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Correlation matrix on weed parameters, growth and yield attributes of onion (*Allium cepa*) under Sudan savanna agro-ecological zone of Nigeria

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Abstract

Controlling weed development during the onion crop cycle is essential to obtain high yields and marketable produce. Field experiments were conducted in a farmer's field at Birnin Kebbi during the 2017/2018 and 2018/2019 dry seasons to assess the association between weed parameters, growth, and yield attributes of onion (*Allium cepa* L.) under Sudan Savanna agro-ecological zone of Nigeria. The experiment was made up of three planting populations (500,000, 333,333, and 250,000 plants per hectare) and twelve weed control methods (Pre-emergence application of pendimethalin at; (i) 1.0 kg a.i. ha^{-1}, (ii) 1.5 kg a.i. ha^{-1} and (iii) 2.0 kg a.i. ha^{-1}. Butachlor; (iv) 2.0 kg a.i. ha^{-1}, (v) 2.8 kg a.i. ha^{-1} and (vi) 3.6 kg a.i. ha^{-1}. Post-emergence application of fluazifop-p-butyl, (vii) 2.0 kg a.i.ha^{-1}, (viii) Oxyfluorfen at 1.0 kg a.i. ha^{-1}, (ix) Weeding at 3 WAT, (x). Weeding at 3 and 6 WAT, (xi) Weed free, and (xii) Weedy check given 36 treatment combinations replicated three times and arranged in Randomized Complete Block Design (RCBD). Data collected were planted height, leaf area, weed control index, weed dry matter, weed control efficiency, crop vigor score, bulb diameter, fresh bulb weight, total bulb weight, marketable bulb yield, and cured bulb yield. Results showed that Fresh bulb yield, total bulb weight, bulb diameter and marketable yield correlated positively and highly significantly ($p<0.01$) with cured bulb weight. Correlations between any two parameters also showed that leaf area index and plant height, marketable bulb yield and bulb diameter were strongly and significantly correlated in both years. It is therefore recommended that fresh bulb weight, bulb diameter and marketable bulb yield should be used as higher yielding character for improving onion production in this agro-ecology of Nigeria.

Introduction

Onion has been described as an herbaceous biennial bulbous monocot that grows up to 90 cm tall (Akobundu *et al*., 2016). The crop is a cool season crop that has some frost tolerance but is best adapted to a temperature range between 13 and 24°C, optimum temperatures for early seedling growth are between 23 and 27°C; growth is slowed at temperatures above 30°C (Jilani *et al.,* 2010). It was reported to have originated from Central Asia between Turkmenistan and Afghanistan (Bagali *et al*., 2012). China, India, the USA, Turkey, Japan, and Spain are the onion-producing and exporting countries in the world, while Malaysia, the United Arab Republic, Canada, Japan, Lebanon, and Kuwait are the major onion-importing countries, while China ranked the highest producers of onion, followed by India (Sharma *et al*., 2017).

The average annual global production of dry onion was 89.18 million tonnes (t), with an average annual yield of 18.74 t/ha (ha) between 2010 and 2018, while dry onion production in Nigeria accounted for roughly 1.43% of the world production in 2018 (Adeoti *et al*., 2021). Onion production in Nigeria is concentrated in the Northern Guinea and Sudan savanna ecological zones and it is mainly grown under irrigation in the dry season in Kano, Kaduna, Jigawa, Sokoto, Plateau, Bauchi, and Kebbi States (Magaji *et al*., 2021). Mature onion bulbs are used in vegetables, spices, soups, and sauces purpose, the green leaves and immature/mature bulbs are eaten raw or used in the preparation of vegetables and are known for their high medicinal properties (Basha and Lakshmi, 2018). Tripathi and Lawande (2006) reported that several anti-inflammations, agents present in onions have been found helpful in reducing the severity of pain and swelling of joints and rheumatoid arthritis, sore throat, sinusitis, tonsillitis, allergic inflammation, and respiratory congestion during common cold.

