ISSN: 2449 - 0539
BAYERO JOURNAL OF ENGINEERING AND TECHNOLOGY VOL 18 NO. 2 MAY 2023 PP. 49-60

EFFECT OF DEFICIT IRRIGATION AND MULCH ON ONION GROWTH AND YIELD PARAMETERS IN SEMI-ARID REGION OF NIGERIA

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ABSTRACT

Water insufficiency is one of the major challenges for irrigated agriculture, particularly in water-stressed regions, which prompted the need to promote water-saving irrigation methods such as deficit irrigation (DI) and mulch practices (MP). An experiment was conducted to assess the effect of DI and MP on the productivity of Onions at Dala Alhamderi Irrigation Site, Borno State, Nigeria, during the 2020/2021 irrigation season. The experiment consisted of 4 levels of irrigation (100, 85, 70, and 55% of weekly reference evapotranspiration and 4 levels of mulches (no mulch NM, synthetic plastic SM, wood shaving WM and rice straw RM). The treatments were replicated 3 times making 48 plots and laid using a split-plot design. The data on Onion height, canopy cover, number of leaves, bulb yield, and water use efficiency (WUE) were collected and analyzed using the Statistics 8.0 software package. The interaction effect of DI and MP has significantly ($p<0.05$) affected the Onion growth parameters, yield and WUE. The higher growth parameters were recorded at mulched compared to no-mulch plots. However, among the mulched, plots irrigated at 85% with SM mulch yielded high values of Onion height, canopy cover, and the number of leaves of 42cm, 72%, and 8 respectively, Whereas the lower mean values of the Onion growth parameters were recorded at plots irrigated at 70 and 55% under WM and RM mulch. Higher Onion yields of 15.10 t/ha were recorded at plots irrigated at 85% with SM mulch, which was 19.4% higher than plots irrigated at 100% with no mulch treatment. The highest crop water use efficiency value of 19.08 kg/m^3 was observed at 85% irrigation with SM mulch. Meanwhile, the lowest crop WUE of 12.53 kg/m^3 was obtained for treatment at 100% irrigation under no-mulch. The crop WUE increases as the irrigation decrease under the mulching order of NM, RM, WM, and SM mulch during the cropping season. It can be concluded that the Onion farmers in the study area should adopt the DI at 85% with SM mulch that increased Onion bulb yield production by 19.4% and saved water by 15% when compared to the conventional full irrigation with no mulch. The saved water could be used to expand more land for crop cultivation.

Keywords: Deficit Irrigation, Mulching, Onion production, Semi-arid and Region

1.0 INTRODUCTION

Water plays a crucial role in the sustenance of life on earth as it is a significant component of sustainable agricultural production, particularly in arid and semi-arid regions (FAO, 2007). Freshwater is a limiting factor for agricultural development mainly due to climate change impacts, and ever-increasing competition from industrial, environmental, and domestic sectors (UNESCO-WWAP, 2012). Some of the causes of water scarcity comprise climate change impact, water wastage, and rapid increase in demand due to the expansion of socio-economic activities (Shanono, 2021a). For example, the agricultural sector is the major user of water as it consumed about 70% of the total global freshwater. However, this sector has the highest water wastage behaviour due to reluctance to employ efficient irrigation methods and techniques (Gan et al. 2013). These among other reasons made agricultural water demand grow at an alarming rate, particularly in water-stressed regions of the world including Maiduguri, Borno State, in Nigeria (Forouzani and Karami 2011). Adequate and sustainable agricultural water management is therefore crucial at all levels ranging from the catchment to irrigated district, to farm and field scale (Shanono, 2021b). Managing water resources at the macro-level is relatively difficult, time-consuming and expensive, even though it is unavoidable. The field-level water management is relatively low-cost and more practicable. Improving field-scale level water management through the adoption of more efficient and effective irrigation methods and techniques such as deficit irrigation and mulch practices is crucial (Syial, 2016). Farmers should be trained on such on-farm irrigation strategies to achieve efficient utilization of the available scarce water resources (Shanono & Ndiritu, 2020). In recent years, deficit irrigation and mulch practices attracted attention, especially in water-stressed areas (Chartzonlakis and Bertaki, 2015).

