is used throughout the year, for example in curries in the form of spices, in salads as a condiment, or cooked with other vegetables in boiled or baked form. It is also used in different forms of processed food like pickles, powder, paste and flakes, and it is known for its medicinal values.

Nigeria is one of the main producers of onion in the world and the major producer in Africa (Aliyu et al., 2009a, 2009b; 2009c) with its annual world production surpassing 2 million tons. Due to the several forms in which is traded, onion is now one of the most important trade commodities in the world (Maitasamu, 2010). It is a cash crop for income generation by many households in Nigeria.

Water deficiency is a limiting factor for agricultural crop exerting negative impact on molecular, biochemical, physiological and morphological processes, and negative traits in plants, causing decrease in growth and yield (Mariani and Ferrante, 2017; Begna, 2020). Global warming is one of the reasons to cause drought and flooding(Wang et al., 2023).

There is high demand for onion in Nigeria because of its numerous uses. The northern part of Nigeria is where onion cultivation is currently thriving, thereby causing limitation in the availability of the crop in southern Nigeria. The crop isn't usually cultivated in southern Nigeria which might not be unconnected to climatic factors particularly soil water regime as soil moisture status is known to be critical in its production (Wang et al., 2023).

There are several research reports on watering regime of onions worldwide including African nations such as Ethiopia (Temesgen et al 2018; Tolossa, 2021), Ghana (Shu-aib et al., 2023) and Nigeria (Gwandu and Idris, 2016). This research has some departures from existing literature as most works on onions in relation to irrigation have centered majorly on field studies. Interestingly, field experiments are characterized by limitations to test waterlogging as a stress factor, and this research was meant to fill this knowledge gap. Besides, cultivation of vegetables in screen houses using pots is gaining popularity in recent times. Crops like pepper, tomatoes, and cucumber etc. are grown as potted plants with huge yield for income generation. We hypothesized that onion should not be an exception, premised on the fact that Shah (2020, https://greenhouseplanter.com/how-to-grow-onions) postulated that onion is one of the crops that can be successfully grown in a greenhouse; and a comprehensive guide was provided by him. Therefore, this study serves in determination of suitable watering treatment for optimal growth and yield of the crop. The objective was to investigate the watering regime for its optimal yield and determine bulb nutritional composition of the plant under different watering regimes.

2 Materials and Methods

2.1 Experimental site

The experiment was conducted in the screenhouse of Plant Science and Biotechnology Department, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria.

2.2 Experimental set up

Onion bulbs were planted in polyethylene bags filled with 9 kg top soil (0~15 cm depth). At 2 weeks after planting, they were subjected to wet conditions: watering daily (W_0), 3 times/week (W_1) and once/week (W_2); drought conditions: watering once/1½ weeks (W_3) and once/2 weeks (W_4); and waterlogged condition: planted in water-saturated soil (W_5). Except waterlogging, each pot was perforated and plants received 250 ml of water (volume enough to keep the soil at field capacity) at every watering time. The volume was based on 36.13% field capacity, equivalent to 250 ml in 9 kg of the soil. Soil bulk density was determined using a procedure described by Stanley and Bernard (1992) with undisturbed soil samples at 4 cm height and 4.6 cm internal diameter of core sampler. Field capacity and permanent wilting point were analyzed through pressure plate apparatus: pressure of 1/3 bar (for field capacity) and 15 bars (for permanent wilting point).There was 5 replicates per treatment in completely randomized experimental design.

2.3 Data collection

Plant height was measured from the base of the stem to apical bud using meter rule and leaves were counted manually. At harvest, plants were separated into shoot and root, weighed fresh and after drying in oven to constant weight at 80 °C. Bulbs were counted with length, diameter and circumference measured. Bulbs were also weighed fresh and after drying in oven maintained at 80 °C.

2.4 Laboratory analyses

Samples of the soil used for planting were taken, shade-dried, passed through a 2 mm sieve, and analyzed for the physico-chemical parameters using standard methods of the Association of Official Analytical Chemists (AOAC, 1990). Dried onion bulbs were milled into fine powder and analysed for nutrients and proximate compositions using standard methods of AOAC (1990).

2.5 Data analysis

Data were statistically analyzed using the statistical package for Social Sciences (SPSS version 24.0). Statistical means were separated using Least Significant Difference Test at 95% level of significance.