The use of appropriate agronomic management has an undoubted contribution to increased crop yields. One of the major problems with onion production is improper agronomic practice used by farmers. The optimum level of any agronomic practice, such as plant population, planting date, and weed management, varies with the environment, purpose of the crop, and cultivar (Tekle, 2015). Globally, weeds are at present one of the major biotic constraints to increased onion production. One of the important things about increasing onion production is to minimize crop loss which is caused by weed competition because weeds do not only reduce the onion production but also have an adverse effect on the bulb quality. Weeds compete with onions for light, nutrients, water, and space, and harbored several harmful insects and pathogens (Uygur *et al*., 2010). Kraehmer and Baur (2013) reported that the effect of weed interference caused a reduction in crop yield and quality, delaying or interfering with harvesting, leading to billions of dollars' worth of crop losses annually. The use of herbicides supplemented with hoe weeding usually resulted in higher weed control efficiency, which is a reliable integrated weed control method compared with weedy check plots. In this regard, Osadebe *et al*. (2014) reported that lower weed control efficiency in weed check was due to higher weed density and weed dry matter.

However, there was less emphasis on how to improve the yield potential of onion, which is dependent on some agronomic characters, which Baliyan (2014) reported that onion yield could be regarded as a complex character that depends on several agronomic characters, especially bulb and leaf quality. To identify important component characters, correlation is considered an important tool. For the purpose of collecting information on the association of various kinds of characters on cured bulb yield as the basic requirement for improving better growth and yield of onions, the current study becomes paramount. This is in line with the report of Rahman *et al*. (2002), who revealed that if improvement is to be through selection, it is therefore important to have information on the nature and degree of association on yield and yield-contributing characters such as fresh bulb weight, bulb diameter, neck diameter, aboveground biomass, etc.

The objective of this study was therefore to determine the correlation between weed parameters, growth, and yield components of onion (*Allium cepa* L.) as influenced by weed control methods and plant population under Sudan savanna agro-ecological zone of Nigeria.

Materials and methods

1. Experimental site:

Field studies were conducted in Farmer's field at Birnin Kebbi, Kebbi State during the 2017/2018 and 2018/2019 dry seasons to evaluate the correlation of weed parameters with growth and yield attributes of onion as influenced by weed control methods and plant population under Sudan Savanna agro-ecological zone of Nigeria. Birnin Kebbi lies on latitude 12°25'N and longitude 4°15'E. The area enjoys a tropical type of climate generally characterized by an annual temperature range of 25-40 °C. The mean annual rainfall is about 500- 700 mm (Gindi *et al*., 2013). To ascertain the soil nutrient status of the soil in the experimental site, a soil sample was collected across the field and analyzed in the laboratory using standard procedures, and the result is presented in Table (1).

2. Experimental design and details:

The treatments consisted of factorial composition of three plant populations (500,000 plants/ha^{-1}; 333,333 plants/ha^{-1} and 250,000 plants/ha^{-1}) and twelve weed control methods (Pendimethalin at 1.0 kg a.i ha^{-1}, pendimethalin at 1.5 kg a.i ha^{-1}, pendimethalin at 2.0 kg a.i ha^{-1}, butachlor at 2.0 kg a.i ha^{-1}, butachlor at 2.8 kg a.i ha^{-1}, butachlor at 3.6 kg a.i ha^{-1}, fluazifop-P-butyl at 2.0 kg a.i ha^{-1}, oxyfluorfen at 1.0 kg a.i ha^{-1}, hoe weeding (Hw) at 3 weeks after transplanting (WAT), Hw at 3 and 6 WAT, Weed free (Weeding at intervals of one week throughout the growing period) and weedy check (No weeding throughout the growing period) arranged in a Randomized Complete Block Design and replicated three times. The name of the onion variety used for this study was Violet de Galmi, reported to have originated from Niger Republic. The variety was obtained from an agro dealer in Illela market, Sokoto State, Nigeria. The experimental field was irrigated, manually ploughed, and a plot size of 2m × 3m was constructed. Onion seedlings were raised from the nursery and transplanting was done in November 2017 and 2018, while harvesting was done in March 2018 and 2019 respectively. Poultry manure at the rate of 4 t/ha was uniformly incorporated on each experimental plot during land preparation. Administering of herbicides was conducted 2 days after transplanting (DAT) based on the treatments. The plots were irrigated 4-day intervals throughout the growing period. Data collection was ascertained at 3, 6, and 9 weeks after transplanting (WAT) on weed parameters (dry weed weight, weed control efficiency, and weed control index), growth parameters (Plant height (cm), leaf area index, crop vigour score) and yield parameters (fresh bulb yield, bulb diameter, total bulb weight, aboveground biomass, marketable bulb yield and cured bulb yield) and yield which were extrapolated to kg ha^{-1}

