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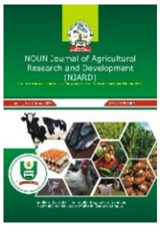

Original Article

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Weed Infestation, Growth and Bulb Yield of Onion (*allium cepa* l.) As Influenced by Weed Control and Fertilization in Northern Guinea Savanna Zone of Nigeria.

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ABSTRACT

Field trials were conducted during the 2021 and 2022 wet seasons at the research farm of the Institute for Agricultural Research, Samaru, Zaria to determine the best weed control treatment and fertilization rates on growth and bulb yield of onion (Allium cepa L.). The treatments were laid out in a Randomized Complete Block Design (RCBD) in split block arrangement and replicated three times. Weed species with higher Important Value Index was Cyperus rotundus in both seasons. Application of pendimethalin at 1.63 kg a.i ha^{-1} + one hoe weeding at 6 WAT and hoe weeding at 3 and 6 WAT recorded higher weed control index. A slight crop injury was recorded by application of pendimetalin + oxyfluorfen at 1.3 + 1.2 kg a.i ha^{-1}. All weed control treated plots recorded higher growth parameters and bulb yield than the weedy check. In contrast, application of N.P.K + AZ at 65: 45: 45 kg ha^{-1} + 0 L ha^{-1}, 0 kg ha^{-1} + 12 L ha^{-1} and the untreated control recorded higher weed control index. Application of N.P.K + AZ at 32.5: 22.5: 22.5 kg ha^{-1} + 6 L ha^{-1} and 65: 45: 45 kg ha^{-1} + 0 L ha^{-1} increased growth and bulb yield than other fertilization rates. In conclusion, all herbicides treatments were safe on onion and comparable to hoe weeding at 3 and 6 WAT in enhancing weed control index, growth performance and higher bulb yield. Application of N.P.K + AZ at 32.5: 22.5: 22.5 kg ha^{-1} + 6 L ha^{-1} and 65: 45: 45 kg ha^{-1} + 0 L ha^{-1} significantly (P ≤ 0.05) enhanced better growth and higher bulb yield than other fertilization rates in both seasons.

Keywords: *Onion, pendimethalin, oxyfluorfen, Agric zyme 3x, inorganic fertilizer*

1.0 INTRODUCTION

Onion (*Allium cepa* L.) belongs to the family *Amaryllidaceae,* it is one of the most important vegetable crops in the world. Although its point of origin remains uncertain, the middle Asian countries of Iran and Pakistan are considered the primary centre of its origin (Anon., 2003). Onion is a cool season crop that is frost tolerant, but is best adapted to temperatures of 13 – 24 **°C**. It is also requires fertile, well-drained and slightly acidic soil with optimum pH of 6 - 6.8 (Yassen and Khalid, 2009). There is a rapid development in onion production in Nigeria accounting for 1.692 million metric tonnes, and which is ranked as the 13th country among the highest producers on the world scale and 3rd in Africa (FAOSTAT, 2023). This could probably be due to cultivation of improved and high yielding cultivars recently introduced into the country by some international seed companies. However, improper weed management and inadequate crop nutrition, among other factors are major hindrances to yield enhancement (Borse *et al*., 2015, Elian *et al*., 2016 and Garba, 2021). It therefore becomes necessary to improve on the cultural practices in order to attain higher yield of the cultivars.

Weed control is often the most important crop management activity in onion production. Uncontrolled weed growth, especially in the early stages of crop growth can greatly decrease crop yield through competition for nutrients, moisture, space and light (Hillocks, 1998). Muhammad (2018) reported that low onion yield was attributed to weed infestation. Regular weed control is essential for successful onion production and presently, weed control is achieved through mechanical tillage and/or the use of herbicides (Anon., 2012). However, research has revealed that over time weeds have developed resistance to single herbicide use and no herbicide can give season long weed control. Therefore there is need to adopt the use of combination of herbicides for effective weed management in onion.

