

INTEGRATION OF WEED CONTROL STRATEGIES ON THE MANAGEMENT OF CHICKEN WEED (*Portulaca quadrifida* L.) IN ONION (*Allium cepa* L.) AS AFFECTED BY PLANT POPULATION AT SUDAN SAVANNA, NIGERIA

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ABSTRACT

During the dry seasons of 2017/2018 and 2018/2019, an experiment was conducted in a farmer's field in Birnin Kebbi, Nigeria, to assess the effectiveness of integrating plant population and control approaches in managing chicken weed (*Portulaca quadrifida* L.) in onion. The study included three plant populations (500,000, 333,333, and 250,000 p/ha) and twelve weed control strategies (Fluazifop-p-butyl @ 2.0 kg a.i. ha⁻¹; pendimethalin @ 2.0 kg a.i. ha⁻¹ followed by (fb) one hoe weeding (1 HW); butachlor @ 2.0 kg a.i. ha⁻¹ fb oxyfluorfen @ 1.0 kg a.i. ha⁻¹; butachlor @ 3.6 kg a.i. ha⁻¹ only; fluazifop-p-butyl @ 2.0 kg a.i. ha⁻¹ only; oxyfluorfen @ 1.0 kg a.i. ha⁻¹ fb 1 HW; HW @ 3 and 6 Weeks after transplanting (WAT); HW @ 3, 6, and 9 WAT; Weed free and Weedy check. Three replications of the Randomized Complete Block Design were used to lay out the treatments. The results showed that plots with 500,000 plants/ha had the most overall bulb yield, while those with 333,333 plants/ha had the best weed control efficiency. The most effective weed control was obtained with all pendimethalin and butachlor rates, including weed-free. The highest overall bulb output was achieved with pendimethalin at 1.5 kg a.i. ha⁻¹ fb fluazifop-p-butyl at 2.0 kg a.i. ha⁻¹ and butachlor at 2.0 kg a.i. ha⁻¹ supplemented with 1 HW. Weed control efficiency was consistently low for weedy check. To control chicken weed and other weed species, farmers in Birnin Kebbi should use pendimethalin at 1.5 kg a.i. ha⁻¹ fb fluazifop-p-butyl at 2.0 kg a.i. ha⁻¹ or butachlor at 2.0 kg a.i. ha⁻¹ supplemented with 1 HW.

Key words: weed control, plant population, herbicides, weed cover, weed control efficiency

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INTRODUCTION

The plant *Portulaca quadrifida* L., sometimes known as Chicken weed, is a member of the Portulacaceae family (Nyffeler and Eggli, 2010). Despite its origin in India, it has spread globally to various temperate and tropical areas (Lie *et al.*, 2015; Zhou, 2015). Chicken weed

is a succulent annual plant that is a pan-tropical weed of farmed fields, but it is also widely found in poor soils, yards, along roadsides, and waste places (Akobundu *et al.*, 2016). Their habit of unfurling their petals precisely at 10:00 a.m. earned them the common name "ten o'clock plants" (Grubben and Derton 2004), however it is better known as Chicken weed (PROTA, 2014).

Netala *et al.* (2014) reported that *P. quadrifida* and *P. oleraceae* belong to the same genus (*Potulaca*) and are an aggressive weed that is regarded a big concern in many crops around the world. *P. quadrifida* is present in all African countries, mainly as weeds, and is infrequently cultivated (Jansen, 2004). The plant is a major weed of maize (*Zea mays*) and onions (*Allium cepa* L.) (Kachare *et al.*, 2005).

Onion production in Nigeria is shown to be primarily concentrated in the northern section of the country, notably the dry tropical zone (Ojo *et al.*, 2009). According to Abuga (2014), Nigeria's producing areas include Kaduna, Kano, Jigawa, Katsina, Sokoto, Kebbi, Plateau, and Bauchi states. Carlson and Kirby (2005), Qasem (2006a), and Smith *et al.* (2011) corroborated that many writers have stated that onion plants are poor weed competitors. The crop's low competitive ability with weeds has been linked to its initial slow development and lack of enough foliage to smother weeds. Singh and Singh (2000) claim that establishing an appropriate plant population per unit area of the field was an important component in achieving maximum yields. Chemical weed management can be achieved through pre-sowing, pre-emergence, early post-emergence, or a combination of these methods (Sureshkumar *et al.*, 2016). The study's goal was to assess the impact of weed control approaches on the management of Chicken weed (*Portulaca quadrifida* L.) in onion (*Allium cepa* L.) fields as a function of plant population.