3. Observation on weed, growth, and yield parameters:

3.1. Weed dry matter:

The whole sample of weeds from each plot was collected by throwing the quadrate at 12 WAT. The weed samples collected were oven dried at 70^0C until constant weight was achieved.

3.2. Weed control efficiency (WCE):

Weed control efficiency (WCE) denotes the magnitude of weed reduction due to weed control treatment. It was obtained by using the formula suggested by Mani *et al.* (1973**)** and expressed in percentage.

$$\text{WCE (\%)} = \frac{\text{Weed density in control plots} - \text{weed density in treated plots}}{\text{Weed density in control plots}} \times 100$$

3.3. Weed control index (WCI):

Weed control index was worked out by using the formula developed by Mishra and Tosh (1979).

$$\text{WCI (\%)} = \frac{\text{Dry weight of weeds in control plots} - \text{dry weight of weeds in treated plots}}{\text{Dry weight of weeds in control plots}} \times 100$$

3.4 Plant height:

Plant height was measured using a meter rule from the ground level to the tip of the leaves from 5 randomly selected plants at 3, 6, and 9 WAT, and records were taken.

3.5 Leaf area index (LAI)

LAI is a dimensionless quantity that characterizes plant canopies. It is defined as the one-sided green leaf area per unit ground surface area or the ratio of the leaf area to the area of ground cover (Harper, 1983).

$$\text{LAI} = \frac{\text{Leaf area of plant (cm}^2\text{)}}{\text{Plant ground area (cm}^2\text{)}}$$

3.6. Crop vigor score:

A Crop vigor score was obtained through visual assessment of onion plants at 3, 6, and 9 WAT using a scale of 1-5, where scale 1 was scored for the least vigorous plots and 5 was scored for plots with the most vigorous onion plants.

3.7. Total bulb yield:

The total bulb yield was measured from the total harvest of the net plot as a sum weight of marketable and unmarketable yields that were measured in kg per plot and converted into kg ha^{-1}.

$$\text{Onion bulbs yield per hectare} = \frac{\text{Yield per plot (kg)}}{\text{Area of the plot (m}^2\text{)}} \times 10{,}000$$

3.8. Fresh bulb weight:

The fresh weights of 5 randomly selected matured onion bulbs were measured using a top loading balance to obtain fresh bulb weight during harvest, and the value was extrapolated and expressed as kilograms per hectare.

3.9. Cured bulb yield:

These are fresh, matured onion bulbs that were randomly selected from the population and air-dried at room temperature for 2 weeks. The matured onion bulbs were measured, and value extrapolated to and expressed in kilograms per hectare at 2 weeks after harvest**.**

3.10. Aboveground biomass:

This was obtained by separating the randomly selected underground bulb from the leaves. The weight of the leaves was measured, and the value was extrapolated and expressed in kilograms per hectare at harvest**.**

3.11. Marketable bulb yield:

Marketable bulb yield is described as the weight of healthy and marketable bulbs that range from 20 g to 160 g in weight. Lemma and Shimeles (2003) consider those bulbs below 20 g in weight to be too small to be marketed while those above 160 g were considered oversized. This parameter was determined from the net plot at the final harvest and expressed in kg ha^{-1}.

4. Statistical analysis:

Data collected was subjected to analysis of variance (ANOVA) using statistical analysis software (SAS, 2013) at a 5% level of probability and means were separated using the Duncan Multiple Range Test (DMRT).