3 Results

3.1 Soil used for planting

The soil used for planting was topsoil (0~15 cm depth) collected from the experimental field of Plant Science and Biotechnology Department, Adekule Ajasin University, Akungba-Akoko. It was a sandy soil with 5.60 pH, 6.19% clay, 4.29% silt, 89.7% sand, 2.89% C, 0.14% N, 9.02 mg/100 g P, 6.24 mg/100 g Ca, 1.84 mg/100 g Mg, 0.34 mg/100 g Na, 0.23 mg/100 K, 0.20 mg/100 g H, and 8.86 mg/100 g CEC. It had 1.12 mg/cm^3 bulk density, 36.13% field capacity, and 19.08% permanent wilting point.

3.2 Effect of water stress on growth

Water stress (waterlogging and drought) had significant negative impact on growth of onion (Table 1). Plant height and number of leaves were reduced from (38.00±1.21) cm and (13.40±0.68) under daily watering (W_0) to (11.96±0.15) cm and (4.00±0.32) under waterlogging (68.53% and 70.15% reduction) respectively. Likewise, waterlogging reduced shoot fresh weight, root fresh weight, shoot dry weight and root dry weight from (38.42±3.72) g to (19.41±1.51) g, (14.00±1.95) g to (2.60±0.68) g, (6.01±0.28) g to (1.31±0.27) g, and (3.56±0.56) g to (0.73±0.09) g respectively relative to daily watering.

Table 1 Effect of watering regime on growth and vegetative biomass of *Allium cepa*

Growth parameter	Watering regime						
	W_0	W_1	W_2	W_3	W_4	W_5	LSD (0.05)
Plant height (cm)	38.00±1.21^{cd}	40.28±0.41^{d}	35.02±0.56^{bc}	32.94±0.93^{b}	31.12±0.92^{d}	11.96±0.15^{a}	0.80
Number of leaves	13.40±0.68^{b}	13.20±0.58^{b}	13.40±0.24^{b}	11.60±0.68^{b}	10.20±0.97^{b}	4.00±0.32^{a}	0.12
Shoot fresh weight (g)	38.42±3.72^{bc}	43.21±4.21^{bc}	40.3±3.11^{bc}	32.11±2.61^{bc}	25.32±2.01^{a}	19.41±1.51^{b}	1.50
Root fresh weight (g)	14.00±1.95^{b}	17.20±3.93^{bc}	13.40±2.79^{b}	10.40±0.75^{b}	9.20±1.16^{b}	2.60±0.68^{a}	0.03
Shoot dry weight (g)	6.01±0.28^{ab}	7.28±0.12^{ab}	7.02±0.09^{ab}	3.21±0.15^{ab}	3.32±0.22^{ab}	1.31±0.27^{b}	Ns
Root dry weight (g)	3.56±0.56^{b}	4.72±1.01^{a}	2.01±0.21^{b}	1.76±0.30^{a}	1.55±0.21^{ab}	0.73±0.09^{b}	0.02

Note: Values are mean ± standard error of 5 replicates. Means with the same letter(s) in superscript on the same row are not significantly different at p=0.05 (LSD Test). $W_{0=}$ watered 4 times/week, W_1= watered 3 times/week, W_2= watered 2 times/week, W_3= watered once/week, W_4= watered once/2 weeks, W_5= permanently waterlogged, Ns = non-significant, LSD =Least Significant Difference

Drought conditions also significantly reduced plant height and number of leaves but with less intensity than waterlogging. Reduction increased with increasing severity of drought with the highest reduction obtained under watering once per 2 weeks (W_4). This brought about 18.11% and 23.88% reduction in plant height and number of leaves respectively. W_1 resulted in higher values of growth parameters than other treatments.

3.3 Effect of water stress on biomass

Drought had negative effect on biomass parameters leading to 34.11%, 35.71%, 44.76% and 56.46 % for shoot fresh weight, root fresh weight, shoot dry weight and root dry weight respectively (Table 1). W_1 resulted in higher values for root fresh weight and dry weight than W_0. Higher values were recorded both at W_1 and W_2 for shoot fresh and dry weight than at W_0. Meanwhile, the highest values were obtained at W_1 in the dry and fresh weight parameters.