MATERIALS AND METHODS

Experimental site

Field experiments were carried out at farmers' fields in Birnin Kebbi, Kebbi State, Nigeria during the 2017/2018 and 2018/2019 dry seasons to assess the effectiveness of weed control methods in managing Chicken weed (*Portulaca quadrifida* L.) and other weeds in onion fields as affected by plant population. Birnin Kebbi is located at 12°25' N, 4°15' E. According to Gindi *et al.* (2013), Birnin Kebbi has a tropical climate with yearly temperatures ranging from 25 to 40 degrees Celsius and an average annual rainfall of 500 to 700 millimeters. People of Birnin Kebbi are Hausa speaking and they are predominant growers of onions, rice, cowpeas, millet, and vegetables.

Treatment and experimental design

The experimental treatment consisted of three plant populations (500,000, 333,333, and 250,000 p/ha) and twelve weed control techniques (pendimethalin @ 1.0 kg a.i ha⁻¹ followed by (fb) one hoe weeding (1 HW); pendimethalin @ 1.5 kg a.i ha⁻¹ fb fluazifop-p-butyl @ 2.0 kg a.i ha⁻¹; pendimethalin @ 2.0 kg a.i ha⁻¹ fb 1 HW; b.utachlor @ 2.0 kg a.i ha⁻¹ fb oxyfluorfen

@ 1.0 kg a.i ha⁻¹; butachlor @ 3.6 kg a.i ha⁻¹ only; fluazifop-p-butyl @ 2.0 kg a.i ha⁻¹ only; oxyfluorfen @ 1.0 kg a.i ha⁻¹ fb 1 Hw; Hw @ 3 and 6 Weeks after transplanting (WAT); Hw @ 3, 6, and 9 WAT; Weed free and Weedy check and laid out in a Randomized Complete Block Design (RCBD) and replicated three times. Onion seedlings used for this research were raised from the nursery and all agronomic parameters were observed.

Data collection

Data collection that justify this study includes weed parameters (weed density, fresh weed weight, weed dry matter, weed cover score, and weed control efficiency), growth (plant height, number of leaves, plant stand count, and leaf area) and yield parameters (bulb diameter, above ground biomass, total bulb, and marketable bulb yield).

Weed control efficiency (WCE)

Weed control efficiency (WCE) refers to the magnitude of weed reduction achieved through weed management procedures. The formula proposed by Mani *et al.* (1973) was used to calculate WCE, which was expressed in percentage (%).

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

Crop vigour score

Crop vigour score was obtained through visual assessment of onion plant at an interval of 3 weeks using a scale of 1 - 5, where scale 1 was scored for least vigorous plots and 5 was scored for plots with most vigorous onion plants. Plant height, greenness colour of the leaves, spread of plant canopy and thickness of the stem were the features taken into consideration in scoring crop vigour and records were taken per plant.

Total bulb yield

The total bulb yield was calculated from the complete harvest of the net plot as a sum weight of marketable and unmarketable yields, which was taken in kg per plot and then translated to kg ha⁻¹ and then to tons per hectare by multiplying the figure in kg/ha by 1,000.

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

Data analysis

The data collected for this research was subjected to analysis of variance (ANOVA) and mean separation was done using Duncan's Multiple Range Test (DMRT). All analysis was carried out using the SAS package version 9.0 (SAS, 2002)

RESULTS

Weed flora composition

The site of the experimental was naturally infested with noxious weeds, which included grasses, broad-leaves and sedge in both years of the study. The number of weed species identified showed that in 2017/2018, grasses (10), broad leaves (29) and sedges (4) were recorded, while in 2018/2019, grasses (7), broad leaves (23) and sedges (3) were recorded.

Weed control efficiency

Table 1 shows the impact of plant population and weed control strategies on weed control efficiency and weed cover score in Birnin Kebbi between 2017/2018 and 2018/2019. In 2017/2018, plant population had no significant ($p < 0.05$) impact on weed control efficiency, however there was a substantial difference in 2018/2019. The results showed that plots with a plant population of 333,333 had the maximum weed control efficacy, which was comparable to plant populations of 500,000 plants per ha. The lowest weed control efficacy was observed with a plant population of 250,000 plants per hectare.

