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EFFECTS OF MOISTURE STRESS AT DIFFERENT GROWTH STAGES ON THE PERFORMANCE OF ONION (*Allium cepa* L.) VARIETIES

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ABSTRACT

Climate change is imparting negatively on global crop production and compromising food security worldwide. To breed for moisture stress tolerance in any given crop, it is important to know the precise water needs of the plants and the growth stage at which moisture stress affect the crop most. Hence, this research aimed at determining the response of onion varieties to moisture stress at different stages of growth. The field experiment was carried out at Maizube Farms Limited field, Minna, Niger State (latitude $9^0 3817.1^0 N$; longitude $6^0 32^1 04.2^0 E$). The treatments consisted of five varieties of onion (red creole, sivan, prema, wuyan makwarwa, wuyan bijimi) and moisture stress at three growth stages of the plant (flag leaf emergence to two true leaves stage (10-50 days post seeding (PS)), three to seven leaves stage (50-90 days PS), bulb initiation to bulb enlargement stage (90-170 days PS) as well as irrigation throughout the growth stages on a daily basis and at 3 days interval. The 5 x 5 factorial experiments were laid out in Completely Randomized Design (CRD) with three replications. Data were collected on growth and yield parameters. The result obtained shows that the varieties responded to moisture stress in similar ways. Drought stress significantly reduced the growth and yield of the onion varieties tested at all the growth stages compared to plants watered throughout the growth stages at 3 days interval which produced the highest number of leaves, plant height and bulb yield. However, the effect of the drought stress was more critical at the early growth stage (flag leaf to two true leaf stage) reducing bulb yield by 57.74%. Similarly, daily irrigation induced flood stress in onion and significantly reduced onion bulb yield by 59.22% .

Key words: Moisture stress, Onion, Growth stages, Climate change, Irrigation

Introduction

Water is the most important factor in agricultural production for proper development and productivity. Every plant needs optimum water supply to meet its physiological requirements (Evans and Sadler, 2011). Water stress is referred to as a limited water supply to plant roots (drought stress) or too much water resulting in flood stress in plant. Water stress results in disruption of agriculture, hence it affects food production in the world, resulting in famine (Chaves *et al.*, 2012). Drought stress commonly affect crops; reduces the rate of transpiration in plants thereby affecting metabolism, growth and development of crops. The profound alterations to physiological processes under dehydration slow down or even arrest growth and endanger yield stability (Anjum *et al.*, 2011). Yield losses in the field under drought typically range between 30% and 90%; they differ between crop species (Hussain *et al.*, 2019). Flood stress similarly impair gaseous exchange thereby causing energy imbalance and reduction of photosynthesis.

Onion (*Allium cepa* L.) is one of the most important vegetable crops commercially grown in the world. It is a popular vegetable and its bulb is used raw, sliced for seasoning salads, and cooked with other vegetables and meat. Onion bulbs are essential ingredients in many African sauces and dishes. The leaves, whole immature plants called 'salad onion' or leafy sprouts from germinating bulbs are used in the same way. It probably originated from Central Asia between Turkmenistan and Afghanistan where some of its relatives still grow in the wild (Brewster, 1999). It is a shallow rooted crop; its root penetration is around 0.18 m which indicates it cannot take up moisture from deep soils. This makes it sensitive to drought stress. Bulk of the onions planted in Nigeria is produced in the north where irrigation water is a limiting factor. It is mostly planted at the onset of dry season so that it matures into the dry season to avoid flood stress. Previous studies indicated that water deficit negatively affects onion bulb formation which resultantly hinders its quality and yield (Chaudhry *et al.*, 2020; Ghodke *et al.* 2020). Water stress at specific stages can negatively impact onion size and quality (Pérez-ortolá and Knox, 2015). To reduce the impact of climate change on food security, it is important to use moisture stress tolerant varieties. To breed for moisture stress tolerance in any given crop, it is important to know the precise water needs of the plants and evaluate the growth stage at which moisture stress affect the crop most. Hence, this research aimed at determining the response of onion varieties to moisture stress at different stages of growth.

