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Response of Onion (*Allium cepa* L.) to Irrigation Intervals and Plant Density in Zuru, Northern Guinea Savanna of Nigeria

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ABSTRACT: Field experiments were conducted during the dry seasons of 2006/07 and 2007/08 at the Teaching and Research Farm of the College of Agriculture, Zuru, Kebbi State, Nigeria. The objective was to investigate the response of onion to irrigation interval and plant population density. The treatments consisted of factorial combination of four irrigation intervals (3, 6, 9 and 12 days) and five plant population densities (160,000, 200,000, 250,000, 350,000 and 500,000 plants/ha), corresponding to 25x25, 25x20, 20x20, 20x15 and 20x10 cm spacing respectively. The treatments were laid out in a split plot design with three replications. Irrigation interval was allocated to the main plots and population density to the sub plots. Results reveal that mean bulb diameter, mean cured bulb weight and onion yield in both trials and the combined analysis were significantly ($p < 0.05$) favoured by irrigation intervals at 3 and 6 days. Lower plant densities (160,000 and 200,000 plants/ha) increased both bulb diameter and cured bulb weight but decreased total yield. The result of the research concluded by recommending 6 days irrigation interval and plant population density of 500,000 plants/ha for maximum onion yield in the study area.
Keywords: Onion, irrigation, population, Northern Guinea savanna, Nigeria.

INRODUCTION

Onion (*Allium cepa* L.) is an important vegetable crop valued for its pungent or mild flavour and for being the essential ingredient of the cuisine of many regions (Anonymous, 1993). World production of onion is estimated at over 61.6 million metric tons of bulb, and yield per hectare averaged 18.45tons with Nigeria's average yield put at 14.8 tons (FAOSTAT, 2006).

Based on the level of consumption, onion is the major spice in the diet, ranking 5th most important vegetable in Nigeria (Denton and Ejeifo, 1990). The main production period of onion in Nigeria is during the dry season between September and April. The crop is produced in dry areas in the northern parts of the country, and three crops are possible in a year, two rain fed and one irrigated (Anonymous, 1993).

Farmers' production practice of onion involved complex mixture of cropping with other vegetables such as lettuce, tomato and pepper among others. Plant population densities under such mixed cropping were estimated to be between 160,000 and 500,000 plants per hectare (Uzo and Currah, 1990).

Water as a natural resource is inadequate in most areas where onion production is prevalent. Its application must be done efficiently to ensure profitability, while at the same time maximizing yield. This study therefore deemed it justified to look into the optimum combination of watering regime and onion plant density needed to optimize onion production in the study area.

MATERIALS AND METHODS

Two experiments were conducted during 2006/07 and 2007/08 dry seasons at the Teaching and Research Farm (latitude 12^0

9'N and longitude $4^{0}15$'E) of the Kebbi State College of Agriculture, Zuru. The area is in the Northern Guinea Savanna agro-ecological zone with a rainfall range of 660-800mm per annum, spread over a period of 5 - 6 months (May - October) (Anonymous, 2009). A mean monthly temperature range of 14 – 41^{o}C was recorded in 2003 – 2008 (Table 1). The soil of the study area was clay loam (pH=5.7) (Table 2). The treatments consisted of four irrigation intervals (3, 6, 9 and12 days) and five plant population densities (160,000, 200,000, 250,000, 350,000 and 500,000 plants/ha) corresponding to 25x25, 25x20, 20x20, 20x15 and 20x10 cm spacings respectively.

Table 1: Mean monthly temperature, relative humidity, solar radiation and wind speed at the experimental site during the period of the experiments (2006/07 and 2007/08 cropping seasons).

Month	Temperature (^{O}C)			Relative Humidity (%)			Solar Radiation (kcalcm^{-1})			Wind Speed (Km/h)		
	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
Jan	-	23.9	26.1	-	26	25	-	14.5	15.7	-	151.4	86.15
Feb	-	25.9	28.6	-	22	22	-	18.3	17.5	-	157.2	91.20
March	-	31.2	29.9	-	22	21	-	18.3	17.6	-	103.0	115.59
April	-	34.9	34.6	-	34	39	-	18.0	17.8	-	105.3	114.28
May	-	34.9	34.7	-	41	36	-	18.7	18.5	-	126.1	122.09
June	-	32.1	-	-	51	-	-	17.3	-	-	168.8	-
July	-	28.7	-	-	69	-	-	15.2	-	-	135.9	-
Aug	-	27.1	-	-	79	-	-	14.7	-	-	91.4	-
Sept	-	27.8	-	-	77	-	-	17.2	-	-	74.3	-
Oct	29.3	27.7	-	47	63	-	17.8	16.4	-	66.43	50.9	-
Nov	29.4	29.1	-	29	30	-	17.3	17.6	-	80.05	64.5	-
Dec	27.7	26.4	-	27	26	-	16.7	16.5	-	104.9	91.1	-