Weed management strategies have a considerable effect on weed control efficiency, as shown in Table 1. The results showed that the highest weed control efficiency in 2017/2018 was achieved with butachlor at a rate of 2.0 kg a.i. ha^{-1} , followed by one hoe weeding, but the outcome was comparable to all rates of pendimethalin and butachlor, including weed free. Weed control efficiency was improved by using fluazifop-p-butyl at 2.0 kg a.i. ha^{-1} , oxyfluorfen at 1.0 kg a.i. ha^{-1} , and weeding twice and thrice compared to the weedy check plots, which had the lowest weed control efficiency. In 2018/2019, similar highest weed control efficiency was recorded when all rates of pendimethalin and butachlor were used, including weed-free, and was greater than the application of Fluazifop-p-butyl at 2.0 kg a.i. ha^{-1} , Oxyfluorfen at 1.0 kg a.i. ha^{-1} , weeding twice, and weeding three times, while the weedy check plots was the least. The interaction of plant population and weed control methods on weed control effectiveness in 2018/2019 was investigated, and the results showed that using butachlor at a rate of 2.0 kg a.i. ha^{-1} plus I HW under a plant population of 333,333 plants/ha resulted in the maximum weed control efficiency. Weedy check plots had significantly lower weed control efficiency across all plant population treatments (Table 2).

Weed cover score as a function of plant population and weeds control interventions at Birnin Kebbi during the 2017/2018 and 2018/2019 dry seasons is also presented on Table 1. In both years, there was no significant ($p > 0.05$) difference in weed cover score based on plant population between treatments. The results show that weed control methods have a

considerable effect on weed cover score. In 2017/2018, all butachlor rates (2.0 Kg a.i. ha⁻¹, 2.8 Kg a.i. ha⁻¹, 3.6 Kg a.i. ha⁻¹) had similar lowest weed cover scores ($p < 0.05$), but were statistically at par with plots applied with pendimethalin (1.0, 1.5, and 2.0 Kg a.i. ha⁻¹). Weedy check plots had the highest weed cover score. In 2018/2019, similar lowest weed cover score was observed in plots treated with all the rates of pendimethalin (1.0, 1.5 and 2.0 Kg a.i. ha⁻¹) and butachlor (2.0, 2.8 and 3.6 Kg a.i. ha⁻¹) which was statistically identical with the result obtained with weed free plots. Similar weed cover score was reported in plots with fluazifop-p-butyl at 2.0 Kg a.i. ha⁻¹, oxyfluorfen at 1.0 Kg a.i. ha⁻¹ and plots with weeding twice and weeding thrice, but greater than the results obtained in weedy check which recorded the highest weed cover score in 2018/2019. An interaction of plant population and weed control treatments on weed cover score was noticed at 6 WAT in 2018/2019 (Table 1). The results of the interaction of plant population and weed control treatments on weed cover score at 6 WAT in 2018/2019 is presented on Table 3. The result showed that plots with plant population of 250,000 plants per hectare in combination with weedy check plots recorded the highest weed cover score which was statistically similar to all other plant populations. The lowest weed cover score is produced in plots with plant population of 250,000 and 333,333 plants per hectare in combination with pendimethalin at 1.5 Kg a.i. ha⁻¹ followed by fluazifop-butyl at 2.0 Kg a.i. ha⁻¹ and butachlor at 2.0 Kg a.i. ha⁻¹ followed by 1 HW respectively, but at par with all weed control treatments (Table 3).

Plant height (cm)

Table 4 shows the influence of plant population and weed control on onion plant height. The results demonstrate that plant population had no significant ($p > 0.05$) effect on plant height at 6 WAT in both years. Plant height was significantly affected by weed control methods in 2017/2018, and the results show that pendimethalin at 1.0 Kg a.i. ha⁻¹ recorded the tallest plant, which was statistically at par with the result obtained in plots sprayed with pendimethalin at 1.5 Kg a.i. ha⁻¹ fb by Fluazifop-p-butyl at 2.0 Kg a.i. ha⁻¹, pendimethalin at 2.0 Kg a.i. ha⁻¹, and butachlor at 2.0 Kg a.i. ha⁻¹. Other treatments were shown to reduce plant height, however the plots treated with butachlor at 2.8 kg a.i. ha⁻¹, followed by oxyfluorfen at 1.0 kg a.i. ha⁻¹, had the shortest plants in 2017/2018. In 2018/2019, the application of pendimethalin at 1.0 kg a.i. ha⁻¹ fb 1HW resulted in similar taller plants in plots treated with pendimethalin at 1.5 kg a.i. ha⁻¹ fb post emergence fluazifop-p-butyl at 2.0 kg a.i. ha⁻¹, and the result was comparable to plots sprayed with pendimethalin at 2.0 kg a.i. ha⁻¹, butachlor at 2.0 kg a.i. ha⁻¹ fb 1HW, weeding twice, and weed-free plots. Other plots showed a reduction, with weedy check plots having the shortest plants in 2018/2019.