MATERIALS AND METHODS

The field experiment was carried out at Maizube Farms Limited field, Minna, Niger State (latitude.$9^0$3817.1^{0}N; longitude $6^0$32^{i}04.2^{0}E). It is semi- arid with average rainfall of about 750- 1209.7 mm per annum. The relative humidity ranges from 21- 47% and 51-79% during the dry and rainy seasons respectively. Temperature averages between 14-30°C during the rainy season and 27-41°C during the dry season (NNN, 2020).

The onion cultivars were obtained from the Institute of Agricultural Research (IAR), Zaria Nigeria. The treatments were five varieties of onion (Red creole, Sivan, Prema, Wuyan makwarwa, Wuyan bijimi) and moisture stress at three growth stages of the plant (flag leaf emergence to two true leaves stage (10-50 days post seeding (PS)), three to seven leaves stage (50-90 days PS), bulb initiation to bulb enlargement stage (90-170 days PS), irrigation at 3 days interval throughout the growth stages) and daily irrigation throughout the growth stages). The 5 x 5 factorial experiments were laid out in Randomized Complete Block Design (RCBD) with three replications. The seeds were planted at a spacing of 20 cm between rows and 15 cm within rows. The net plot size was 2 m x 3 m. Drip irrigation was used in wetting the crop at root level through the use of hose with emitters, the emitters emit water in a trickle form. The diameter of the drip tape was 16 mm and emitters were spaced at 15 cm. The water emission rate was 4 liters per hour per treatment plot. Moisture stress was imposed at the different stages by delaying irrigation till plants

show symptoms of temporary wilting. Data were collected on plant height, number leaves, leaf area index, number of days to flowering, bulb diameter and length, bulb yield (kg/ha). The data collected were subjected to Analysis of Variance (ANOVA). Means were separated using least significant difference (LSD) at 5% level of probability.

RESULT

The effect of moisture stress at different growth stages on the plant height of onion varieties is presented in Table 1. Plant to which moisture stress was imposed at 10-50 days had the least plant height (8.57cm) at 4 WAS. The value was statistically similar to plants that were watered every day. Similar trend was observed at 8 and 12 WAS but at 16 WAS, plant stressed at 10-50 days PS appeared to have overcome the initial stress having statistically similar plant height with plants watered at three days interval throughout the growth stages. Plants watered throughout the growth stages at three days interval had the tallest plants throughout the sampling period except at 4 WAS. The varieties responded to moisture stress in similar ways as there was no significant difference ($p>0.05$) among the varieties in respect of plant height throughout the sampling period. The interaction between moisture stress treatments and varieties were not also significant

Table 1: Effect of moisture stress at different growth stages on the plant height(cm) of onion varieties

Treatments	Weeks after sowing			
	4	8	12	16
Moisture stress (M)				
10 – 50 days	8.57c	14.26b	18.89b	36.46a
50 – 90 days	10.83a	17.23a	21.37a	35.62ab
90 – 140 days	10.13ab	15.55ab	20.97a	36.20ab
Daily watering	9.21bc	15.17b	19.88ab	32.79b
3 days Interval watering	10.27ab	17.39a	21.65a	39.17a
LSD (0.05)	1.14	1.96	1.95	3.67
Varieties (V)				
Red creole	9.65a	15.66a	19.83a	35.75a
Sivan	9.69a	15.93a	20.97a	36.77a
Prema	10.17a	16.63a	21.68a	36.32a
Wuyan makwarwa	9.88a	16.44a	20.09a	36.47a
Wuyan bijimi	9.64a	14.93a	20.19a	34.92a

LSD (0.05)	1.14	1.96	1.95	3.67
Interaction M x V	NS	NS	NS	NS

Means followed by same letter(s) in a column within the same factor are not significantly different at 5% level of probability using least significant difference (LSD). NS- Not significant

