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Evaluation of the effect of nicosulfuron and bentazone herbicides on growth and yield performance of two maize varieties in Mubi, Nigeria

TARI D. TIZHE[1,♥], SAMSON O. ALONGE[2], DAVID I. ADEKPE[3], DORA N. IOORTSUUN[2]
[1]Department of Botany, Adamawa State University. P.M.B. 25, Mubi, Nigeria. Tel.: +234-7066274008, ♥email: taritizhe@yahoo.com
[2]Department of Botany, Faculty of Life Sciences, Ahamdu Bello University. Samaru Main Campus, Zaria 810106, Kaduna State, Nigeria
[3]Department of Agronomy, Faculty of Agriculture, Ahamdu Bello University. Samaru Main Campus, Zaria 810106, Kaduna State, Nigeria

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Abstract. *Tizhe TD, Alonge SO, Adekpe DI, Ioortsuun DN. 2023. Evaluation of the effect of nicosulfuron and bentazone herbicides on growth and yield performance of two maize varieties in Mubi, Nigeria. Asian J Agric 7: 122-130.* This study aimed to determine the effect of nicosulfuron and bentazone herbicides on the growth and yield performance of maize (*Zea mays* L.) varieties SAMMAZ 17 and SAMMAZ 37 in Mubi, Nigeria. The study was carried out between 2019 and 2020 wet seasons. Nicosulfuron and bentazone herbicides at 50, 100, 150, and 200 g/ha and 0.5, 1.0, 1.5, and 2.0 kg a.i/ha concentrations, respectively, along with hoe weeded and weedy check controls were applied in the field of the two maize varieties at 3, 5 and 7 Weeks after Sowing (WAS). The maize growth parameters were determined two weeks after treatment at three different times, while the yield parameters were determined using standard procedures. The results showed that nicosulfuron and bentazone had no significant effect on the Crop Growth Rate (CGR), Net Assimilation Rate (NAR), days to 50% silking (except Relative Growth Rate and days to 50% tasselling), and plant height, leaf area index and total biomass of the two maize varieties, when sampled at 2 and 4 (except at 6 weeks) weeks sampling after herbicides application at 3, 5 and 7 WAS. The application at 3 WAS resulted in lower values for virtually all the growth parameters than that at 5 and 7 WAS. The two herbicides, however, significantly affected most of the maize yield parameters. The maize plants on plots treated at 3 WAS had the highest values for all the yield parameters (except kernel depth) than those treated at other periods. The study concluded that the post-emergence application of nicosulfuron and bentazone herbicides had no significant influence on the growth parameters of SAMMAZ 17 and SAMMAZ 37; however, there was a significant effect on the yield parameters.

Keywords: Bentazone, herbicides effect, maize, nicosulfuron effect, yield parameters

INTRODUCTION

Maize (*Zea mays* L.) is an annual cereal crop belonging to the Poaceae family. It can be cultivated in every continent except Antarctica due to the lack of good environmental conditions favorable for its growth. Based on days to maturity, the crop is divided into four (4) categories, namely late, medium, early, and extra early maturing varieties that take 100-120, 91-95, 86-90, and 80-85 days to mature respectively (Ibrahim and Sunusi 2019). It is the most widely distributed crop grown globally in tropical and sub-tropical regions in not less than 166 countries. In 2020, the global production rate of maize was 1.16 billion metric tonnes cultivated on 197 million hectares (FAO 2014), with Nigeria having 12.8 million metric tonnes that however, rose to 13.94 million metric tonnes in 2021, thus placing Nigeria the 11th producer globally, and the second largest in Africa after South Africa (ThriveAgric 2022).

Maize is consumed by people of different food preferences and socio-economic backgrounds in Africa (Olaniyan 2015). Its consumption rate is estimated to be more than 116 million metric tonnes, with about 30% and 21% of the consumption rates being globally and in Sub-Saharan Africa, respectively (Knoema 2021). The entire parts of the plant can be used for food and non-food products. It could be consumed as a vegetable because of its richness in dietary fiber and nutrients or used as feed for poultry and livestock, for extraction of edible oil, and for the starch and glucose industry (Hawaldar and Agasimani 2012).