The interaction effect of plant population and weed control strategies on plant height at 6 WAT in 2018/2019 was observed on Table 4. The result of the interaction of plant population with weed control strategies on plant height, as shown in Table 5, demonstrated that plots with a plant population of 250,000 plants per hectare, along with the administration of pendimethalin at a rate of 2.0 Kg a.i. ha⁻¹, generated the tallest plants. The results were comparable to those obtained with a plant population of 500,000 plants per hectare in combination with

pendimethalin at 1.5 kg a.i. ha⁻¹ followed by fluazifop-p-butyl at 2.0 kg a.i. ha⁻¹ and butachlor at 2.0 kg a.i. ha⁻¹ followed by 1HW including pendimethalin at 1.5 kg a.i. ha⁻¹ which was applied to plots with a plant population of 333,333 plants per hectare, followed by fluazifop-p-butyl at 2.0 kg a.i. ha⁻¹ and pendimethalin at 2.0 kg a.i. ha⁻¹ in plots with a plant population of 250,000 plants per hectare. The shortest plant is recorded in plots with 333,333 plants per hectare in combination with butachlor at a dose of 2.8 Kg a.i. ha⁻¹ followed by oxyfluorfen at a dose of 1.0 Kg a.i. ha⁻¹, but also statistically at par with all other weed control treatments (Table 5).

Leaf area (cm)

Table 4 shows the effects of plant population and weed control methods on onion leaf area during the 2017/2018 and 2018/2019 dry seasons in Birnin Kebbi. The study found no significant ($p < 0.05$) effect of plant population on onion leaf area in both years. Pendimethalin at 1.5 kg a.i. ha⁻¹ produced the most leaf area, although it was comparable to plots treated with pendimethalin at 1.0 kg a.i. ha⁻¹ fb 1HW, pendimethalin at 2.0 kg a.i. ha⁻¹, and butachlor at 2.0 kg a.i. ha⁻¹ fb 1HW. There was a significant decrease in leaf area, indicating that plots treated with butachlor at 2.0 kg a.i. ha⁻¹ fb 1HW, fluazifop-p-butyl at 2.0 kg a.i. ha⁻¹, weed-free, and weedy check had similar lowest leaf area in 2017/2018. In 2018/2019, pendimethalin at 2.0 kg a. ha⁻¹ had the widest leaf area and was statistically comparable to plots sprayed with pendimethalin at 1.0 kg a. ha⁻¹ fb 1HW, pendimethalin at 1.5 kg a.i. ha⁻¹ fb fluazifop-p-butyl at 2.0 kg a.i. ha⁻¹, butachlor at 2.0 kg a.i. ha⁻¹, oxyfluorfen at 1.0 kg a.i. ha⁻¹ fb 1HW, and weeding twice. The lowest leaf area at 6 WAT in 2018/2019 was reported in plots treated with butachlor at 2.8 kg a.i. ha⁻¹, but it was comparable to butachlor at 3.6 kg a.i. ha⁻¹, fluazifop-p-butyl at 2.0 kg a.i. ha⁻¹, all hoe weeding, and weedy check.

Total bulb yield (t/ha)

Table 6 shows total bulb yield as a function of plant population and weed management methods in Birnin Kebbi for the 2017/2018 and 2018/2019 dry seasons, as well as pooled data. In 2017/2018, plant population had no significant effect on total onion bulb output, but there was a substantial difference in 2018/2019 and pooled. The results showed that in 2018/2019, plant population of 500,000 plants/ha recorded the maximum total bulb yield, which was equal to plant population of 333,333 plants/ha, while the lowest total bulb yield was obtained in plant population of 250,000 in 2018/2019. At the aggregate level, a similar trend to the 2018/2019 results was seen. Weed control had a significant ($p < 0.05$) effect on total bulb production. The results showed that the use of pendimethalin at 1.0 fb 1HW recorded the highest total bulb yield in 2017/2018, but the result was statistically at par with the result obtained in plots applied with pendimethalin at 1.5 kg a.i ha⁻¹ fb fluazifop-p-butyl at 2.0 kg a.i. ha⁻¹, butachlor at 2.0 kg a.i. ha⁻¹ fb 1HW and two and three weeding regimes. The weedy check had the lowest total bulb yield, which was comparable to plots sprayed with pendimethalin at 2.0 kg a.i. ha⁻¹ only, butachlor at 2.8 kg a.i. ha⁻¹ fb1HW, butachlor at 3.6 kg a.i. ha⁻¹ only, fluazifop-p-butyl at 2.0 kg a.i. ha⁻¹, and oxyfluorfen at 1.0 kg a.i. ha⁻¹ and weeding twice. In 2018/2019, pendimethalin at 1.5 kg a.i. ha⁻¹ fb fluazifop-p-butyl at 2.0 kg a.i. ha⁻¹ produced the highest total bulb