The effect of moisture stress at different growth stages on the number of leaves of onion varieties is presented in Table 2. There was no significant difference between the moisture stressed and control plants at 4 WAS. At 8 WAS however, the plants stressed at the different growth stages had similar number of leaves which were significantly lower than the values recorded in the non-stressed plants watered at 3 days interval. Daily watered plants had similar lower number of leaves like the plant stressed at different growth stages. Similar trend was observed at 12 WAS. At 16 WAS however, plant stressed at the bulb formation stage had the least number of leaves. The value obtained was however similar to what was recorded in the daily watered plants. The highest number of leaves was recorded in the non-stressed plants watered at 3 days interval throughout the sampling period. There was no significant difference among the varieties in respect of the number of leaves throughout the sampling period.

Table 2: Effect of moisture stress at different growth stages on the number of leaves of onion varieties

Treatments	Weeks after sowing			
	4	8	12	16
Moisture stress (M)				
10 – 50 days	2.00a	3.13b	4.00b	6.07b
50 – 90 days	2.13a	3.07b	4.07b	5.80bc
90 – 140 days	2.00a	2.93b	4.20ab	5.40c
Daily watering	2.27a	3.13b	4.07b	5.47bc
3 days watering interval	2.46a	3.60a	4.73a	6.80a
LSD (0.05)	0.49	0.41	0.56	0.66
Varieties (V)				
Red creole	2.07a	3.07a	4.07a	6.07a
Sivan	2.33a	3.27a	4.33a	6.20a
Prema	2.13a	3.13a	4.13a	5.60a
Wuyan makwarwa	2.20a	3.27a	4.40a	5.93a

Wuyan bijimi	2.13a	3.13a	4.13a	5.73a
LSD (0.05)	0.49	0.41	0.56	0.67
Interaction (M x V)	NS	NS	NS	NS

Means followed by same letter(s) in a column within the same factor are not significantly different at 5% level of probability using least significant difference (LSD). NS- Not significant

Table 3 shows the effect of moisture stress at different growth stages on the bulb size and yield of onion varieties. The stressed plants produced significantly shorter bulbs than the non-stressed plant watered at 3 days interval except plants stressed at mid growth stage (three to seven leaf stage) which had statistically similar bulb length with the non-stressed plants. The daily watered plants also had similar short bulb with the drought stressed plants. Bulbs of the daily watered plants were the smallest (with the least bulb diameter). The value obtained was however statistically similar to what was recorded in plant stressed at the early (flag leaf emergence to two true leaves stage) and mid growth stage. Non stressed plants watered at 3 days interval throughout the growth stages had the highest yield (4299.95 kg ha^{-1}). Moisture stress at flag leaf to two true leaf stage reduced onion yield by 57.74% compared to the non-stressed plants. While drought stress at mid growth stage and bulb formation stage reduced bulb yield by 40% and 48.54 % respectively compared to the non-stressed plants. The highest yield reduction (59.22%) was observed in the daily watered plants when compared to the non-stressed plant watered at three days interval throughout the growth stages. The value obtained (1753.35 kg ha^{-1}) were however similar to the bulb weight recorded in plants stressed at the flag to true leaf stage (1817.35 kg ha^{-1}). There was no significant difference among the varieties in respect of the bulb length and diameter. Sivan variety produced the highest bulb yield (2754.15 kg ha^{-1}) but statistically similar to the value recorded in Red creole, Prema and Wuyan Bijimi. The least yield was obtained in Wuyan makwarma (2018.55 kg ha^{-1}).