3.4 Effect of water stress on yield

There was increase in number of fruits from 2.60 at W_0 to a range of 2.80~3.82 at W_1-W_4 (Table 2). However, size of bulbs was highest at W_1 and W_2 relative to other treatments. For example, bulb length increased from 3.54 cm at W_0 to 4.82 cm and 4.01 cm at W_1 and W_2 respectively. Bulb diameter likewise increased from 8.46 cm to 9.02 cm and 9.00 cm at W_1 and W_2 respectively. Bulb circumference likewise increased from 9.46 cm at W_0 to 11.02 cm at W_1.

Higher values of fresh and dry weight of bulbs were also recorded at W_1 and W_2 than other treatments. Fresh weight increased from 134.60 g at W_0 to 149.00 g and 148.80 g under W_1 and W_2 respectively. Dry weight also increased from 16.80 g to 31.10 g and 26.50 g at W_1 and W_2 respectively.

3.5 Effect of water stress on bulb nutritional and proximate compositions

Watering regime had significant impacts on nutritional and proximate composition of onion bulbs (Table 3; Table 4). Except Ca and Mg, bulb nutrients were reduced by drought, with the highest values of 2.44, 20.26 and 1.84 (mg/100 g) for N, P and K respectively (Table 3). W_5 on the other hand reduced all the bulb nutrients: N (48.06%), P (12.61%), K (50.66%), Ca (28.00%) and Mg (47.69%). Except nitrogen free extract (NFE), all bulb proximate parameters were highest under watering 3 times per week (W_1) with increase by 12.50%, 18.21%, 3.54%, 9.91% and 2.80% for ash, fat, moisture and crude protein contents respectively relative to W_0 (Table 4). Relative to daily watering, bulb proximate composition was reduced by W_5: ash (70.24%), NFF (51.42%), fat (68.17%), moisture (56.94%) and crude protein (76.03%).

Table 2 Effect of watering regime on yield of *Allium cepa*

Yield parameter	Watering regime						
	W_0	W_1	W_2	W_3	W_4	W_5	LSD (0.05)
Number of bulbs	2.60±0.81^a	3.82±0.86^a	2.80±0.66^a	3.00±5.05^a	2.80±0.73^a	1.92±0.24^a	Ns
Bulb length (cm)	3.54±0.21^b	4.82±0.46^{ab}	4.01±0.10^b	3.21±0.22^b	2.56±0.76^a	2.01±0.20^{ab}	0.05
Bulb diameter (cm)	8.46±0.76^b	9.02±1.01^b	9.00±0.76^b	7.78±1.10^b	7.54±1.11^b	1.42±0.16^a	0.09
Bulb fresh weight (g)	134.60±00^c	149.00±0.00^e	148.80±0.00^f	121.10±0.00^b	142.70±0.00^d	20.26±0.00^a	0.20
Bulb dry weight (g)	16.80±0.00^e	31.10±0.00^f	26.50±0.00^d	14.80±0.00^c	13.40±0.00^b	1.58±0.00^a	0.02
Bulb circumference (cm)	9.46±0.76^b	11.02±1.01^b	10.56±0.76^b	8.58±1.11^b	7.34±1.10^b	1.40±0.18^a	0.04

Note: Values are mean ± standard error of 5 replicates. Means with the same letter(s) in superscript on the same row are not significantly different at p=0.05 (LSD Test). W_0= watered 4 times/week, W_1= watered 3 times/week, W_2= watered 2 times/week, W_3= watered once/week, W_4= watered once/2 weeks, W_5= permanently waterlogged, Ns = non-significant, LSD =Least Significant Difference

Table 3 Effect of watering regime on nutritional composition of *Allium cepa* bulbs

Watering Regime	Nutritional composition				
	N	P	K	Ca	Mg
W_0	2.06^a	18.32^a	1.52^a	1.00^{ab}	0.65^a
W_1	2.44^a	20.26^a	1.84^a	0.90^b	0.60^a
W_2	1.50^b	17.53^a	0.91^b	0.84^b	0.54^a
W_3	1.30^b	17.40^a	0.82^b	0.79^b	0.40^a
W_4	1.24^b	16.23^a	0.79^b	0.77^b	0.35^a
W_5	1.07^b	16.01^a	0.75^b	0.72^b	0.34^a
LSD (0.05)	0.02	Ns	0.02	0.01	Ns