The use of inorganic fertilizer alone is discovered to generate several deleterious effects on the environment and human health (Ali *et al.*, 2007). Therefore, in order to obtain a significant yield increase in onion while safeguarding the environment and human health, there is need to supplement inorganic nutrient source with other sources. The use of organic fertilizers is effective in promoting plant growth and environmental sustainability under long-term use. However, previous studies have focused primarily on the conventional solid organic fertilizer product, such as straw and manure (Atiyeh *et al.,* 2001, Sun *et al.,* 2014). Manures are usually bulky and the cost of transporting them from one location to another is high. Specialized horticultural production has fostered the emergence of new liquid organic fertilizers (Pichyangkura and Chadchawan, 2015), which are derived from natural products and their biological efficacies require limited doses. Soluble nutrients in liquid organic fertilizers could maintain soil and plant health compared to conventional organic fertilizer and organic matter (Dordas *et al.,* 2007, Hou *et al.,* 2017). In addition, its folia application could improve the nutrients use efficiency and decrease the risk of nutrients loss (Ceretta *et al.,* 2010, Toonsiri *et al.,* 2016).

1.1 Objectives of the Study

This study was therefore undertaken with the following objectives:

1. To determine the best weed control treatments for better crop growth and optimum bulb yield of onion cultivar in Northern Guinea savannah of Nigeria.
2. To determine the best fertilization rates for optimum growth and bulb yield of onion cultivar in Northern Guinea savannah of Nigeria.

3.0 MATERIALS AND METHODS

3.1 Experimental Site

Field trials were conducted during the wet seasons of 2021 and 2022 at the research farm of the Institute for Agricultural Research, Samaru (11°10'N; 07°38' E; 686m above sea level), Zaria in the Northern Guinea savanna zone of Nigeria.

3.2 Treatments and Experimental Design

The experiment consisted of factorial combinations of two onion cultivars [Prema and Ex-Kudan (Yar-Huguma)], four weed control treatments (Pendimethalin + oxyfluorfen at 1.3 + 1.2 kg a.i ha^{-1}, pendimethalin at 1.63 kg a.i ha^{-1} + one hoe weeding at 6 WAT, hoe weeding at 3 and 6 WAT and weedy check) and four fertilization rates [Inorganic + liquid organic {Agric Zyme 3X (AZ)} fertilizers at 0: 0: 0 + 0, N.P.K + AZ at 32.5: 22.5: 22.5 kg ha^{-1} + 6 L ha^{-1}, N.P.K + AZ at 65: 45: 45 kg ha^{-1} + 0 L ha^{-1} and N.P.K + AZ at 0 kg ha^{-1} + 12 L ha^{-1}]. The treatments were laid out in a Randomized Complete Block Design (RCBD) in split block arrangement with cultivars assigned to sub – plots, while weed control and fertilization were assigned to main plots and replicated three times.

3.3 Cultural Practices

3.3.1 Land preparation

The land was ploughed and harrowed, after which the plots were marked out and made into raised seed beds of 2.1 m × 2 m (4.2 m^2) with 1 m gaps between the plots and replications.

3.3.2 Seed treatment

The seeds were dressed with Apron Star (200g Kg^{-1} Thiamethoxam + 200g Kg^{-1} Metalaxyl-M + 20g Kg^{-1} Difenoconazole) before sowing in the nursery bed at the equivalent rate of 5 g to 2 kg of onion seed and this was thoroughly mixed by hand using hand glove.

3.3.3 Nursery practice and transplanting

The nursery was established on 15th May, 2021 and 18th April, 2022 at the Artemisia Research Programme Garden, Institute for Agricultural Research, Samaru, Zaria. The seeds were sown in the nursery beds, each 5 × 1.2 m by drilling method and there after mulched with dry straw for 5 days from sowing. This was done to enhance effective seed germination, emergence and prevent the young seedlings from excessive sun light and damage by insect pests and birds. Weeds were controlled by regular hand pulling on the nursery beds. Cow dung was incorporated into the nursery beds at rate of 3 kg per 6 m^2 and was irrigated twice depending on the availability of moisture in nursery beds. The seedlings were uplifted from the nursery beds at 7 weeks after sowing (WAS) and transplanted at the experimental site. One seedling per stand, at 20 × 15 cm inter and intra-row spacing, which gave approximately population of 333,333 plants / ha.

3.3.4 Herbicide application

Herbicides were applied according to treatments. Pendimethalin was applied pre-emergence at 3 days before transplanting (DBT) and oxyfluorfen was applied post – emergence at 4 weeks after transplanting (WAT). Each herbicide was applied using a CP15 knapsack sprayer fitted with a green deflector nozzle and set at a pressure of 2.1 kgcm^{-2} with discharge spray volume of 200 L ha^{-1}. Spraying was done in the morning when the weather was cold to avoid wind drift. All herbicides used are selective on onion and the rates was based on crop tolerant.