Water use efficiency (WUE) can be maximized by applying deficit irrigation (DI) and mulch practices (MP) which can result in an increased crop yield per volume of water used. The DI is a deliberate practice of irrigating crops below their water requirements. The main aim was to minimize water applied to the crops without adversely affecting crop yield and hence, maximize crop yield per water applied (Temesgen, 2018). Such deliberate reduction in water can be applied either during specific growth stages or throughout the growing season (Rop et al, 2016). According to Garg & Dadhich (2014)**,** DI is commonly employed in water-stressed areas with which the net WUE and economic returns can be improved. The WUE has been found to improve substantially when DI strategy is coupled with mulch practices (Hamdan and Mubarak, 2018). It is a valuable technique that can be effectively utilized for expanding irrigable land with the same amount of water and thus, will help to increase overall production. This practice has been recognized as an important water-saving approach for the production of many fields and horticultural crops (Chai, 2016). In semi-arid areas, DI strategies have a significant advantage in terms of yield and water use efficiency and for reduction of salinity build-up. However, before adopting this strategy, there is a need to have prior knowledge of the crop yield responses to deficit irrigation and mulch materials.

Mulching is a management practice that is used for increasing soil water use efficiency by conserving moisture. It is a practice that involves the laying/spreading of organic or inorganic material on the soil surface. The basic purpose is to protect the soil from direct solar radiation, modify the soil temperature, reduce the rate of evaporation, and thus, make more soil moisture available for the plant's growth, which ultimately leads to higher crop yield and improved WUE. There are various types of mulching materials including bio-residuals (crop straw, sawdust, wood shaving, grasses, etc.) and synthetic materials (polyethene sheet of different thicknesses and colours) (Khaledian et al., 2010). Onion (Allium cepa L.) is one of the horticultural crops of higher nutritional and economic value. It is shallow-rooted and sensitive to water stress. According to Obeng et al., (2007), the cultivation of Onions in West Africa is concentrated in Northern Nigeria, Niger, Senegal, and Northern Ghana. In Northern Nigeria, however, the crop is grown at the commercial level in Borno and Kebbi States. Onion is used widely in Nigeria and many parts of the world for flavouring and seasoning foods, as a vegetable, and for medication. It forms an essential part of the daily diet, creating year-round demand for it.Kadayifci et al. (2005) stated that to obtain a high Onion bulb yield water deficits should be avoided especially during the period of bulb formation. Tsegaye et al. (2016) found that DI at 75% of the required water was found to be optimum in southern Ethiopia. Igbadun, et al, (2012), reported that irrigating Onion at a water application depth of 50% of the weekly reference evapotranspiration (WRET) caused a yield reduction of about 28.8%. However, irrigating at water application depths of 75% of WRET only reduced bulb yield by about 5 – 9%. This suggests that water application depth per irrigation may be reduced to 75% of atmospheric water demand without causing a significant loss in bulb yield of onion. This study was conducted to assess the Onion performance on sandy-loam soils under changing water applications and different mulch materials in the semi-arid region of Nigeria. Section 2 of the paper presents the methodology while sections 3 and 4 present the results and conclusions respectively.

2.0 MATERIALS AND METHODS

2.1 Study Location and Experimental Design

This study was conducted at Dala Alhamderi Irrigation Project, Maiduguri, Borno State, Nigeria. The Irrigation project is located between Latitudes 11° 05` and 11° 55'N, Longitudes 13° 02` and 13° 16'E, and an altitude of 345 m above mean sea level as indicated in fig. 1 The mean annual rainfall of the study location is about 625 mm and the temperature range of 28.5 °C – 40.5 °C (Adeniji et al., 2013). The climate of Maiduguri is generally semi-arid with moderate variation in temperatures. The soils in the study location is predominantly sand to sandy-loam having low moisture retention and high permeability, and few places with clay to clay-loam.

The field experiments consisted of two factors (water application depth and mulch practice) each at four levels. The four levels of water application depths are 100, 85, 70, and 55% of weekly reference evapotranspiration (WRET), while the four levels of mulch practice consisted of no mulch (NM); rice straw (RM), Wood shaving mulch (WM) and white synthetic plastic mulch (SM). The treatments were replicated 3 times making 4 × 4 × 3 = 48 experimental plots. The experiment was laid out using a split-plot design (SPD). The block was separated by a distance of 0.5 m and the basins in each block were also separated by a distance of 0.5 m. Such separation aims to minimize the lateral movement of water from one basin to another.