Note: Values are mean of 3 replicates. Means with the same letter(s) in superscript on the same column are not significantly different at p=0.05 (Tukey HSD Test). W_0= watered 4 times/week, W_1= watered 3 times/week, W_2= watered 2 times/week, W_3= watered once/week, W_4= watered once/2 weeks, W_5= permanently waterlogged, Ns = non-significant, LSD =Least Significant Difference

Table 4 Effect of watering regime on proximate composition of *Allium cepa* bulbs

Watering Regime	Proximate composition					
	Ash	NFE	Fat & oil	Moisture	Protein	Fibre
W_0	11.46^a	66.12^a	15.71^a	2.81^a	8.76^a	2.64^a
W_1	12.50^a	65.40^a	18.21^a	3.54^a	9.91^a	2.80^a
W_2	10.52^a	52.20^{ab}	15.13^a	2.42^a	9.83^a	1.90^{ab}
W_3	7.52^b	45.60^{ab}	13.54^a	2.10^a	5.71^{ab}	1.32^{ab}
W_4	5.32^b	46.02^{ab}	11.21^a	1.90^b	6.20^a	1.04^{ab}
W_5	3.41^b	32.12^b	5.00^b	1.21^b	2.10^b	0.81^b
LSD (0.05)	0.32	1.20	0.43	0.09	0.12	0.02

Note: Values are mean of 3 replicates. Means with the same letter(s) in superscript on the same column are not significantly different at p=0.05(LSD Test). W_0= watered 4 times/week, W_1= watered 3 times/week, W_2= watered 2 times/week, W_3= watered once/week, W_4= watered once/2 weeks, W_5= permanently waterlogged, Ns = non-significant, LSD =Least Significant Difference

4 Discussion

4.1 Effect of water stress on growth

This study reveals that onion plants exposed to water stress conditions had decreased growth and yield compared to wet conditions. There was a decrease in growth in terms of number of leaves and plant height under drought and waterlogging (Table 1). Khatiwada et al. (2020) reported that exposure of wheat to drought stress decreased root and shoot growth, and decline of biomass accumulation. It has been reported that drought stress caused reduced growth of seedlings, root and shoot dry weight reduction, undersized length of hypocotyl and poor vegetative growth in crops like *Oryza sativa* L., *Pisum sativum* L. and *Medicago sativa* L. (Okcu et al., 2005; Zeid and Shedeed, 2006). Drought caused *Pisum sativum* (pea) plants to grow slowly, have fewer leaves, and declined productivity (Fatima et al., 2024). Drought stress enforces modifications in fundamental morphology, physiology and biochemical aspects in plants. Cell division and differentiation, followed by cell enlargement, are the basic requirements of plant growth, but due to drought stress, cell elongation and mitosis are effected which results in reduced growth of plant (Farooq et al., 2009). Basu et al. (2016) described that cell growth is inhibited as turgor pressure is hindered due to drought stress. They further stated that water restraining conditions result in reduced cell elongation, primarily because of reduced water movement through xylem tissues and adjoining cells. Severity of drought lowers nutrient and water flow which brings about limited availability of nutrient for absorption by the root (Marschner, 2012).

In an earlier report, *Zea mays* had a significant reduction in crop growth and development during waterlogged condition (Ren et al., 2014). Also, according to Xianquing Lin (2018), plant height, stem width, number of branches and floral bud of *Brassica napus* were significantly decreased by waterlogging. Liu et al. (2019) also revealed that there was decrease in plant height of *Zea mays* under waterlogged condition. The reduced number of leaves observed under waterlogged condition is similar to what was reported in *Trifolium alexandrinum* by Mensah et al. (2011). They stated that waterlogging affects the physiological and morphological functions of plants, thereby reducing the plant status such as the height, number of leaves, shoots and root growth.

4.2 Effect of water stress on biomass

Drought condition led to a significant reduction in fresh and dry weight of shoot and root of onion, with the shoot more severely affected than the root (Table 1). In previous researches, frequent irrigation was observed to be necessary for good growth and yield performances of onion especially at bulbing stage (Bottcher et al., 1979; Choi et al., 1980). Gwandu and Idris (2016) reported that in 2012/2013 and 2013/2014 growing seasons, onions irrigated at 3 day interval had significantly the highest number of leaves, growth rate, bulb weight, bulb yield, cured bulb yield and bulb diameter compared to 5, 7 and 9 day intervals. They stated that 7 and 9 day irrigation intervals negatively affected growth and yield performances, and concluded that frequent application of water is required for good growth and yield performances of onions in Nigeria.