3.3.5 Fertilizer application

Inorganic fertilizer was applied in two split doses; the first application (N.P.K 15: 15: 15) served as basal dose at 2 weeks after transplanting (WAT) and the second dose (Urea 46% N) was applied at 6 WAT. The liquid organic fertilizer was applied on the foliage according to treatments in two split doses. The first dose was applied at 2 WAT, and the second dose at 6 WAT. This was also done using CP15 knapsack sprayer in a spray volume of 1 litre of Agric Zyme 3X mixed into 100 litres of water ha^{-1}. All fertilization rates were based on the nutrients requirement of onion.

3.3.6 Pests and disease control

The major insect pest observed during the experimental period was cricket at one week after transplanting. This was controlled by application of chlorpyrifos 35 % + cypermethrin 10 % EC and repeated after seven days. However, there was no disease infection observed and so no control measure was taken.

3.3.7 Harvesting and curing

The bulbs were harvested manually with hand hoe by digging and pulling out the bulbs in the net plots at fully physiological maturity (13 weeks after transplanting) when the top of the foliage had dried off and the neck began to fall. The harvested bulbs were kept under shade on a curing platform for 10 days. The foliage was cut off leaving about half inch at the base.

3.4 Observation and Data Collection

Data were collected on the following characters:

3.4.1 Weed parameters

3.4.1.1 Weed species and their Important Value Index

Weed species were collected using a 0.5 x 0.5 m quadrat placed randomly along the diagonal across each plot at 6 and 9 WAT. The weeds samples within each quadrat were uprooted washed with tap water and separated by species. The weeds Important Value Index (IVI) were computed using the equations below according to Das (2011).

IVI = Relative density (RD) + Relative frequency (RF) + Relative dominance (RDo)

***3.4.1.2 Weed control index* (WCI):**

It is a derived parameter that compares different treatments of weed control on the basis of weed dry weight across them. It is an estimate of weed competition/ control in crops. This was done at 3, 6 and 9 WAT and expressed in percentage.

$$WCI = \frac{DMC - DMT}{DMC} x\ 100$$

Where: DMC is weed dry matter in control treatment; DMT is weed dry matter in a weed control treatment (Das, 2011).

3.4.2. Crop growth parameters

3.4.2.1 Crop injury score

Crop injury score was taken at 3, 6 and 9 WAT by visual assessment of the leaf colour and form of the onion plant (green to yellow) using a scale of 1 - 9, where 1 represented completely dark green colour show least injury, and 9 represent complete injury (Completely scorched plants) as described by Frans *et al.* (1986).

3.4.2.2 Leaf area index (LAI)

The leaf area index per plant was taken from the field at 3, 6, and 9 WAT using leaf area ceptor metre.

3.4.2.3 Crop growth rate (CGR)

Crop Growth Rate (CGR) is the dry matter accumulation of plant material per unit area per unit time. This CGR was measured at 3 – 6 and 6 – 9 WAT; as per the formula as described by Radford (1967) as: $CGR = \frac{W2 - W1}{T2 - T1}$ (gwk^{-1})

Where: W_1 = Dry matter taken at initial sampling period, W_2 = Dry matter taken at second sampling period, t_1 = Time when W_1 was taken and t_2 = Time when W_2 was taken

3.4.2.4 Bulb yield (t ha^{-1})

The four centred rows constituting each net plot were harvested for bulb yield and the bulbs were weighed after curing.

3.5 Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA) to test the significance of differences between treatment means using the general linear model (GLM) of statistical analysis system package (SAS, 2002). The treatment means were separated using the Duncan's Multiple Range Test as described by Duncan (1955).

4.0 RESULTS AND DISCUSSIONS

4.1 Weed Species and their Important Value Index (IVI)

Table 1 showed that the higher weed infestation was recorded with greater prevalence of noxious and aggressive weeds (such as *Cyperus rotundus, Cyperus difformis, Commelina difformis, Commelina benghalensis and Rottboelia cochinchinensis,* among others), which could be highly competitive for growth factors, thereby resulting in poor growth and yield of onion. This could be attributed to the frequent rainfall supply which might have resulted in reducing the efficacy of the herbicides on weeds through wash – off, particularly post-emergence herbicides. In addition to this, weeds like *Cyperus spp* and *Commelina spp* are characterized by perennating propagules such as rhizomes and stolons which are hardly controlled by certain herbicides. This result is in line with the findings of Muhammad *et al.* (2019a and b). Kuchinda *et al.* (2006) reported that Samaru site has been continuously used for research for many years, and this has resulted in proliferation of weeds in terms of species and severity.