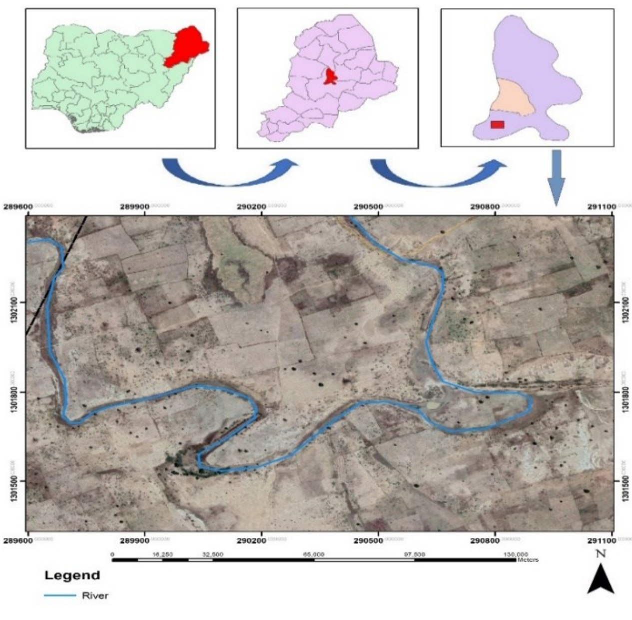

Fig. 1 Location of the study area

2.2 Field and Laboratory Analysis

Soil samples were taken from the experimental field at 0 - 15 cm and 16 - 30 cm and soil physical properties (soil texture, bulk density, field capacity, permanent wilting point, and available water) were determined using standard procedures as described by Michael (2008) and Yaji (2003).

2.3 Agronomic Operations and Irrigation Water Application

A land area of 36 m by 15 m was cleared and prepared into leveled basins of 2.0 m x 2.0 m and Onion seedlings were transplanted on 1st December 2020. The variety of Onion used was a red creole, which is commonly grown in the study area. The Onion seedlings were raised in the nursery and transplanted eight weeks after sowing. The Transplanting was then done at crop spacing of 20 cm between plants and 25 cm between rows resulting in a crop density of 80 plants per plot. Fertilizer (NPK) was applied at the rate of 450 kg/ha, given in two applications. Diammonium phosphate fertilizer (NPK 15:15:15) was first applied at the rate of 32.5 kg/ha N at two and eight weeks after transplanting. The mulch materials were placed two weeks after transplanting. All other agronomic practices were conducted according to standard procedure (Igbadun et al., 2012, Sinnadurai, 1992; and Sen *et al,* 2006).

The surface irrigation method which is not uncommon in the study location was used. The major source of water in the study area is the tube well because the surface water gets dried up immediately after the rainy season. Water was released from the main source (Tube well) into the canal then to a lateral ditch which conveys the water by gravity to the field ditches and then the experimental plot basins. A PVC tube of 5 cm diameter and 50 cm length was installed in each basin to admit water into the basins. The PVC tubes were also installed through the embankment of each basin with one end in the field ditch and the other end in the basin. The tube was installed such that it can enable a free orifice flow into the basins. Stage gauges were placed at the water inlet of each basin to measure the depth of water over each tube as water enters the basin. Rubber corks were placed at the entrance such that when the corks are removed, water flows into the basins. When the desired volume of water is applied the PVC corks would be put back to stop the flow of water into the plot. Using the orifice flow Equation 2.1 (Nally, 2013), the depth of flow recorded from the stage gauge was quickly used to determine the flow rates into each basin and the time of application was used to compute the desired volume of water application. The time required to apply the volume of water was monitored using a stopwatch. The soil moisture status of each plot was monitored throughout the crop growing season using a soil moisture meter.

$$Q = AVK = \pi \left({}^{d}/_{2}\right)^2 \sqrt{2gh}\,\mathrm{K} \qquad \ldots \qquad (2.1)$$

$$t = \frac{V}{Q} \qquad \ldots \qquad (2.2)$$

Where, Q = flow in cubic meters per second (m^3/sec), A = area of the orifice in square meters (m^2), V = velocity of the liquid in meters per second (m/sec), K = 0.82 Constant for tube, g = 9.81 m/s^2 = Acceleration due to gravity in meter per square second (m/s^2), h = Head across the orifice in meters (m), d = diameter of the orifice in meters (m), t = time taken to apply the required volume of water (s), v= volume of water to be applied (m^3).

During the initial period, all experimental plots were irrigated at full irrigation to ensure proper plant establishment. Then, different irrigation strategies were applied to the developmental, mid and late growth stages. The amount of water applied at every irrigation event was observed throughout the crop growing season and was based on the reference evapotranspiration amount for the days of irrigation and the experimental treatment plots. The average weekly reference evapotranspiration for December, January, February, and March were 25 mm, 37 mm, 53 mm, and 58 mm, for treatment Irrigated at 100% respectively. The seasonal water applied for the treatments irrigated at 100%, 85%, 70%, and 55% WRET were 577, 490, 404, and 317 mm respectively throughout the crop growing season.