Source: Kebbi State Environmental Protection Agency (KESEPA)

Table 2: Physico - chemical Properties of the Soil at the Experiment Site in 2004/05 and 2005/06 Cropping Seasons.

Physical and Chemical Characteristics	2004/2005	2005/2006
Chemical properties		
pH (Water)	6.35	5.61
pH ($CaCl_2$)	5.92	5.56
Organic Carbon (g/kg)	0.27	0.74
Total N (g/kg)	0.05	0.77
Available P (ppm)	0.025	0.024
Cation Exchange Capacity (CEC) (cmol/kg)	3.16	3.16
Exchangeable Bases (cmol/kg)		
Ca	0.095	0.040
Mg	0.065	0.040
K	1.025	1.0505
Na	1.080	0.113
Physical Properties(gkg^{-1})		
Sand	44.2	33.8
Silt	44.4	35
Clay	11.4	31.2
Textural Class	Loam	Clay

The treatments were factorially combined and laid out in a split plot design with three replications. Irrigation interval was allocated to the main plots while population densities to the subplots. All plots received water to field capacity (at 3 days interval) for 9 days to enable proper crop establishment before imposition of irrigation treatment. Gross plot size was 2 x 4m ($8m^2$), while the net plot was 2x2m ($4m^2$). In both experiments, a Sokoto land race seed called *Jar-Yar Ankara* (Red ex-Accra) was used. Seedlings were raised in a nursery bed using nursery management techniques (thinning out and hardening off were carried out before transplanting). The seedlings (after 40 days of sowing) were transplanted to the field on the 14th and 17th November, for the 2006 and 2007 trials respectively. A complete compound fertilizer (NPK 15:15:15) at the rate of 300 kg/ha was applied in two split doses. Half dose as basal dressing, and the rest at three weeks after transplanting (WAT) as top dressing. Also 150kg/ha of urea was applied as top dressing at 5 WAT. The plots were kept free of weeds as much as possible throughout the period of the experiment using hand hoe. Flies and other insect pests were sprayed at an interval of 3WAT, using a broad base insecticide KARATE (Lambdahalothrin M-25EC) at $4mLL^{-1}$.

Data were collected on mean bulb diameter, mean cured bulb weight and bulb yield per hectare. Data were also subjected to analysis of variance (ANOVA) and means were separated using Least Significant Difference (LSD) and Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Mean Bulb Diameter (cm): Mean bulb diameter of onion was significantly ($p<0.05$) affected by irrigation frequency in both seasons and the two years combined (Table 3).

Table 3: Mean Bulb Diameter (cm) of Onion as Affected by Irrigation Frequency and Plant Population Density in 2006/2007 and 2007/2008 Cropping Season and Two Years Combined.

Treatment	2006/07	2007/08	Combined
Irrigation(1)			
3	4.10a	4.25a	4.31a
6	3.98a	4.19a	4.10a
9	93.3b	3.48b	3.41b
12	3.25b	3.43b	3.35b
SE±	0.09	0.10	2.20
Significance	*	*	*
Population (P)			
160,000	4.56a	4.68a	4.59a
200,000	3.98b	4.09b	4.01b
250,000	3.66c	3.73c	3.53c
350,000	3.28d	3.52c	3.42c
500,000	2.83e	3.03d	2.94d
SE±	0.06	0.11	0.13
Significance	*	*	*
Interaction			
I x P	NS	NS	*

Within treatments, means in a column followed by same letter (s) are not significantly different at 5% level using LSD. NS = not significant; * = significant

Irrigation intervals of 3 and 6 days produced the highest bulb diameter compared with 9 and 12 days interval. This trend could be linked to adequate supply of the photosynthetic raw material (water), which controls most of the plant physiological processes including bulb development. According to Brown (1984), high temperatures reduce the rate of photosynthesis in most plants. With the characteristic high temperatures (up to 34^0C) of the experimental site, the rate of evapotranspiration was very high. Therefore keeping irrigation interval above six days has greatly deprived the plant the available water for optimum photosynthesis, hence less dry matter was partitioned to bulbs, which might have resulted in reduced size of the bulbs (Brown, 1984).