Results and discussion

1. Soil analysis:

Soil analysis indicated that the soil in the experimental site was sandy loam with pH levels of 5.3 and 5.8 in 2017/2018 and 2018/2019, respectively (Table 1). There was low organic carbon, low total nitrogen, and very low available phosphorus in both years. The exchangeable cations (Ca, Mg, K, and Na) in both years were low. The cation exchange capacity (CEC) was low (4.92 c mol. Kg^{-1}) in 2017/2018 and high (13.0 c mol. Kg^{-1}) in 2018/2019. These results indicate the low nutrient status of the soil at the experimental sites could be because of the intensification of agricultural activities in the area. This corroborates the report of Noma *et al*. (2011), who stated that continuous cultivation, a common practice in an area, could be followed with the removal of crop residuals, which may expose the soil to degradation.

Table (1): Physical and chemical properties of soil at the experimental site.

Soil	2017-2018	2018 -2019
Physical properties		
Sand (%)	69.6	71.7
Clay (%)	9.4	5.5
Silt (%)	21.0	22.8
Textural class	**Sandy loam**	**Sandy loam**
Chemical properties		
pH (in water) 1:2	5.3	5.8
Organic carbon (%)	0.04	0.74
Total nitrogen (%)	0.074	0.042
Available P (mg kg^{-1})	0.63	0.71
Exchangeable bases		
Ca (c mol kg^{-1})	0.65	0.65
Mg (c mol kg^{-1})	0.30	0.90
K (c mol kg^{-1})	1.46	1.05
Na (c mol kg^{-1})	0.83	0.52
CEC (c mol kg^{-1})	4.92	13.0

Source: Soil Laboratory, Faculty of Agriculture, Usmanu Danfodiyo, University Sokoto

2. Matrix of correlation coefficient between growth, weed and yield attributes of onion:

The correlation matrix between weed, growth, yield, and yield attributes of onion in the 2017/2018 and 2018/2019 dry seasons are presented in Tables 2 and 3 respectively. During the 2017/2018 dry season, weed dry matter was negative but significant ($p<0.05$) correlated with cured bulb yield (-0.2839*), but in 2018/2019 the correlation between weed dry matter and cured bulb yield (-0.0769ns) was negative and not significantly correlated with cured bulb yield. Similarly, Geries and Azza (2018) reported the values of the correlation coefficient between weed dry matter and average bulb weight, marketable bulb yield, and total bulb yield to be negative and significantly correlated. The weed control index correlated positively and highly significantly ($p<0.05$) with cured bulb yield (0.3609**) in 2017/2018, but in 2018/2019 weed control index with cured bulb yield (0.0965) was positive but not significantly correlated. Likewise, the correlation between weed control efficiency and cured bulb yield in 2017/2018 and 2018/2019 (0.2235* and 0.2968* respectively) was positively and significantly correlated. This result could be due to the effective increase of weed control methods which might have led to a significant increase in cured bulb yield.

These results corroborate the report of Marwat *et al*. (2005), who stated that the variability of the treatments is due to the effectiveness of the control methods, which ultimately increased the nutrient availability for the crop.