The soil moisture status of the experimental field was monitored throughout the crop growing season using a soil moisture meter. Soil moisture measurements were carried out twice a week, two days after irrigation and on the seventh day (just before the next irrigation). It is assumed that most soil will attain field capacity two days after irrigation.

Reference evapotranspiration (ETo) of the site was computed using the FAO-Penman-Monteith method incorporated in the CROPWAT model (FAO, 1977). The weather data for the calculation of ETo was obtained from Meteorological Station (NIMET) situated in Maiduguri International Airport, Maiduguri. The crop water use (actual crop evapotranspiration) between successive moisture measurements was estimated using the soil water depletion method as expressed in Equation 2.3 (Igbadun and Oiganji, 2012).

$$ET_a = \frac{\sum_{i=1}^{n}(\mathrm{MC_1} - \mathrm{MC_2})\,\mathrm{A_s} x \mathrm{D_i}}{\mathrm{t}} \qquad \ldots \qquad (2.3)$$

Where: ET_a is the weekly crop water use between successive soil moisture content sampling (mm/day); MC_1 is soil moisture content (g/g) two days after irrigation in the i^{th} soil layer; MC_2 is soil moisture content (g/g) at the time just before next irrigation in the i^{th} layer; A_s is bulk density (g/cm^3) of the i^{th} layer; D_i is the thickness of the i^{th} layer (mm); n is the number of soil layers sampled in the root zone depth D, and t is days between successive soil moisture content sampling.

The crop consumptive use (CWU) of the treatments irrigated at 100% WRET (I_{100}), was regarded as actual consumptive use (ACWU) while the CWU of the deficit irrigated treatments (I_{85}, I_{70}, I_{55}) was regarded as deficit consumptive use (DCWU).

2.4 Determination of Onion Growth Parameters, Yield, and Water Use Efficiency

To ascertain the treatment responses and influence on crop growth and yield parameters, the plant height, the number of leaves per plant, canopy cover, crop biomass, harvest index, and yield attributes were determined as follows:

- The plant height (PH) in each experimental plot was measured at 2, 4, 6, 8, and 10 weeks after transplanting using a 100 cm long meter rule from the leaf base to the tip of the plant.
- The number of leaves (NL) per plant was manually counted during 2, 4, 6, 8, and 10 weeks after transplanting in each experimented unit. The average value for each plot was computed and recorded separately.
- The canopy cover (CC) was determined using equation 2.4 as expressed by Hsiao et al., (2009).
- Leaf area (LA) was obtained by a non-destructive indirect method using a linear regression model described by Corcoles *et al*. (2015) in equation 2.5.
- The total crop biomass (CB) was determined as the weight of the below and above-ground parts of the Onion, as given in equation 2.6.
- Harvest index (HI) was calculated as the percentage ratio of bulb yield to total biomass as given in equation 2.7.

$$CC = \frac{LA_m N}{A} \times 100 \quad \ldots \quad (2.4)$$

$$LAI = 0.000199 + 1.277L \times A_{25} \quad \ldots \quad (2.5)$$

$$CB = BB + LB \quad \ldots \quad (2.6)$$

$$HI = \frac{Y}{B} x100\% \quad \ldots \quad (2.7)$$

Where; CC is the canopy cover in %, LA_m is the average leaf area in m^2, N is the number of leaves and A is the area occupied by crop in m^2. L is the total leaf length and A_{25} is the leaf width taken from a distance of 25% from the leaf base. HI is the harvest index, Y is the onion yield in Kg/ha, CB is the crop biomass, BB is the bulb biomass, LB is the leaves biomass and B is the total onion biomass in Kg/ha.

The Onion bulb yield (Y) was computed for each of the experimental plots following Igbadun et al. (2012). The ratio of the weight (W) of the harvested Onion bulb in Kg to the area (A) of the experimental plot in ha is shown in Equation 2.8.

$$Y = \frac{W}{A} \quad \ldots \quad (2.8)$$

Where; Y = Onion bulb yield in kg/ha, W = crop weight in kg, and A = experimental plot in ha.

The crop water use efficiency (CWUE) was calculated as the ratio of the yield of Onion in Kg to the total amount of water consumed by the crop in m^3 as expressed by Bagg and Turner, (1976) and shown in Equation 2.9

$$CWUE = \frac{Y_a}{ET_a} \quad \ldots \quad (2.9)$$

Where: CWUE = Crop Water Use efficiency, ET_a = Actual crop Evapotranspiration (m^3) and Y_a is the crop yield (Kg/m^2)

2.6 Data Analysis

The data collected from the experiment were analyzed using Analysis of Variance (ANOVA) for split-plot design (SPD) using the Statistics 8.0 software package. The least significant differences (LSD) at a 0.05 probability level were used as the mean separation test.