The cultivation of maize is faced with the challenge of competition with weeds over growth resources that include soil nutrients, water, sunlight, and space during vegetative growth and reproduction, eventually leading to very poor grain yield (Haji et al. 2012). Considering the increase in demand for food by humans, the use of hand hoe weeding as a means to curtail crop/weeds competition to increase crop yield has been very costly and sometimes not available in the required quantity; this thus culminated in the introduction and use of herbicides (Haji et al. 2012). Nicosulfuron herbicides control broad leaves, sedges, and most grasses in maize fields post-emergence. It has general selectivity that ensures that all plants, including closely related plants growing near maize, are killed. The selectivity of the nicosulfuron herbicides is brought about by the ability of the maize plant to metabolize the nicosulfuron into harmless compounds (ThriveAgric 2022). Therefore, due to effective weed control and the use of nicosulfuron in maize fields, a significant increase in some yield parameters of the maize was recorded (Akadiri et al. 2017). Although nicosulfuron herbicides are made to control and kill plants other than maize, about 30% of visible injuries, reduction in height, and even death of some varieties of maize when applied as post-emergence were reported (Robinson et al. 2017). Tianjun et al. (2018) reported that the significant reduction in growth parameters of maize due to the post-emergence application of nicosulfuron depended upon the maize variety and concentration used. Bentazone herbicides are selective contact herbicides that could be applied post-emergence in maize fields to control mostly broadleaf weeds, sedges, and a few grasses (Eastmond and Balakrishnan 2010). Using herbicides significantly increases maize plants' yield due to effective weed control (Sharara et al. 2005) and wheat (El-Rokiek et al. 2022). Although bentazone herbicides are selective for maize, rice, cowpea, sorghum, soybeans, and peanut, however, its application at the different developmental stages of soybeans resulted in some visual injuries that impacted negatively on the growth of the plant (Ali et al. 2021). The application of herbicides in crop fields, however, must be done at the appropriate time and dosage, as wrong timing for the application of post-emergence herbicides, even at the recommended doses, could inflict some injuries on plants that might affect the grain size and yield or even kill the desirable plants (Legleiter and Johnson 2012; Varshney et al. 2012). The period for application of post-emergence herbicides could also determine how effective the herbicides could be on different weed species available in the crop fields (Mayerová et al. 2018).

SAMMAZ 17 and SAMMAZ 37 are improved medium and late-maturing maize varieties developed by the Institute for Agricultural Research (IAR) Samaru, Zaria, in collaboration with the International Institute of Tropical Agriculture (IITA). The SAMMAZ 17 possesses a white color kernel and has tolerance to *Striga hermonthica*. The SAMMAZ 37 also has tolerance to *S. hermonthica* but possesses a yellow kernel and resistance to streak virus disease and drought. Therefore, because of the qualities these two maize varieties possess, farmers in areas with a high infestation of *S. hermonthica* and low annual rainfall are found to cultivate these maize varieties. However, there is a shortage of literature on the effect of nicosulfuron and bentazone herbicides on the growth and yield parameters of the two maize varieties. Also, farmers in the Adamawa State region are found to use nicosulfuron and bentazone-containing herbicides for the post-emergence control of weeds in maize fields because of their effectiveness in controlling narrow and broadleaved weeds. Therefore, because the effect of herbicides on plants depended upon some factors like time of application, the species and variety of plant, and concentrations of herbicide, this study was deemed necessary to assess the effect of nicosulfuron and bentazone herbicides on SAMMAZ 17 and SAMMAZ 37 growth and yield parameters.