4.2 Effects of Weed Control Treatments and Fertilization Rates on Weed Growth

The effects of weed control treatments and fertilization rates on weed growth are presented in Table 2. Generally, there was higher weed control index with application of pendimethalin + oxyfluorfen at 1.3 + 1.2 kg a.i ha^{-1} and pendimethalin at 1.63 kg a.i ha^{-1} + one hoe weeding at 6 WAT than hoe weeding at 3 and 6 WAT and the weedy check at the early sampling stage in both seasons. But there were similarities to hoe weeding at 3 and 6 WAT in some sampling periods at later stage. The reduction in weeds could be due to low weed cover recorded under these treatments, which was an indication of better weed suppression at early stage in both seasons by pre – emergence application of pendimethalin and oxyfluorfen as post emergence followed by supplementary hoe weeding.

Table 1: Weed species and their importance value index in onion cultivars under varying levels of weed control and fertilization methods during the 2021 and 2022 wet seasons at Samaru.

Weeds Important Value Index at 9 WAT					
	2021			2022	
S/N	SPECIES	IVI	S/N	SPECIES	IVI
	Broad leaf			Broad leaf	
1.	*Ageratum conyzoides* (L.)	8.63	1.	*Ageratum conyzoides* (L.)	14.63
2.	*Alternanthera punges* (H.B K.)	22.56	2.	*Alternanthera punges* (H.B K.)	6.99
3.	*Aneilema lanceolatum*	5.01	3.	*Aspilia africana* (Pers.) C.D	13.29
4.	*Aspilia africana* (Pers.) C.D	10.94	4.	*Cleome rutidosperma* (D.C)	7.88
5.	*Cleome rutidosperma* (D.C)	18.50	5.	*Commelina benghalensis* (L.)	26.62
6.	*Commelina difformis* (L.)	19.95	6.	*Commelina difformis* (L.)	19.41
7.	*Crotalaria retusa*	3.06	7.	*Hippobroma longiflora* (L.) G. Don	2.20
	Grasses		8.	*Ipomea muricata* (L.) Jacq	3.05
8.	*Cynodon dactylon* (L.) Pers.	6.36	9.	*Richardia humistrata*	10.29
9.	*Dactylonium cynodous*	6.90		Grasses	
10.	*Paspalum scrobiculatum* (L.)	12.67	10.	*Cynodon dactylon* (L.) Pers.	5.34
11.	*Rottboellia cochinchinensis* (Lour.)	5.74	11.	*Dactyloctenium cyndeous* (L.)	5.55
	Sedges		12.	*Paspalum scrobiculatum* (L.)	14.25
12.	*Cyperus bulbiferus* (L.)	17.26	13.	*Rottboellia cochinchinensis* (Lour.)	30.99
13.	*Cyperus difformis* (L.)	50.01		Sedges	
14.	*Cyperus rotundus* (L.)	111.87	14.	*Cyperus bulbiferus* (L.)	1.36
			15.	*Cyperus difformis* (L.)	35.0
			16.	*Cyperus rotundus* (L.)	103.13

IVI = Important Value Index

The result is in line with those of Kalhapure *et al.* (2013), who reported that three hand weeding at 20, 40, and 60 DAT showed highest weed control index in onion, followed by pendimethalin at 1.0 kg (PE) + oxyfluorfen at 0.250 kg a.i ha^{-1} + one hand weeding at 20 DAT, Muhammad *et al.* (2019 a and b), who observed that hoe weeding at 3 and 6 WAT was superior to other weed control treatments in terms of weed control index and was at par with pendimethalin at 3.0 kg a.i ha^{-1} which in turn resulted in higher weed control index than other weed control treatments.

Table 2: Weed control index in onion cultivars as influenced by weed control and fertilization rates during the 2021 and 2022 wet seasons at Samaru.