production, which was statistically comparable to the results obtained from plots sprayed with butachlor at 2.0 kg a.i. ha⁻¹ fb 1HW and weeding three times. All other treatments were equivalent, with the exception of plots sprayed with fluazifop-p-butyl at 2.0 kg a.i. ha⁻¹, which produced the lowest overall bulb yield. The pooled results showed a similar pattern to the total bulb yield in 2017/2018, with the lowest total bulb yield in 2018/2019 plots treated with fluazifop-p-butyl at 2.0 kg a.i. ha⁻¹ and oxyfluorfen at 1.0 kg a.i. ha⁻¹.

DISCUSSION

The experimental field contained a variety of weed species ranging from grasses to broadleaves and sedges, with broadleaf weeds being the most prevalent. The broad leaves' dominance in the experimental field may be attributed to their rapid growth and capacity to shade other weed species. Yakubu *et al.* (2006) found that many weed species that are closely associated with field crops have requirements that are very similar to those of cultivated crops, and Karaye *et al.* (2018) discovered that some weeds and crops are site specific, while others thrive in a wide range of habitats. The population of 500,000 plants per hectare resulted in the highest total bulb production. This could be attributed to high plant density, which led to increased light interception by the crop canopy. This conclusion is consistent with Brewster's (2008) report, which stated that an increase in plant population resulted in an increase in onion bulb yield due to a higher percentage of light intercepted by the leaf canopy. Kanton *et al.* (2002) study on the impact of plant density on bulb onion development and yield in Northern Ghana found a substantial increase in overall bulb yield ($p < 0.05$) with population. In this study, all weed management strategies were more effective in controlling Chicken weed as well as other weeds. The injection of pendimethalin and butachlor at all rates produced comparable highest weed control efficiency to other weed control treatments, including weed-free. Weedy check demonstrated the lowest weed control efficiency. This finding is similar to that of (Adewale *et al.*, 2019), who found that two hoe weeding at 3 and 6 WAT had statistically the highest percentage of weed control efficiency and was closely followed by the application of pendimethalin or metolachlor at 2.5 kg a.i. ha⁻¹ when compared to all other types of management. The lowest weed cover score was found in plots sprayed with Butachlor at a rate of 2.8 Kg a.i. ha⁻¹ and augmented with a post-emergence application of oxyfluorfen at a rate of 1.0 Kg a.i. ha⁻¹. However, weed control treatments employing butachlor at 2.0 Kg a.i. ha⁻¹ combined with one hoe weeding and 3.6 Kg a.i. ha⁻¹ of butachlor alone, including weeding every 10 days throughout the growing season, both reduced weed cover score. Weedy check plots had the highest weed cover score, as reported by Ishaya *et al.* (2016) in their evaluation of pre and post-emergence herbicides for weed control in groundnut fields. When analyzing the efficiency of rice production strategies in controlling weeds, a similar weed cover score was regularly recorded in the weedy check plots (Alhassan *et al.*, 2015).

The application of pendimethalin at 1.0 kg a.i. ha⁻¹ fb 1HW resulted in taller onion plants, whereas doses of pendimethalin and butachlor at 2.0 kg a.i ha⁻¹ resulted in equivalent taller plants compared to other treatments. This outcome can be due to the combined effort of two weed control techniques (herbicide treatment complemented with hoe weeding), which resulted

in decreased weed-crop competition and better utilization of available resources such as soil nutrients, sunlight, and soil moisture. This finding supports the findings of Patel *et al.* (2012), who discovered a similar situation due to the plant's use of a favorable environment in the root zone, which aids in the absorption of more water and nutrients from the soil as well as good control of weed competition during the growing season of onion.