Population density had significantly ($p<0.05$) affected mean bulb diameter in both trials and the two years combined (Table 3). Plant density of 160,000 plants/ha produced the highest bulb diameter (4.59cm), followed by 200,000 plants/ha (4.01cm). Plant densities of 250,000 and 350,000 plants/ha followed, with 3.53cm and 3.42cm respectively, and the least (2.95cm) bulb diameter was at 500,000 plant/ha. Bulb enlargement requires spacing and since high plant density implies closer spacing and ultimate reduction in space available per plant, then tendency is real that bulb expansion might be limited, due to smaller space for bulbing.

Significant ($p<0.05$) interaction was recorded between irrigation frequency and plant population density on mean bulb diameter (Table 4) in the combined. Combination of 3 and 6 days irrigation intervals with plant population densities of 160,000 and 200,000 plants/ha produced the largest bulbs. The least bulb diameter was obtained in combination of 12 days irrigation intervals with 350,000 and 500,000 plants/ha.

Table 4: Mean Diameter (cm) of Onion as Affected by Irrigation × Plant Density Interaction in Two Years Combined.

Irrigation	Plant density (plants/ha)				
	160,000	200,000	250,000	350,000	500,000
3	4.46a	4.41a	4.40a	4.05b	3.98b
6	4.32a	4.33a	4.01b	4.10b	3.98cd
9	3.59c	3.60c	3.44cc	3.10d	3.01d
12	3.49cd	3.37cd	3.38d	2.75e	2.710e
SE±		0.08			

Across columns and rows, means followed by the same letter (s) are not significantly different at 5% level using DMRT

Mean cured Bulb Weight (g): Cured bulb weight was significantly ($p<0.05$) affected by irrigation frequency in both seasons and in the combined (Table 5). The irrigation intervals of 3 and 6 days produced the highest (53.59 and 53.05g) bulb weight compared to 9 days (42.71g) and the least was at 12 days (33.89g) .The weight of onion bulb depends on both the water content and the percentage soluble solid (brix) of the bulbs. Since curing means reducing water content and the bulbs were given the same curing treatment, the brix would now determine the weight of the bulbs. As explained earlier, high irrigation frequency ensures production of more photosynthate, by supplying enough water to compensate for the high evapotranspiration that resulted due to high temperatures of the experimental area. This ensures concentration of more solutes in high irrigation frequency bulbs than low irrigation frequency bulbs (Greany, 1984) and consequently the bulbs weight.

Plant population density had a significant ($p<0.05$) effect on mean cured bulb weight in both seasons and the combined analysis (Table 5). Plant population densities of 160,000, 200,000 and 250,000 plants/ha were similar and significantly higher than the population densities of 350,000 and 500,000 plants/ha, in terms of mean cured bulb weight. This could be attributed to the space available per plant, which enhances bulb size and weight (Das, 1992). The interaction between irrigation frequency and plant population density was significant in the first trial and the combined analysis (Table 6). Irrigation intervals of 3 and 6 days produced highest mean cured bulb weight at all population densities tested, but the least cured bulb weight was obtained in 12 days irrigation interval at plant density of 500,000 plants/ha.

Table 5: Mean Cured Bulb Weight (g) of Onion as Affected by Irrigation Frequency and Plant Population Density in 2006/2007 and 2007/2008 Dry Seasons.

Treatment	2006/07	2007/08	Combined
Irrigation (I)			
3	56.35a	52.62a	53.59a
6	53.66a	54.23a	53.06a
9	44.23b	41.08b	42.71b
12	35.94c	34.67b	33.89c
SE±	3.01	2.98	2.23
Significance	*	*	*
Population (P)			
160,000	58.22a	57.34a	57.45a
200,000	56.34a	54.43a	55.34a
250,000	55.68a	53.51a	53.56a
350,000	45.38b	46.09b	44.13b
500,000	40.04c	42.62b	41.33b
SE±		2.20	2.81
Significance	*	*	*
Interaction			
I × P	*	NS	*

Within treatments, means in a column followed by same letter (s) are not significantly different at 5% level using LSD. NS = not significant; * = significant

Table 6: Mean Cured Bulb Weight (g) of Onion as Affected by Irrigation Frequency × Density Interaction in the Two Years Combined.