3.0 RESULTS AND DISCUSSIONS

3.1 Effect of Deficit Irrigation and Mulch on Onion Growth Parameters

3.1.1 Number of Onion Leaves

The interaction effect of deficit irrigation (DI) and mulch practices (MP) has significantly ($p < 0.05$) influenced the Onion number of leaves as shown In Figure 3.1. The mean values of Onion number of leaves obtained at mulched plots were higher compared with no mulch plots for all the treatments and this has been observed throughout the cropping season. There was a less significant difference among the mean values of the Onion number of leaves obtained for all the treatments in mulched plots. However, the white synthetic mulch (SM) plots recorded the highest mean value range 3 to 8 irrespective of irrigation depth compared to plots with other mulch materials throughout the cropping season. While the lowest mean values of 3 to 7 were obtained at the plots with a wood shave and rice straw mulched materials at different levels of crop growth throughout the cropping season. The average Onion number of leaves recorded at 85% irrigation with SM was not statistically significantly different from the values of the number of leaves obtained at fully irrigated (100%) plots. This is an indication that the Onion crop could be irrigated at 85% with SM to produce more leaves and save 15% water. There was a significant difference between the mean values of the number of leaves recorded at 100 and 85% irrigation compared with the mean values at 70 and 55% irrigation. This result seems closely related to that of Biswas *et al.* (2003), who reported that Onion bulbs of fully irrigated treatments gave the highest leaves number per plant than the less irrigated ones. Irrigation and mulch facilitate nutrient availability and photosynthesis for the undisrupted growth of the plant. Similarly, the reduced number of leaves per plant at 70 and 55% irrigation levels is attributed to the water stress on cell expansion (Abbey and Joyce, 2004). This indicated that plants respond to water-stress by closing their stomata to slow water loss by transpiration, gas exchange within the leaf is limited. Consequently, photosynthesis and growth will be slowed down (Curah and Proctor, 1990).

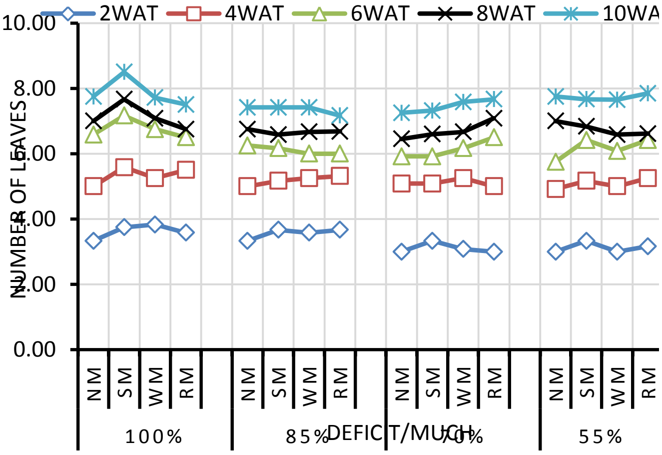

Figure 3.1: Effect of deficit irrigation and mulch material on Onion number of leaves

3.1.2 Onion Leaves Height

Onion leaves height has been significantly ($p < 0.05$) affected by the interaction effect of deficit irrigation and mulch materials as indicated in Figure 3.2. There was a significant difference between the mean values of Onion leave height recorded at mulched plots compared to no mulched plots throughout the cropping season. The mean values of Onion leave height observed during the experiment at the no mulch plots were less than the mean values at the mulch plots. Notwithstanding, among the values obtained at mulched plots, the mean values recorded at white synthetic mulch (SM) plots yielded high Onion leaves height values of 18.90 to 42.13cm when compared with the values of 18.25 to 41.17cm recorded at other mulch materials. There was no significant difference in the mean values of Onion plant height recorded at 85% irrigation with SM compared with the values recorded at 100% irrigation. But a significant difference was noticed at 70% and 55% irrigation throughout the growing season.

The result also shows that there was a rapid increase in leave height at 2 to 8 WAT for all the treatments, while a steady increase in Onion leave height was reached at 8 and 10 WAT. The highest mean value of 42cm of Onion leaves height observed at 85% irrigation with white synthetic could be due to the availability of soil moisture that in turn enhance effects on the vegetative growth of plants by increasing cell division and elongation. The increasing plant height with adequate depth of irrigation application also indicates the favorable effect of water in maintaining the turgor pressure of the cell which is the major prerequisite for growth. On the contrary, the shortening of leave height under soil moisture stress may be due to stomata closure and reduced CO_2 and nutrient uptake by the plants and hence, photosynthesis and other biochemical process are hampered, affecting plant growth (El-Noemani *et al.,* 2009). This is in agreement with the report by Wien (1997) indicated that plant height had a linear correlation with the availability of soil moisture. The present result was also in line with the work of Al-Moshileh (2007) who reported that with increasing soil water supply, plant growth parameters (plant height) were significantly increased.