Barley plants, when subjected to drought stress, showed decreased root and shoot length as well as their fresh and dry weights (Ahmed et al., 2013; 2015). It was also reported that fresh and dry weight of rice were repeatedly abridged due to limited water resource (Zhao et al., 2016). Drought was reported to have negative influence on photosynthetic apparatus of pea (*Pisum sativum*) which might be responsible for reduced biomass (Pandey et al., 2023).

Shanxi (2012) reported that root dry weight of *Hordeum vulgare* L. were lower in waterlogged soil than those under proper watering. Armstrong et al. (2003) findings supported reduced fresh and dry weights of leaf and root parts of Marigold (*Tagetes erecta* L.) under waterlogged condition, highlighting the vulnerability of the leaf part to waterlogging stress. Waterlogging causes decrease in root biomass, hampering vegetative development and inducing plants organ senescence. This condition occurs whenever soil moisture levels go beyond the field capacity. In such cases, excess water saturates the soil pores in the presence of a very slim water layer on the soil surface. This stress usually have negative effect on the majority of terrestrial plants, limiting crop yield through changes in physical, chemical, biological and electrochemical properties of the soil (Ding et al., 2020).

4.3 Effect of water stress on yield

Drought condition negatively impacted bulb development, resulting in production of significantly fewer and smaller bulbs than wet condition (Table 2). This shows that water availability plays a crucial role in bulb formation and development in *A. cepa*. In an earlier experiment, Shu-aib et al. (2023) found that morning and evening daily irrigation of onions produced the highest yield of 28.68 tons/ha, followed by morning daily with 28.12 tons/ha. In morning and evening alternate days however, the lowest yield of 25.80 tons/ha was recorded. According to research results, regular watering of is necessary for the growth of onion, as water stress at particular stages can adversely impact on growth resulting in reduction in yield (Ortola and Knox, 2015; Shu-aib et al., 2023). Higher yield under regular watering than water deficit has also been confirmed by Pejic et al. (2011) and Temesgen et al. (2018) who stated that there was an improvement in the yield of onions, particularly with regards to the marketable bulbs as regular supply of water to the onion plants (morning and evening) resulted in improved growth and yields of the onion bulbs.

Moges (2021) indicated that variation in the level of irrigation water application had a significant effect on onion growth and yield. Similarly, Tolossa (2021) observed that onions with treatments of deficit irrigation and skipping of irrigation in one growth stage had a lower yield than those that had full irrigation. They recorded the highest total onion yield from a control treatment (full irrigation). Deficit by 75% and above resulted in the highest yield reduction. Islam and Takagaki (2012) likewise reported negative effect on garlic bulb development under different moisture regimes resulting in smaller bulb sizes. Likewise, onion could sustain little water deficits and its bulb yield declined with increasing drought (Wakchaure et al., 2018). Yield reduction might be due to water deficit as a result of early maturity without attainment of full growth potential. This concurs with the results of Tolossa (2021) who observed that onion plants that received an optimum amount of irrigation water or a slightly less amount, had prolonged days to maturity whereas those, which received only one- fourth of full irrigation requirement throughout the growing season, had maturity earlier. This emphasises the importance of managing water availability for optimal bulb formation and development in onion cultivation.

Islam and Takagaki (2012) likewise reported negative effect on garlic bulb development under low moisture regimes resulting in smaller bulb sizes. Additionally, due to drought conditions on a worldwide scale, about 21% decline in the yield of *Triticum aestivum* L. and 40% decline in the yield of *Zea mays* L. were recorded (Daryanto et al., 2016; Zhang et al., 2018). It was postulated that while encountering drought stress, plants seize more NaCl in the leaf, lowering its osmotic potential and reducing the root hydraulic conductance and leaf tissue (Vysotskaya et al. 2010; Bhat et al. 2020). Overproduction of reactive oxygen species (ROS), caused by decrease in CO_2 assimilation rates and excessive light absorption is another common occurrence under this condition, causing lipid peroxidation, DNA mutation, and cell damage (Kumar et al., 2019). Hence, drought conditions can severely affect the overall growth and yield of plants, increase leaf and flower abscission, frequent senescence and cell necrosis (Ahmed et al., 2015; Sahin et al., 2018). Under soil water deficiency, cotton yield was reduced as a result of reduced canopy absorption of photosynthetically active radiation, decreased efficiency in the use of radiation, and reduced harvest index (Earl and Davis, 2018).