	Weed control index (%)					
	2021			2022		
Treatment	3 WAT	6 WAT	9 WAT	3 WAT	6 WAT	9 WAT
Cultivars (C)						
Prema	28.21	53.08	58.17	27.69	52.57b	50.63
Ex-Kudan	30.90	54.63	58.94	29.74	61.30b	60.24
SE±	0.825	0.383	0.457	0.763	0.403	0.614
Weed control (W)						
W1	54.55a	85.05a	77.39a	45.91a	89.55a	51.59b
W2	55.69a	51.79b	84.44a	46.76a	60.54c	87.21a
W3	7.99b	78.58a	72.39a	22.18b	77.65b	82.92a
W4	0.0b	0.0c	0.0b	0.0c	0.0d	0.0c
SE±	1.649	0.765	0.913	1.525	0.806	1.228
Fertilization (F) (N.P.K kg ha^{-1} + AZ L ha^{-1})						
0: 0: 0 + 0	28.15	55.13	55.76	22.30	55.05	60.51a
32.5: 22.5: 22.5 + 6	23.12	52.32	57.55	29.13	61.89	41.01b
65: 45: 45 + 0	40.14	55.61	62.36	25.76	53.67	57.0ab
0 + 12	26.81	52.37	58.56	37.68	57.13	63.20a
SE±	1.649	0.765	0.913	1.525	0.806	1.228
Interaction						
C x W	NS	NS	NS	NS	NS	NS
C x F	NS	NS	NS	NS	NS	NS
W x F	NS	NS	NS	NS	NS	NS
C x W x F	NS	NS	NS	NS	NS	NS

Means followed by unlike letter (s) within a column of any treatment group are significantly different at 5% level of probability. NS= not significant; W1= Pendimethalin + oxyfluorfen at 1.3 + 1.2 kg a.i ha^{-1}; W2= Pendimethalin at 1.63 kg a.i ha^{-1} + one hoe weeding at 6 WAT; W3= Hoe weeding at 3 and 6 WAT (Weeks after Transplanting); W4= Weedy check; N.P.K= Nitrogen phosphorus and potassium; AZ (Agric- Zyme 3X) = Liquid organic fertilizer.

There was a significant (P ≤ 0.05) variation on weed parameters as influenced by fertilization rates at some sampling periods in both seasons at Samaru. The higher weed control index by application of N.P.K + AZ at 0 kg ha^{-1} + 12 L ha^{-1} and the untreated control, indicated that the nutrients supplied were not sufficiently available for weed growth and therefore, reduced weeds species survival, reduced weed population and weed dry matter. The result is in agreement with that of Patel *et al.* (2011), who reported that increasing fertilizer rate increased the availability of nutrients for growth and development of weeds.

4.3 Effect of Weed Control Treatments and Fertilization Rates on Growth and Bulb Yield

The result of this study showed that application of pendimethalin + oxyfluorfen at 1.3 + 1.2 kg a.i ha^{-1} resulted in slight crop injury at 6 WAT in both seasons (Table 3). However, at the subsequent sampling periods, the crop was fully recovered from the injury. This indicated that the crop was able to tolerate the herbicides by recovering from slight injury at later stage of growth. This result confirmed the result of Muhammad *et al.* (2019b), who observed that onion recovered from the toxic effects of oxyfluorfen at 0.96 and 1.92 kg a.i ha^{-1} at later growth stage. It is also in line with the early result of Umeda and McNeil (1999), who observed that onion treated at two leaf stage of growth with oxyfluorfen exhibited no significant crop injury. Fertilization rates did not significantly (P ≤ 0.05) influence crop injury score throughout the sampling periods in both seasons.

Tables 4 and 5 show the variation and similarities in the responses of growth indices and bulb yield to weed control treatments and fertilization rates at various growth stages of onion plant in both seasons. In most cases, application of pendimethalin + oxyfluorfen at 1.3 + 1.2 kg a.i ha^{-1} and pendimethalin at 1.63 kg a.i ha^{-1} + one hoe weeding at 6 WAT were either higher or statistically at par with hoe weeding at 3 and 6 WAT with respect to LAI and CGR (Table 4). The higher bulb yield were significantly (P ≤ 0.05) enhanced (6.99 and 6.30 t ha^{-1}) with application of pendimethalin + oxyfluorfen at 1.3 + 1.2 kg a.i ha^{-1} and pendimethalin at 1.63 kg a.i ha^{-1} + one hoe weeding at 6 WAT respectively in 2022 (Table 5). The superiority of these growth attributing characters and bulb yield under these weed control treatments might be due to timely and effective control of broad spectrum of weeds during the critical stage of weed competition, which reduced crop – weed competition for space, light, moisture and nutrients.

Table 3: Crop injury score in onion cultivars as influenced by weed control and fertilization rates during the 2021 and 2022 wet seasons at Samaru.