Table 3: Effect of moisture stress at different growth stages on the Bulb length, bulb diameter and bulb yield of onion varieties

Treatments	Bulb length (cm)	Bulb diameter (cm)	Bulb yield (kg ha^{-1})
Moisture stress (M)			
10 – 50days	4.49b	4.08bc	1817.35c
50 – 90days	4.83ab	4.09bc	2583.15b
90 – 140days	4.47b	4.36b	2212.75bc

Daily watering	4.52b	3.89c	1753.35c
3 days watering interval	5.07a	5.43a	4299.95a
LSD (0.05)	0.53	0.30	715.6
Variety (V)			
Red creole	4.54ab	4.42a	2664.15ab
Sivan	5.06a	4.27a	2754.15a
Prema	4.55ab	4.45a	2548.55ab
Wuyan makwarwa	4.69ab	4.23a	2018.55b
Wuyan bijimi	4.53b	4.49a	2681.15ab
LSD (0.05)	0.53	0.30	715.6
Interaction (M xV)	NS	NS	NS

Means followed by same letter(s) in a column within the same factor are not significantly different at 5% level of probability using least significant difference (LSD). NS- Not significant

DISCUSSION

Drought stress significantly reduced the growth and yield of the onion varieties compared to the non-stressed plants in this study. This was expected as water is needed for cell division and elongation which is responsible for increase in plant growth. Onion is a shallow-rooted plant that requires frequent irrigation to achieve good yield. Drought induces a complex array of responses in plants including stomatal closure, reduced turgor pressure, altered leaf gas composition and reduced photosynthesis rates leading to reduced growth and crop yield (Farooq *et al.*, 2012). Al-Jammal *et al.* (2000) reported that onions under water deficiency decrease in its evapotranspiration and consequently yield. Plants watered daily similarly had reduced growth and bulb yield like the drought stressed plants. This is an indication of overwatering which results to flood stress in plants. Too much soil moisture presents another extreme condition for plants leading to inhibition of gas exchange; oxygen is depleted which restricts respiration and therefore causes energy imbalance and reduction of photosynthesis. Olalla F. *et al.* (2004) reported that the lower the volume of water onion received, the higher the efficiency obtained. However, if the volume of water is low enough to induce moisture stress in the plant, growth and yield will be affected.

There was significant reduction in the plants performance when drought stress was introduced at the different growth stages but plant stressed at the early growth stage; flag leaf to two true leaf stage appears to be more affected. Pelter *et al* (2004) similarly reported that moisture stress at 3-7 leaf stage reduced onion bulb yield by 26% compared to the control which were irrigated throughout the growth stages. Contrary to the result obtained in this study however, Dirirsa *et al* (2021) reported that moisture stress at

early growth stage did not significantly reduce the bulb yield of onion. The difference may be as a result of the extent of the moisture stress in the two studies as well as the varieties used. Plants stressed at the early growth stage had the least survival rate in this study. This contributed to the reduced yield recorded compared to the moisture stress imposed at other stages. The mid growth stages was not as affected as much as early growth and bulb formation stage in this study. Dirirsa et al (2021) similarly reported that depriving onion water at bulb formation stage resulted in lower bulb yield compared with the other stages. The significantly lowest number of leaves recorded in plant stressed at the bulb formation stage may be attributed to preferential partitioning of assimilates to bulb at this stage which is further aggravated by insufficient moisture. At reproductive stage, plants partition more assimilates to the reproductive structures than other organs. With the occasion of drought stress, the plant will rather partition the little assimilate available to the reproductive structures than the leaves. This explains why the drought stressed plant senesce faster. Sivan variety produced significantly higher yield than Wuyan makwarwa in this study. This may be attributed to the fact that Sivan is a hybrid and Wuyan makwarwa a landrace. Hybrids possess higher yield traits and tolerance/resistant to environmental stress than unimproved varieties. Adediran (2020) reported between 143-318% increase in grain yield and gross margin increase by 300% and above in cowpea when some improved varieties were used compared to landraces.

CONCLUSION

Drought stress significantly reduced the growth and yield of the onion varieties tested at all the growth stages compared to the control. However, drought stress introduced at the early growth stage (flag leaf to two true leaf stage) appeared to be more critical. Furthermore, overwatering significantly affected onion growth and yield more than drought stress hence should also be avoided as much as drought stress in onion production. Watering at 3 days interval throughout the growth stages is therefore recommended for optimum performance of onion in the agro-ecology.

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