The who cited that number of leaves at maturity directly contributed negatively to the bulb yield of garlic and contrary to the current result which shows in 2018/2019, that the leaf area index (0.4224**) was positive and highly significantly correlated with cured bulb yield. In correlation of plant height and cured bulb yield (0.0492 ns) in 2017/2018 correlated positively and was not significant, but in 2018/2019 the relationship was positive and highly significant (0.4046**). In 2017/2018, the leaf area index was negatively and not significantly correlated with cured bulb yield. (-0.0760ns) which was similar to the report of Ahmed and Magaji (2009) 2017/2018, crop vigor score and cured bulb (0.1394ns) was positive and not significantly correlated at $p<0.05$), but in 2018/2019, crop vigor (0.5389**) was positive and highly significantly correlated with cured bulb yield. This signified that the higher the number of leaves in the process of crop growth, the more the photosynthate would be utilized for vegetative growth rather than reproductive growth. This result also corroborates the report of Gulumbe *et al*. (2018), who stated that selection for cured bulb yield is expected to go along with leaf number, leaf area, leaf area index, plant height, and average bulb weight. Total bulb weight, fresh bulb weight, marketable bulb yield correlated positively and highly significantly ($p < 0.01$) with cured bulb yield with values at 0.7002**, 0.8595** and 0.6111**, respectively, while bulb diameter (0.2413*) was positive and significantly correlated with cured bulb yield in 2017/2018. In 2018/2019, bulb diameter (0.7258**), total bulb yield (0.7825**), fresh bulb weight (0.9536**), and marketable bulb yield (0.7639**) correlated positively and highly significant ($p < 0.05$) with cured bulb yield. This result revealed that with reduced weed shading, crop plants can photosynthesize more efficiently, leading to increased biomass production, which has mostly resulted in the positive and significant correlation observed between the yield components and cured bulb yield characters. This result relates to the report of Malik *et al*. (2011) who cited that the value increase of one of these parameters seeds an increase in the parameter to which it is significantly correlated. Similar results on onion were also reported by Junior *et al*. (2019), who stated that the genotypic and phenotypic association was positively and significantly correlated between marketable yield of bulbs with bulb mass, total yield, and number of cloves per bulb, indicating that selection based on these characteristics will help increase the yield of garlic.

The strongest and highly positive significant ($p < 0.01$) correlation was in both years with fresh bulb weight and cured bulb yield (r = 0.8595** and 0.9536**), total bulb weight and cured bulb yield (r = 0.7002** and 0.7825**), marketable bulb yield and cured bulb yield (r = 0.6111** and 0.7639**), respectively. The strong and significant correlation between leaf area index and plant height, marketable bulb yield, and bulb diameter indicated that the combination of these characters can make up a good selection for a better-cured bulb. These combinations might also be attributed to their importance as a great determinant of the cured bulb yield of onion. A similar result was reported by Gulumbe *et al*. (2018), who stated that a highly significant ($P < 0.001$) positive correlation between plant height and leaf area, plant height and leaf area index (0.84676), and bulb diameter and cured bulb weight (0.28133) were obtained in a correlation study for bulb yield and yield-contributing traits among onions in Sokoto. This finding agrees with the report of Aliyu *et al*. (2007) who stated that cured bulb yield had a significant positive correlation with plant height, number of leaves per plant, bulb diameter, and bulb weight.

Assessing the study of two cropping seasons as indicated in Tables 2 and 3, the strong and highly significant correlation between any factors was that from leaf area index at 9 WAT and plant height at 9 WAT (r = 0.9717** and 0.9776**), fresh bulb weight and cured bulb yield (r = 0.85935** and 0.9536**), total bulb yield, and fresh bulb weight (0.7109** and 0.7873**), followed by total bulb weight and cured bulb yield (r = 0.7002** and 0.7825**), respectively. However, the positive and significant correlation between most of the weeds, growth, and yield characters observed in this study indicates interdependency amongst the characters, and these matrices are of great importance in assisting breeders in establishing and thus selecting those characters.

The association between weed parameters, growth, and yield attributes of onion revealed important characteristics for higher yield of onion in this study. It could be deduced that weed control efficiency ensures that the crop has optimal growing conditions, leading to increased photosynthesis and overall plant health. Significantly, plant height, leaf area index, crop vigor score, bulb diameter, fresh bulb, and total bulb weight appear to be the most important yield contributing characters. Nevertheless, the correlation between cured bulb yield and the other yield parameters have shown that total bulb weight, fresh bulb weight, aboveground biomass, and marketable bulb yield are the most important yield determinants in onions as regards this study. The improvement of the leaf area index will improve the plant height of the onion, and marketable bulb yield will improve the bulb diameter of onion in this agroecology of Nigeria. Therefore, in an attempt to improve or increase the yield ability of onions, efforts should be directed toward encouraging these attributes during the selection of genotypes for breeding.

Table (2): Matrix of correlation coefficient between cured bulb yield and components of weed, growth, and yield of onion at Birnin Kebbi during the 2017/2018 dry season.