	Crop injury score (Scale 1 – 9)					
	2021			2022		
Treatment	3 WAT	6 WAT	9 WAT	3 WAT	6 WAT	9 WAT
Cultivars (C)						
Prema	1.0	1.1	1.0	1.0	1.0	1.2
Ex-Kudan	1.0	1.2	1.0	1.0	1.0	1.2
SE±	0.000	0.004	0.002	0.000	0.002	0.005
Weed control (W)						
W1	1.0	1.5a	1.1	1.0	1.2a	1.2ab
W2	1.0	1.0b	1.0	1.0	1.0b	1.0b
W3	1.0	1.0b	1.0	1.0	1.0b	1.1ab
W4	1.0	1.1b	1.0	1.0	1.0b	1.3a
SE±	0.000	0.008	0.003	0.000	0.003	0.011
Fertilization (F) (N.P.K kg ha^{-1} + AZ L ha^{-1})						
0: 0: 0 + 0	1.0	1.1	1.0	1.0	1.0	1.1
32.5: 22.5: 22.5 + 6	1.0	1.2	1.0	1.0	1.0	1.1
65: 45: 45 + 0	1.0	1.2	1.0	1.0	1.0	1.3
0 + 12	1.0	1.1	1.0	1.0	1.0	1.1
SE±	0.000	0.008	0.003	0.000	0.003	0.011
Interaction						
C x W	NS	NS	NS	NS	NS	NS
C x F	NS	NS	NS	NS	NS	NS
W x F	NS	NS	NS	NS	NS	NS
C x W x F	NS	NS	NS	NS	NS	NS

Means followed by unlike letter (s) within a column of any treatment group are significantly different at 5% level of probability. NS= not significant; W1= Pendimethalin + oxyfluorfen at 1.3 + 1.2 kg a.i ha^{-1}; W2= Pendimethalin at 1.63 kg a.i ha^{-1} + one hoe weeding at 6 WAT; W3= Hoe weeding at 3 and 6 WAT (Weeks after Transplanting); W4= Weedy check; N.P.K= Nitrogen phosphorus and potassium; AZ (Agric- Zyme 3X) = Liquid organic fertilizer.

Table 4: Leaf area index and crop growth rate of onion cultivars as influenced by weed control and fertilization rates during the 2021 and 2022 wet seasons at Samaru and Bagauda.

Treatment	Leaf area index (LAI) plant^{-1}						Crop growth rate (CGR) (g wk^{-1})			
	2021			2022			2021		2022	
	3 WAT	6 WAT	9 WAT	3 WAT	6 WAT	9 WAT	3 – 6 WAT	6 – 9 WAT	3 – 6 WAT	6 – 9 WAT
Cultivars (C)										
Prema	0.21b	0.39	0.60a	0.13	0.39	0.60a	0.35	0.32b	0.15a	0.06a
Ex-Kudan	0.23a	0.35	0.53b	0.18	0.35	0.53b	0.37	0.43a	0.10b	-0.07b
SE±	0.000	0.001	0.003	0.003	0.003	0.003	0.003	0.004	0.002	0.002
Weed control (W)										
W1	0.22	0.31a	0.44a	0.17	0.48a	0.80a	0.44a	0.45a	0.17a	0.07a
W2	0.23	0.29a	0.39a	0.13	0.37b	0.59b	0.40a	0.45a	0.10b	0.02a
W3	0.22	0.31a	0.42a	0.17	0.41ab	0.61b	0.46a	0.50a	0.15a	0.07a
W4	0.22	0.24b	0.25b	0.16	0.22c	0.25c	0.15b	0.09b	0.07b	-0.17b
SE±	0.001	0.003	0.006	0.005	0.005	0.006	0.005	0.008	0.003	0.005
Fertilization (F) (N.P.K kg ha^{-1} + AZ L ha^{-1})										
0: 0: 0 + 0	0.22	0.28	0.34b	0.13	0.35b	0.57ab	0.35	0.33	0.11	-0.03b
32.5: 22.5: 22.5 + 6	0.23	0.31	0.35b	0.15	0.37b	0.55b	0.42	0.43	0.13	0.04a
65: 45: 45 + 0	0.23	0.29	0.44a	0.19	0.47a	0.65a	0.34	0.41	0.14	0.01ab
0 + 12	0.22	0.28	0.37ab	0.16	0.30b	0.49b	0.35	0.32	0.10	-0.03b
SE±	0.001	0.003	0.006	0.005	0.005	0.006	0.005	0.008	0.003	0.005
Interaction										
C x W	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
W x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C x W x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by unlike letter (s) within a column of any treatment group are significantly different at 5% level of probability. NS= not significant; W1= Pendimethalin + oxyfluorfen at 1.3 + 1.2 kg a.i ha^{-1}; W2= Pendimethalin at 1.63 kg a.i ha^{-1} + one hoe weeding at 6 WAT; W3= Hoe weeding at 3 and 6 WAT (Weeks after Transplanting); W4= Weedy check; N.P.K= Nitrogen phosphorus and potassium; AZ (Agric- Zyme 3X) = Liquid organic fertilizer.