The study found that weed control treatments using pendimethalin and 2.0 Kg a.i. ha⁻¹ of butachlor, followed by one hoe weeding, resulted in considerably larger leaf area ($p < 0.05$) compared to other treatments. This conclusion contradicts the findings of Reddy *et al.* (2018), who found that weed control strategies had no significant effect on the number of leaves per plant or the leaf area index. However, Muhammad *et al.* (2019) demonstrated that the treatment of pendimethalin at 1.5 kg a.i. ha⁻¹ resulted in a larger leaf area index in onion responsiveness to weed management strategies and poultry manure. The highest total bulb production of onion was obtained when pendimethalin was treated at 1.5 Kg a.i. ha⁻¹ fb fluazifop-p-butyl and butachlor at 2.0 Kg a.i. ha⁻¹ fb 1HW. Increased total bulb yield could be attributed to lower weed density as a result of pre-emergence herbicide application supplemented with post-emergence and conventional hoe weeding, which created an enabling environment for crop leaves to have better photosynthesis, resulting in a higher total onion bulb yield. These findings are consistent with those of Vashi *et al.* (2012), who found that pre-emergence spraying of pendimethalin at 1.0 Kg a.i. ha⁻¹ significantly enhanced bulb weight and bulb volume when comparing different herbicides for weed control. Peer *et al.* (2013) and Imoloame (2014) also discovered that combining herbicides with one hoe weeding was very successful in weed control and increasing yields in diverse crops.

CONCLUSION

The current study concludes that pre-emergence application of pendimethalin at a rate of 1.5 Kg a.i. ha⁻¹ fb fluazifop-p-butyl at a rate of 2.0 Kg a.i. ha⁻¹ can significantly suppress weeds for a longer period of time and increase onion productivity when planted at a plant population of 500,000 plants/ha, however, application of butachlor at a rate of 2.0 Kg a.i. ha⁻¹ fb 1HW can be an alternative. It is thus recommended that pre-emergence application of pendimethalin at a rate of 1.5 kg ai. ha⁻¹ supplemented by fluazifop-P-butyl at 2.0 kg a.i. ha⁻¹ or butachlor at a rate of 2.0 kg a.i. ha⁻¹ supplemented by 1HW can effectively control Chicken weed as well as other onion weed species in the study area.

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Table 1. The impact of plant population and weed control strategies on weed control efficiency (WCE) and weed cover score in Birnin Kebbi during the 2017/2018 and 2018/2019 dry seasons

Treatment	Rate (kg a.i. ha ⁻¹)	2017-2018	2018-2019	2017-2018	2018-2019
Plant population (p/ha)		Weed control efficiency	Weed control efficiency	Weed cover score	Weed cover score
500,000		72.89	81.99ab	19.30	14.02
333,333		74.13	84.70a	18.75	12.91
250,000		69.37	81.19b	18.33	14.58
SE±		1.75	1.03	1.23	1.04
Weed Control Methods					
Pendimethalin	1.0 fb 1HW	84.33ab	95.91a	11.11de	3.89c
Pendimethalin fb Fluazifop-p-butyl	1.5 fb 2.0	78.44abc	95.89a	14.44cde	3.33c
Pendimethalin	2.0	83.57ab	96.46a	11.11de	2.78c
Butachlor	2.0 fb 1HW	85.92a	96.86a	10.00e	2.78c
Butachlor fb Oxyfluorfen	2.8 fb 1.0	84.98ab	91.62a	10.56e	7.22c
Butachlor	3.6	82.95ab	97.33a	10.56e	2.78c
Fluazifop-p-butyl	2.0	71.65cd	78.69b	17.78bcd	20.00b
Oxyfluorfen	1.0 fb 1W	75.30bc	80.98b	16.11b-e	17.78b
Hoe weeding	3 and 6 WAT	62.78d	79.08b	22.22b	18.89b
Hoe weeding	3, 6 and 9 WAT	70.64cd	82.41b	20.56bc	16.11b
Weed free		84.99ab	96.26a	10.00e	3.33c
Weedy check		0.00e	0.00e	71.11a	67.22a
SE±		3.51	2.06	2.47	2.08
Interaction					
PP × WC		NS	*	NS	*

Means with the same letter (s) in a treatment column or rows are not significantly different at 5% level of probability using Duncan Multiple Range Test (DMRT). **NOTE:** NS= not significant; * - significant at 5 % level; fb - follow by; HW- hoe weeding; WAT- weeks after transplanting.