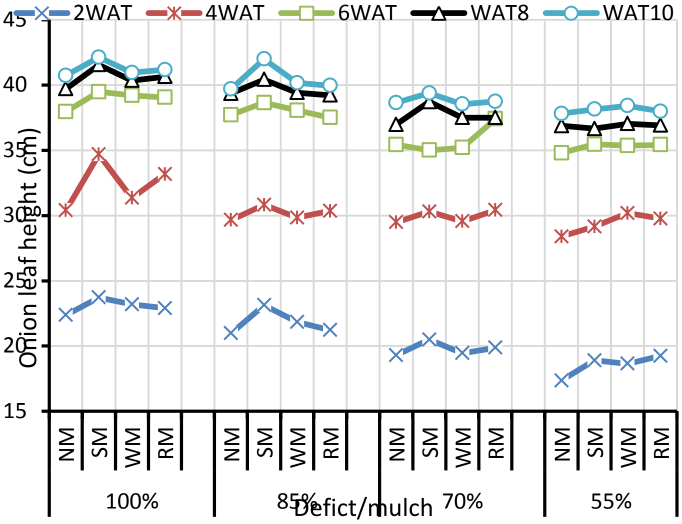

Figure 3.2 Effect of deficit irrigation and mulch on Onion leave height

3.1.3 Onion Canopy Cover

Figure 3.3 show the interaction effect between deficit irrigation and mulch materials on the Onion canopy cover (CC). The result shows that the experimental plots with mulched materials recorded high percentage values of Onion canopy cover than no mulched plots (NM). Among the mulched plots, the results recorded at the experimental plots with the white synthetic mulched materials (SM) recorded high percentage values of CC throughout the cropping season. The high percentage CC values ranging between 14.85 to 71.58% was recorded at 85% irrigation with SM. While the lower percentage values of CC recorded vary between the experimental plots with wood shave and rice straw mulch at 70 and 55% irrigation at different stages of Onion growth. The percentage values of CC recorded at 85% irrigation with all the mulched materials were very close to the values obtained at 100% irrigation with the same mulch materials. This might be a result of the crop water used at both 100% and 85% irrigation being within the FAO recommended water requirements for Onion. This contradicts the findings of Addai *et al.,* (2014) which indicated that drought stress, does not significantly affect the vegetative growth of Onion. But were in line with the report from FAO (2013) which indicated that Onion is sensitive to water deficit.

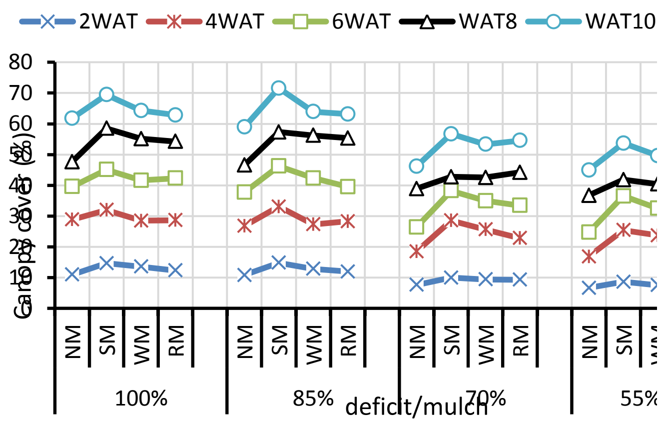

Figure 3.3: Effect of deficit irrigation and mulch on Onion canopy cover throughout the cropping season