Table 5: Bulb yield of onion cultivars as influenced by weed control and fertilization rates during the 2021 and 2022 wet seasons at Samaru .

Treatment	Bulb yield (t ha^{-1}) 2021	2022	Combined
Cultivars (C)			
Prema	1.28b	5.39	3.34
Ex-Kudan	2.70a	4.84	3.76
SE±	0.046	0.041	0.044
Weed control (W)			
W1	2.37a	6.99a	4.68a
W2	2.20a	5.77b	3.99a
W3	2.65a	6.30ab	4.47a
W4	0.69b	1.40c	1.04b
SE±	0.092	0.082	0.087
Fertilization (F) (N.P.K kg ha^{-1} + AZ L ha^{-1})			
0: 0: 0 + 0	1.07	4.30b	2.69c
32.5: 22.5: 22.5 + 6	2.12	5.86a	3.99ab
65: 45: 45 + 0	2.57	6.16a	4.36a
0 + 12	2.16	4.13b	3.15bc
SE±	0.092	0.082	0.087
Interaction			
C x W	NS	NS	NS
C x F	NS	NS	NS
W x F	NS	*	NS
C x W x F	NS	NS	NS

Means followed by unlike letter (s) within a column of any treatment group are significantly different at 5% level of probability using DMRT. NS= not significant; *= significant at 5 %; W1= Pendimethalin at 1.3 + oxyfluorfen at 1.2 kg a.i ha^{-1}; W2= Pendimethalin at 1.63 kg a.i ha^{-1} + one hoe weeding at 6 WAT; W3= Hoe weeding at 3 and 6 WAT (Weeks after Transplanting); W4= Weedy check; N.P.K= Nitrogen phosphorus and potassium; Agric- Zyme 3X= Liquid organic fertilizer, NA = Not available.

These results are in line with those of Muhammad *et al.* (2019 b), who observed higher LAI and CGR by application of oxyfluorfen at 1.92 kg a.i ha^{-1} and Garba (2021), who reported that higher leaf area index was recorded by application of pendimethalin at 1.0 and 1.5 kg a.i ha^{-1} supplemented with one hoe weeding and fluazifop – p – butyl, respectively. The result is also corroborated those of Patel *et al.* (2011), who observed that the higher onion bulb yield in two different years (39.3 and 36.6 t ha^{-1}) were obtained under application of pendimethalin at 1.0 kg ha^{-1} supplemented with one hand weeding and Garba (2021), who reported an increase in cured bulb and marketable bulb yield by application of pendimethalin and butachlor at 1.0 and 2.0 kg a.i ha^{-1}, respectively, followed by one hoe weeding.

The growth of plants is a function of photosynthetic activities of plant and their capacity to utilize available nutrients. All growth parameters such as LAI, CGR and higher bulb yield (6.16 and 5.86 t ha^{-1}) were significantly ($P \leq 0.05$) enhanced by application of N.P.K + AZ at 65: 45: 45 kg ha^{-1} + 0 L ha^{-1} and 32.5: 22.5: 22.5 kg ha^{-1} + 6 L ha^{-1} in 2022. These increased in growth and bulb yield could be attributed to higher level of fertilization rate there by making the nutrients available in the root zone which increased the growth and development of the crop as a result of increase in photosynthetic activities of the plants. Whereas, the negative CGR could be due to stress by weed infestation and insufficient availability of nutrients. These results are in accordance with those of Islam *et al.* (2007), who reported the higher dry matter accumulation and higher bulb yield (14.9 t ha^{-1}) with application of 120: 130: 160 kg ha^{-1} N.P.K. Patel *et al.* (2011), also reported better growth parameters with application of 125: 62.5: 62.5 N: P_2O_5: K_2O kg ha^{-1} which gave higher dry matter and higher bulb yield (37.2, 34.2 and 35.7 t ha^{-1}) while Soubeih (2018), reported that the highest leave area, CGR and higher bulb yield were recorded with application of 100: 60: 100 kg ha^{-1} N.P.K.