Table 2. Interaction between plant population and weed control Strategies on weed control efficiency at Birnin Kebbi 6 WAT during the 2018/2019 dry season

Weed control	Rate (Kg a.i. ha ⁻¹)	Plant population (plants/ha ⁻¹)		
		500,000	333,333	250,000
Pendimethalin	1.0 fb 1HW	98.09abc	91.39d	98.26abc
Pendimethalin fb	1.5 fb 2.0	90.75d	97.62abc	99.31ab
Fluazifop-p-butyl				
Pendimethalin	2.0	97.26abc	96.98abc	95.15c
Butachlor	2.0 fb 1HW	95.30c	100.00a	95.30c
Butachlor fb	2.8 fb 1.0	94.62cd	88.74de	91.52cd
Oxyfluorfen				
Butachlor	3.6	96.38bc	97.02abc	98.61abc
Fluazifop-p-butyl	2.0	80.40g	86.60ef	69.09j
Oxyfluorfen	1.0 fb 1HW	73.11hi	88.50de	81.32fg
Hoe weeding	3 and 6 WAT	84.52f	82.96fg	69.78ij
Hoe weeding	3, 6 and 9 WAT	75.48h	91.40d	80.36g
Weed free		97.97abc	95.19c	95.64c
Weedy check		0.00k	0.00k	0.00k
SE±			3.57	

Means with the same letter (s) in a treatment column or rows are not significantly different at 5% level of probability using Duncan Multiple Range Test (DMRT). **NOTE:** fb - followed by; HW- hoe weeding; WAT- weeks after transplanting.

Table 3. Interaction between plant population and weed control strategies on weed cover score at Birnin Kebbi 6 WAT during the 2018/2019 dry season.

Weed control	Rate (Kg a.i. ha ⁻¹)	Plant population (plants/ha ⁻¹)		
		500,000	333,333	250,000
Pendimethalin	1.0 fb 1HW	1.67hi	8.33e-i	1.67hi
Pendimethalin fb	1.5 fb 2.0	8.33e-i	1.67hi	0.00i
Fluazifop-p-butyl				
Pendimethalin	2.0	3.33ghi	3.33ghi	1.67hi
Butachlor	2.0 fb 1HW	3.33ghi	0.00i	5.00f-i
Butachlor fb	2.8 fb 1.0	3.33ghi	13.33d-h	5.00f-i
Oxyfluorfen				
Butachlor	3.6	3.33ghi	3.33ghi	1.67hi
Fluazifop-p-butyl	2.0	18.33b-e	13.33d-h	28.33b
Oxyfluorfen	1.0 fb 1HW	26.67bc	11.67e-i	15.00c-g
Hoe weeding	3 and 6 WAT	15.00c-g	16.67b-f	25.00bcd
Hoe weeding	3, 6 and 9 WAT	20.00b-e	10.00e-i	18.33b-e
Weed free		1.67hi	5.00f-i	3.33ghi
Weedy check		63.33a	68.33a	70.00a
SE±			3.607	

Means with the same letter (s) are not significantly different at 5% level of probability using Duncan Multiple Range Test (). **NOTE:** fb – followed by; HW- hoe weeding; WAT- weeks after transplanting.

Table 4. Impact of plant population and weed control strategies on plant height and leaf area of onion at Birnin Kebbi during 2017/2018 and 2018/2019 dry seasons

Treatment	Rate (kg a.i. ha ⁻¹)	2017-2018	2018-2019	2017-2018	2018-2019
Plant population (p/ha)		Plant height	Plant height	Leaf area	Leaf area
500,000		26.04	28.11	2928.3	3075.1
333,333		26.71	27.76	2926.8	3058.3
250,000		25.83	27.65	2810.7	3019.8
SE±		0.75	1.01	79.90	113.14
Weed Control Methods					
Pendimethalin	1.0 fb 1HW	31.98a	33.29a	3152.3abc	3073.9a-d
Pendimethalin fb Fluazifop-p-butyl	1.5 fb 2. 0	29.89ab	32.97a	3525.5a	3623.2ab
Pendimethalin	2.0	28.78abc	28.39abc	3287.9ab	3668.5a
Butachlor	2.0 fb 1HW	29.11abc	31.52ab	3208.6abc	3474.2abc
Butachlor fb Oxyfluorfen	2.8 fb 1.0	21.56e	22.18d	2517.6d	2445.4e
Butachlor	3.6	25.16cde	25.57cd	2773.9cd	2722.2de
Fluazifop-p-butyl	2.0	23.82ed	25.60cd	2598.2d	2821.6de
Oxyfluorfen	1.0 fb 1W	26.08bcd	27.76a-d	2844.6bcd	3059.5a-e
Hoe weeding	3 and 6 WAT	25.68cde	28.06abc	2830.9cd	3094.0a-d
Hoe weeding	3, 6 and 9 WAT	25.70b-e	27.00bcd	2832.4cd	2975.7cde
Weed free		23.40de	27.89a-d	2578.4d	2628.1de
Weedy check		23.16de	23.84cd	2513.0d	3026.2b-e
SE±		1.51	2.02	159.81	226.29
Interaction					
PP × WC		NS	*	NS	NS