3.2 Effect of Deficit Irrigation and Mulch on Onion Yield

3.2.1 Onion Bulb Size

The weights of the Onion bulb for the 3 proposed sizes (<=3 cm, 3 to 5 cm, and >5 cm diameter) were significantly affected by the interaction effect between irrigation and mulch materials as presented in Table 3.4 and figure 3.4. The result showed that there was a significant difference between the weights of Onion bulbs for a given size obtained at no mulch plots compared with mulched plots during the experiment. The highest total weight of Onion bulb size of <=3 cm diameter range between 3.00 to 4.88 kg was recorded at no mulch plots compared to 2.33 to 3.95 kg obtained at mulched plots irrespective of the level of irrigation throughout the cropping season. While the mulched plots recorded the highest total weight mean values for both 3 to 5.0 cm and >5.0 cm Onion bulb size. The results revealed that among the mulched plots, white synthetic mulch (SM) recorded the highest Onion bulb weight mean values of 8.95 kg at 3 - 5.0 cm diameter and 5.43 kg for >5.0 cm. while the lowest total weight of Onion bulb mean values of 6.25 kg and 0.55 kg for 3 to 5.0 cm and >5.0 cm bulb size respectively were obtained at 55% irrigation with rice straw mulched plot. This result in line with a report from Sen *et al.,* (2006), showed that all other parameters used on onion such as bulb diameter, bulb length, bulb weight per plant, and yield increase with the increase of soil moisture.

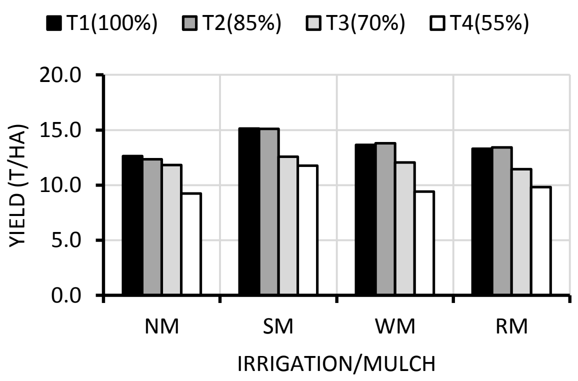

Figure3.4: Effect of deficit irrigation and mulch on Onion bulb yield

3.2.2 Onion Bulb Yield

The interaction effect of deficit irrigation and mulch materials on the Onion bulb yield is presented in Table 3.4 and depicted in figure 3.6. Deficit Irrigation and the mulching combination produced a significant ($p < 0.05$) effect on the total onion bulb yields as presented in Table 3.4. There was a significant difference ($p \leq 0.05$) between the irrigation and mulch treatments during the cropping season. The result indicated that the mulched plots yielded high bulb yield mean values than no mulched plots. It was also observed that among the mulched plots, white synthetic mulched plots produced the maximum mean values of 11.78 to 15.13 t/ha compared with 9.42 to 13.81 t/ha obtained with other mulched materials. The bulb yields of treatments irrigated at 85% with SM were statistically significantly different from those that were irrigated at 100% with no mulch. There was an increase in Onion bulb yield of about 19.4% higher than the yield obtained at full irrigation. The reason might not be far from the fact that actual seasonal evapotranspiration at 85% treatments was relatively within the water requirement for optimum Onion yield production recommended by FAO. It was, however, found that the bulb yields at 100% and 85% irrigation with SM were not significantly different, but highly significantly different were observed with values obtained at 70% and 55% irrigation with SM, wood shave and rice straw mulched plots. This result is in agreement with the study carried by Alenazi et al., (2015) for Melon and Osama (2015) for Olive. It was observed that, for the same level of irrigation, all mulched treatments produced significantly higher Onion yield when compared with un-mulched treatments. This pattern of the result was noticed both in the mulch and no-mulch treatments, which implies that irrespective of mulch materials, water application depth significantly influences bulb yield. It was expected that the least irrigated treatments at 55% would produce the lowest bulb yield, while the irrigation treatments at 100% and 85% would produce the highest bulb yield since the Onion crop is known to be sensitive to water at the development and bulb formation stage. Also, a high yield was expected from white synthetic mulch which is known to reduce evaporation and increase soil temperature thereby improving the yield compared to other mulch materials. The positive effects of mulches over No Mulch on bulb yield in this study agreed with Artyszak et al., (2014), who reported that mulching increased root yield by 9.4 to 11.2 %.

3.3 Effects of Deficit Irrigation and Mulch on Water Use Efficiency

Figure 3.5 show the interaction effects of deficit irrigation and mulching practice on crop water use efficiency (CWUE). The result indicates that the CWUE values were increased as the application of irrigation level decreased from 100%, 85%, and 70% under the mulching order of No Mulch, rice straw, Wood shave, and white synthetic mulch to 55% irrigation with a mulching order of no mulch, wood shave, rice straw and white synthetic mulch (SM) throughout the cropping season. The result also revealed that there were variations in the values of CWUE within the same water application level under mulch or no mulch treatment plots. The highest crop water use efficiency value of 19.08 kg/m^3 was observed at 85% irrigation with white synthetic mulch. The lowest crop water use efficiency value (12.53 kg/m^3) was noted for treatment that received 100% irrigation under No Mulch. The current study results indicated that an increase in the irrigation water application level in the order of white synthetic Mulch, rice Straw Mulch, and No Mulch respectively, caused a corresponding decrease in mean values of CWUE. Similar results were also reported by Hussain, A., (2015) for common bean in the central Rift Valley of Ethiopia, Alenazi et al., (2015) for melon. This, however, shows that Onion water use efficiency has been influenced by mulch materials at various irrigation levels. This is an indication that mulch materials could be used for increasing crop water use efficiency by conserving soil moisture. The increase in crop water use efficiency with decreasing level of irrigation application under rice straw, white synthetic and no mulch in the current study was in agreement with that reported by Mukherjee et al., (2010) for tomatoes.