Table 6: Interaction of weed control and fertilization rates on bulb yield during the 2022 wet season at Samaru.

Treatment	Bulb yield (t ha^{-1}) Weed control (W) (Kg a.i ha^{-1})			
	W1	W2	W3	W4
Fertilization (F) (N.P.K kg ha^{-1} + AZ L ha^{-1})				
0: 0: 0 + 0	5.98c	4.51d	5.74c	0.99f
32.5: 22.5: 22.5 + 6	7.66b	6.47c	7.47b	1.86f
65: 45: 45 + 0	7.90b	9.00a	6.38c	1.34f
0 + 12	6.41c	3.12e	5.59c	1.41f
SE ±	0.327			

Means followed by unlike letter (s) are significantly different at 5% level of probability using DMRT. W1= Pendimethalin + oxyfluorfen at 1.3 + 1.2 kg a.i ha^{-1}; W2= Pendimethalin at 1.63 kg a.i ha^{-1} + one hoe weeding at 6 WAT; W3= Hoe weeding at 3 and 6 WAT (Weeks after Transplanting); W4= Weedy check; AZ (Agric Zyme 3x) = Liquid organic fertilizer.

4.4 Interaction of Weed Control Treatments and Fertilization Rates on Bulb Yield

The interaction of weed control and fertilization rates on bulb yield was significant ($P \leq 0.05$) in 2022 (Table 6). Application of pendimethalin supplemented with one hoe weeding along with higher level of N.P.K + AZ recorded higher bulb yield (9.0 t ha^{-1}) compared to other weed control and fertilization rates. This increased in bulb yield could be attributed to increase in growth and development of the plant as a result of early weed reduction by the herbicides used coupled with increasing level of N.P.K + AZ. Elian *et al.* (2016) reported that interaction between application of 150 kg N + 50 kg K and weed control by Pyraflufen-ethyl + tepraloxydim increase onion bulb yield.

Conclusion

From the result of this study it can be concluded that: Aapplication of pendimethalin + oxyfluorfen at 1.3 + 1.2 kg a.i ha^{-1} and pendimethalin at 1.63 kg a.i ha^{-1} + one hoe weeding at 6 WAT were safe on onion at 9 WAT and all herbicides treatments were comparable to hoe weeding at 3 and 6 WAT in enhancing weed control index, growth performance and higher bulb yield than the weedy check. Application of N.P.K + AZ at 65: 45: 45 kg ha^{-1} + 0 L ha^{-1} and 32.5: 22.5: 22.5 kg ha^{-1} + 6 L improved growth and higher bulb yield in onion.

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Appendix I
Meteorological data showing mean of Rainfall amount, Temperatures, Relative humidity and Solar radiation during the 2021 wet season at Samaru.

Month	Rainfall (mm)	Number of rainy days	Temperatures (^{0}C)		Relative humidity (%)	Solar radiation (Sunshine hours)
			Min	Max		
June	170.90	13	23.00	30.50	74.17	NA
July	238.40	09	22.58	28.16	79.26	NA
August	341.60	17	22.45	29.10	82.32	NA
September	195.60	13	22.57	30.00	74.73	NA
October	48.80	03	22.19	32.84	63.35	NA

Source: IAR Meteorological unit, Ahmadu Bello University, Zaria (2021). NA = Not available

Appendix II
Meteorological data showing mean of Rainfall amount, Temperatures, Relative humidity and Solar radiation during the 2022 wet season at Samaru.

Month	Rainfall (mm)	Number of rainy days	Temperatures (^{0}C)		Relative humidity (%)	Solar radiation (Sunshine hours)
			Min	Max		
June	238.4	14	21.6	30.0	80.5	NA
July	178.1	09	21.8	28.6	77.8	NA
August	251.4	16	21.7	27.6	84.4	NA
September	448.1	18	21.6	29.2	79.7	NA
October	39.3	04	20.6	31.3	59.0	NA

Source: IAR Meteorological unit, Ahmadu Bello University, Zaria (2022). NA = Not available

Appendix III
Weed cover score descriptions (scale 1 – 9)

Effects	Scale	Weed Control Description
Slight	1	Good to excellent control
	2	Good control
	3	Satisfactory control
Moderate	4	Moderate control
	5	Deficient control to control
	6	Deficient control
Severe	7	Poor to deficient control
	8	Poor control
	9	Very poor control

Source by Muhammad (2018).