Waterlogged condition induced detrimental effect on bulb production bringing about fewer and smaller bulbs than other conditions. This has been corroborated by earlier records of Grzebelusi et al. (2017) on bulb size of *A. sativum*. Likewise, grain yield of maize was reported to be reduced by waterlogging (Huang et al., 2022; Hu et al., 2023). Pod yield in *Arachis hypogaea* also decreased under waterlogging (Zeng et al., 2023). In a recent research, grain yield of maize was reportedly reduced by 29.1% by waterlogging through decreased grain weight and numbers (Yang et al, 2024). Waterlogging is known to significantly reduce crop yield, causing plants to show chlorosis and necrotic spots on leaves and also reduces dry matter accumulation, leaf catalase activity and ultimate yield. It was stated that in plants, oxygen deficiency is the first response to waterlogging limiting growth and ultimately lead to root death and stomatal closure and then to a restrained decrease in gas exchange limiting photosynthesis (Kirnak et al., 2002).

4.4 Effect of water stress on bulb nutritional composition

Wet condition favoured bulb nutritional and proximate compositions above drought and waterlogging (Table 3; Table 4). Desclaux (2011) also reported that drought decreased the nutrient uptake in N, K and P of *Hordeum vulgare* L. Nitrogen uptake was also hindered by waterlogging in bread wheat (Arata et al., 2019). This could be ascribed to negative effect of drought on the microbial mineralization of organic matter, which in turn affects the amount of inorganic nutrients available for plant uptake, potentially impairs the mineral nutrition of plants. Kuchenbuch et al. (2018) showed that low levels of soil moisture due to drought reduced root growth and the rate of potassium inflow in onion plants. Urbina et al. (2015) reported that in monoculture and mixed plants, K decreased under drought while the K content in leaves of peanut plant (*Rachis hypogaea* L.) was unchanged under drought. Sanchez-Rodriguez et al. (2010) observed a lower concentration and uptake of P in watermelon and cherry tomato under drought condition.

Except nitrogen free extract (NFE), all fruit proximate composition parameters were better under wet than waterlogging and drought conditions. Within moisture regimes of wet condition, watering three times per week was optimal. In agreement with this, Suleimon (2017) recorded a decrease in crude protein and crude fibre contents of *Brassica napus* L. under drought conditions. As obtained in this study, the highest ash content recorded under wet conditions is in line with the findings of Aliyu et al. (2017) who observed an increase in ash content of alfalfa plant under well-watered condition, while the lowest contents were recorded under waterlogged condition. Morad (2012) also reported that there was a significant decrease of N, P, Mg, K, Mn and Zn concentration in wheat and barley shoots by waterlogging.

5 Conclusion and Recommendations

The study revealed that onion plants grown under wet conditions performed better in growth and yield as well as nutritional values than under water stress (drought and waterlogging). The plant performed optimally under wet condition and partially under drought while waterlogging had significant negative impact on it. It is therefore, recommended that onions, under sreenhouse condition, can be watered regularly to achieve good yield but watering 3 times per week to field capacity is the best in achieving optimal yield and nutritional values. However, controlled experiments in sreenhouse conditions may not be totally applicable under field conditions. This limitation might influence the applicability of the results to field agricultural practices. There is therefore, a need for a research of this nature on long-time effect on the field. In addition, there is a need to investigate the deficit level at which a reasonable level of water saving can be achieved without significant growth yield loss, which could be of significant importance for both onion production and water conservation.

Authors' Contributions

Otitoloju Kekere designed, supervised the research, and prepared draft of the manuscript. Augusta Omolara Ogbedebi set up the experiment and collected data. Yetunde I. Bulu and Taiwo Ekundayo co-designed and monitored the experimental process. Olumakinde Akinbuwa performed statistical analyses of the data. All authors read and approved the final manuscript.

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