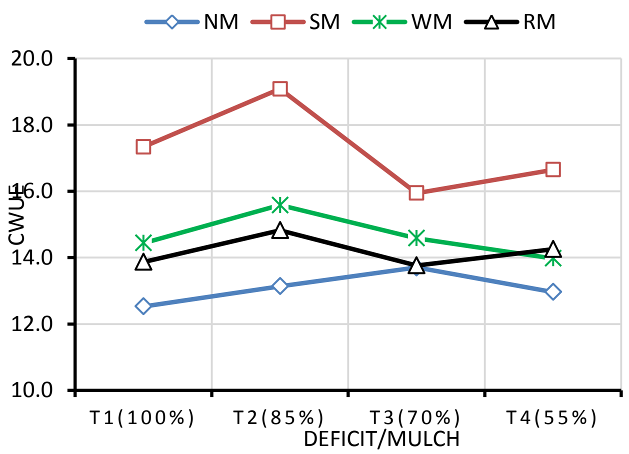

Figure 3.5: Effect of deficit irrigation and mulch on Onion water used efficiency

4.0 CONCLUSIONS

This study was conducted to assess the response of Onion growth parameters, yield and crop water use efficiency to deficit irrigation and mulch practice under sandy-loam soils at Dala Alamderi Irrigation Project Maiduguri, Borno State, Nigeria. The result revealed that the interactions between Irrigation levels and the Mulch combination produced a significant ($p < 0.05$) effect on the Onion growth parameters, yield, and water use efficiency. The mean values for the growth parameters (number of leaves per plant (NL), leaf height (LH), and canopy cover (CC) recorded higher values at mulched plots compared to no mulched plots throughout the experiment. It was also observed that among the mulched plots, experimental plots irrigated at 85% with white synthetic mulch material yielded high values of NL, LH and CC. while the lower mean values of the Onion growth components were recorded at plots irrigated at 70 and 55% underwood shave and rice straw mulch materials at different growth stages. Significantly higher Onion yields of 15.13 t/ha were recorded at plots irrigated at 100% with white synthetic mulch (SM), which statistically were not significantly different from bulb yield of 15.10 t/ha recorded at 85% with SM. A significant Onion bulb yield increase of about 19.4% was recorded at 85% irrigation with SM compared to full irrigation under no mulch. Hence, SM mulch can help in maintaining Onion yield even when water application is reduced. The interaction effect of deficit irrigation and mulch on Onion water use efficiency varies according to irrigation level and mulch materials. The CWUE values were increased as the application of irrigation level decreased from 100%, 85% and 70% under the mulching order of No Mulch, rice straw, Wood shave, and white synthetic mulch to 55% irrigation with a mulching order of no mulch, wood shave, rice straw and white synthetic mulch (SM) throughout the cropping season. The highest crop water use efficiency value of 19.08kg/m^3 was observed at 85% irrigation with white synthetic mulch. Meanwhile, the lowest crop water use efficiency value of 12.53 kg/m^3 was noted for treatment that received 100% irrigation under No Mulch. To obtain higher bulb yield and better crop water use efficiency, it can be concluded that Onion farmers at the Dala Alamderi Irrigation site should adopt the interaction of irrigation at 85% with white synthetic mulch because it increased Onion bulb yield by 19.4% and saved water by 15% compared to full irrigation with no mulch. This practice, besides the saved water and increase yield, it would also reduce the cost of production for the farmers and help mitigate waterlogging and soil salinity which are some of the main hurdles in promoting agricultural activities in most canal irrigated areas. Furthermore, it will also be a valuable strategy in reducing the fertilizers and other chemicals leaching into the groundwater and thus will minimize the risk of groundwater pollution. In the tube-well irrigated area, it will not only be helpful to minimize the risk of groundwater mining and thus avoid environmental catastrophes but will also reduce power consumption. Also, the saved water can be used for bringing new areas under irrigation.

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