Means with the same letter (s) in a treatment column or rows are not significantly different at 5% level of probability using Duncan Multiple Range Test (DMRT). **NOTE:** NS= not significant; * - significant at 5 % level; fb - followed by; HW- hoe weeding; WAT- weeks after transplanting.

Table 5: Interaction between plant population and weed control strategies on plant height at 6 WAT during the 2018/2019 dry season.

Weed control treatment	Rate (Kg a.i. ha ⁻¹)	Plant population (plants/ha ⁻¹)		
		500,000	333,333	250,000
Pendimethalin	1.0 fb 1HW	29.08efg	19.65pr	34.94bc
Pendimethalin fb	1.5 fb 2.0	33.15cd	35.86bc	29.92d-g
Fluazifop-p-butyl				
Pendimethalin	2.0	23.91k-o	33.24cd	42.73a
Butachlor	2.0 fb 1HW	36.99b	30.65de	26.93g-k
Butachlor fb	2.8 fb 1.0	26.61g-l	18.13q	21.82nop
Oxyfluorfen				
Butachlor	3.6	25.11i-n	28.89e-h	22.73m-p
Fluazifop-p-butyl	2.0	23.31l-o	28.51e-i	24.98j-n
Oxyfluorfen	1.0 fb 1HW	28.48e-j	28.79e-h	26.03g-m
Hoe weeding	3 and 6 WAT	27.13f-k	26.61g-l	30.45def
Hoe weeding	3, 6 and 9 WAT	27.89e-j	28.09e-j	25.01i-n
Weed free		24.37k-n	26.47g-l	20.71opq
Weedy check		31.36de	28.27e-ij	25.55h-m
SE±			3.51	

Means with the same letter (s) in a treatment column or rows are not significantly different at 5% level of probability using Duncan Multiple Range Test (DMRT). **NOTE:** fb - followed by; HW- hoe weeding; WAT- weeks after transplanting.

Table 6. Impact of plant population and weed control strategies on total bulb yield at Birnin Kebbi during 2017/2018 and 2018/2019 dry seasons

		Total bulb yield (t/ha)		
	Rate (kg a.i ha ⁻¹)	2017/18	22018/19	Pooled
Plant population (p/ha)				
500,000	-	3.11	5.83a	4.47a
333,333	-	2.99	4.55ab	3.77ab
250,000	-	2.83	4.12b	3.48b
SE±		0.21	0.48	0.31
Weed control treatments				
Pendimethalin	1.0 fb 1HW	4.31a	3.33ab	3.823ab
Pendimethalin fb	1.5 fb 2.0	3.62abc	6.45a	5.04a
Fluazifop-p-butyl				
Pendimethalin	2.0	2.81bcd	4.40abc	3.60ab
Butachlor	2.0 fb 1HW	3.94ab	6.22a	5.08a
Butachlor fb Oxyfluorfen	2.8 fb 1.0	2.25cd	5.85ab	4.051ab
Butachlor	3.6	2.70bcd	3.77abc	3.23ab
Fluazifop-p-butyl	2.0	2.96bcd	2.52c	2.74b
Oxyfluorfen	1.0 fb 1W	2.52bcd	3.43ab	2.97b
Hoe weeding	3 and 6 WAT	2.52cd	5.22ab	3.87ab
Hoe weeding	3, 6 and 9 WAT	3.20a-d	6.07a	4.63ab
Weed free	-	2.99a-d	5.49ab	4.24ab
Weedy check	-	1.90d	5.31ab	3.61ab
SE±	-	0.44	0.97	0.76
Interaction				
PP × WC	-	NS	NS	NS

Means with the same letter (s) in a treatment column are not significantly different at 5% level of probability using Duncan Multiple Range Test (DMRT). **NOTE:** NS= not significant; fb - followed by; HW- hoe weeding; WAT- weeks after transplanting.