Variables	DWW	WCE	WCI	PH9	LAI9	CVS9	BDM	TBW	FBW	AGB	MBY	CBY
DMW	1.0000											
WCE	-05692**	1.0000										
WCI	-07503**	0.6303**	1.0000									
PH9	0.0084ns	0.2487ns	0.0813ns	1.0000								
LAI9	-0.006ns	0.2399*	0.0997ns	0.9717**	1.0000							
CVS9	-0.2592ns	0.4363**	0.2547ns	0.5762**	0.5940**	1.0000						
BDM	-0.1592ns	0.0423ns	0.0047ns	0.4381**	0.4376**	0.3184ns	1.000					
TBW	0.2128*	0.2879*	0.3812**	0.1432ns	0.1334ns	0.2338*	0.4073**	1.0000				
FBW	-0.2952*	0.1829*	0.3639**	0.0105ns	-0.0157ns	0.1445ns	0.2218*	0.7109**	1.0000			
AGB	0.0742ns	0.0934ns	0.1087ns	0.1314ns	0.1207ns	0.1027ns	0.1803ns	0.3491*	0.3697**	1.0000		
MBY	-0.1557ns	0.2329*	0.2507ns	0.1309ns	0.1245ns	0.1970*	0.3773**	0.6255**	0.6469**	0.4663**	1.0000	
CBY	-0.2839*	0.2235*	0.3609**	0.0492ns	-0.0760ns	0.1394ns	0.2413*	0.7002**	0.8595**	0.2465*	0.6111**	1.0000

KEY: ** = Highly significant at 1%. * =significant at 5% ns = not significant at 5%

DWW- Dry weed weight **LAI – Leaf area index** **TBW – Total bulb weight**
WCE - Weed control efficient **CVS – Crop vigor score** **AGB – Above ground biomass**
WCI – Weed control index **BDM – Bulb diameter** **MBY – Marketable bulb yield**
PH – Plant height **FBW – Fresh bulb weight** **CBY - Cured bulb yield**

Table (3): Matrix of correlation coefficient between cured bulb yield and components of weed, growth, and yield of onion at Birnin Kebbi during the 2018/2019 dry season.

Variables	DMW	WCE	WCI	PH9	LAI9	CVS9	BDM	TBW	FBW	AGB	MBY	CBY
DMW	1.0000											
WCE	-0.6428**	1.0000										
WCI	-0.8491**	0.6445**	1.0000									
PH9	0.2279*	0.0825ns	0.2158*	1.0000								
LAI9	0.2028*	0.1221ns	-0.1900*	0.9776**	1.0000							
CVS9	0.0090ns	0.2709*	-0.0063ns	0.7348**	0.7317**	1.0000						
BDM	0.1187n	0.0575ns	-0.1375ns	0.5864**	0.6006**	0.5381**	1.0000					
TBW	-0.0869ns	0.3369*	0.1502ns	0.4798**	0.5931**	0.4752**	0.7297**	1.0000				
FBW	-0.0635ns	0.3200ns	0.0970ns	0.4336**	0.4507**	0.5497**	0.7212**	0.7873**	1.0000			
AGB	-0.0126ns	0.0676ns	0.0049ns	0.2903*	0.3009*	0.3171ns	0.6251**	0.5648**	0.6358**	1.0000		
MBY	0.0888ns	-0.0025ns	-0.1027ns	0.5014**	0.5147**	0.4947**	0.7790**	0.6686**	0.7598**	0.8187**	1.0000	
CBY	-0.0769ns	0.2968*	0.0965ns	0.4065**	0.4224**	0.5389**	0.7258**	0.7825**	0.9536**	0.6326**	0.7639**	1.0000

KEY: ** = Highly significant at 1%. * =significant at 5% ns = not significant at 5%

DMW- Dry matter weight
WCE - Weed control efficient
WCI – Weed control index
PH – Plant height
LAI – Leaf area index
CVS – Crop vigor score
BDM – Bulb diameter
FBW – Fresh bulb weight
TBW – Total bulb weight
AGB – Above ground biomass
MBY – Marketable bulb yield
CBY - Cured bulb yield

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