	Plant density (plants/ha)				
Irrigation	160,000	200,000	250,000	350,000	500,000
3	55.52a	54.81a	51.31a	50.03ab	46.39ab
6	56.32a	54.98a	52.40a	49.85ab	47.34ab
9	48.33ab	47.25ab	42.11bc	41.02bc	35.96d
12	40.17cd	39.03cd	36.25d	36.01d	34.24de
SE±			1.42		

Across columns and rows, means followed by the same letter (s) are not significantly different at 5% level using DMRT

Onion Bulb yield (t/ha) Bulb yield was significantly ($p<0.05$) affected by irrigation frequency in both trials and the combined result (Table 7). Irrigation at 3 and 6 days interval produced the highest bulb yield compared with both 9 and 12 days irrigation interval. Ideally, any practice that favours increase in mean bulb weight must under similar conditions result in proportionate increase in total yield. Therefore the above trend could be attributed to the larger and heavier individual onions obtained in 3 and 6 days irrigation intervals. This result is in line with the findings of Amans (1995) who reported a significant increase in onion bulb yield by increasing frequency of irrigation. Plant population density produced a significant effect on onion yield in both trials and the combined analysis (Table 7). The highest yield was recorded in the population of 500,000 plants/ha, followed by 350,000 and 250,000 plants/ha, while the least yield was in 160,000 plants/ha. The higher yield recorded in high population density was because adequate plant density is a pre - determining factor for unit area return (Frabbel, 1979; Arnold, 1986). According to (Frabbel, 1979; Arnold, 1986), increase in crop yield could be obtained through increase in population through increase in number of plants per unit area. In the interaction between plant density and irrigation interval on onion yield (Table 8), the highest yield was recorded at 3 and 6 days irrigation interval, coupled with the population density of 500,000 plants/ha. The lowest yield was recorded when irrigation frequency was kept at 12 days interval and at the population density of 160,000 - 200,000 plants/ha

Table 7: Onion Bulb Yield (t/ha) as Affected by Irrigation Frequency and Plant Population Density in 2006/07 and 2007/08 Cropping Seasons and the Two Years Combined

Treatments	2006/07	2007/08	Combined
Irrigation(I)			
3	11.97a	12.20a	12.40a
6	11.77a	11.43a	11.65a
9	9.59b	10.27b	9.85b
12	9.12b	10.07b	9.87b
SE±	0.35	0.32	0.30
Significance	*	*	*
Population (P)			
160,000	9.35c	9.33d	9.52d
200,000	10.03bc	10.23c	10.22c
250,000	10.54b	10.96b	10.88b
350,000	10.83b	11.00b	10.92b
500,000	11.66a	12.83a	12.01a
SE±	0.20	0.25	0.20
Significance	*	*	*
Interaction			
I × P	NS	*	*

Within treatments, means in a column followed by same letter (s) are not significantly different at 5% level using LSD. NS = not significant; * = significant

Table 8: Onion Bulb Yield (t/ha) as Affected by Irrigation Interval x Plant Density Interaction in the Two Years Combined.

Treatments		Plant density (plants/ha)			
Irrigation	160,000	200,000	250,000	350,000	500,000
3	10.02ef	10.31e	11.91c	11.28c	13.50ab
6	10.35e	10.42e	12.97b	12.91b	13.66a
9	9.71f	9.87ef	11.34d	11.33d	12.05c
12	8.01g	8.11g	9.411	9.33f	10.12ef
SE±			0.20		

Across columns and rows, means followed by the same letter (s) are not significantly different at 5% level using DMRT.

CONCLUSION

From the findings of this research, 3 and 6 days irrigation interval are most suitable for onion production in the study area. Similarly, plant density of 500,000 plant/ha gives greater yield advantage.

RECOMMENDATION

Irrigation interval of 6 days and plant density of 500,000 plants/ha could be recommended for onion production in Zuru, Kebbi State, Nigeia.

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