MATERIALS AND METHODS

Study area

The study was conducted during the 2019 and 2020 wet seasons in the research farm of the Department of Crop Science, Adamawa State University, Mubi, Nigeria. The location of the research farm falls within the North Eastern region of Nigeria, between Latitude 10°16' 06" N and Longitude 13°16' 01" E, and has an elevation of 582 m above sea level. The area has a tropical climate with an average annual temperature of 32°C, and lies within Nigeria's Sudan Savannah vegetation zone. The area has an average relative humidity of 28-45% and an average annual rainfall of about 1,056 mm.

Treatments and experimental design

The study consisted of two herbicides (nicosulfuron and bentazone), each at 4 different concentrations (i.e., nicosulfuron: 50.0, 100.0, 150.0, and 200.0 g/ha; Bentazone: 0.50, 1.00, 1.50 and 2.00 kg a.i/ha), hoe weeded and weedy check, two maize varieties (SAMMAZ 17 and SAMMAZ 37) and 3 times of application (i.e 3, 5 and 7 WAS). A split plot design that was replicated three times was used for the study. The maize varieties and period of herbicide applications were assigned to the main plot, while the herbicide concentrations were in the sub-plots.

Source of seeds for planting

The seeds of the SAMMAZ 17 and SAMMAZ 37 maize varieties were obtained from the Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria, Kaduna State, Nigeria.

Land preparation

The experimental field, which was 90.5 x 54.5 m^2 in size, was after being cleared of thorns and any other plant regrowth ridged with an inter-row spacing of 75 cm apart using an animal-drawn ridger. It was then divided into 60 plots and replicated three times, thus giving a total of 180 plots.

Seed treatment and planting

The maize seeds for the study were treated with Momtaz 45 WS seed dressing chemical, then planted at three in a hole of about 2 cm deep at an intra-row spacing of 25 cm and inter-row spacing of 75 cm. The seedlings were thinned to one per stand at 2 WAS, thus giving a total of 120 seedlings/plot.

Herbicides application

The herbicides were applied at different concentrations using a back-mounted 16-liter Knapsack sprayer at 3, 5, and 7 WAS.

Fertilizer application

The maize plants in all the plots were supplied with a dose of NPK (15:15:15) fertilizer at the rate of 400 kg/ha at 2 WAS, while at 5 WAS, a dose of urea fertilizer (46% N) was applied at the rate of 130.43 kg N/ha.

Data collection

Measurement of maize growth parameters

The determination of the maize growth parameters that include plant height, leaf area index, total dry matter, crop growth rate, relative growth rate, net assimilation rate, number of days to 50% tasseling, and number of days to 50% silking was carried out according to the methods described by Wood and Roper (2000) and Matusso (2016). As mentioned earlier, the sampling for the growth parameters of the maize plants treated with herbicides at 3, 5, and 7 WAS was carried out at 5, 7, and 9 WAS, 7, 9, and 11 WAS, and 9, 11, and 13 WAS, respectively.

Determination of yield parameters

Cob weight (g). The maize plant cobs from each plot were harvested when fully dried. Furthermore, 5 matured cobs randomly selected were de-husked and weighed from each treatment plot, and the average was recorded and expressed in grams.

Cob length (cm). The meter rule was used to measure the length of each of the 5 sampled cobs and the average taken and expressed in centimeters.

Cob diameter before shelling (cm). The diameter for each of the 5 cobs was measured with a Vanier caliper measured at the middle of the Cob. The average was determined and expressed in centimeters.

Cob diameter after shelling (cm). The diameter of each of the 5 cobs in 2.8.2.3 above was measured after shelling at the middle of the shelled Cob with a Vanier caliper, and the average values were taken and expressed in centimeters.

Kernel depth. The kernel depth was determined by subtracting the values of the cob diameter after shelling from the cob diameter before shelling using the values of cob diameter before and after shelling.

Number of kernel rows per Cob. The number of rows for each of the five cobs randomly selected was counted, and the average was recorded.

Number of kernels per row. The number of grains for each row of the three randomly selected maize cobs was counted, added, and divided by the total number of rows of the cobs, and the average was obtained.

Weight of kernels per Cob. The weight of kernels on each of the sampled 5 maize cobs was taken, and the average was recorded and expressed in grams.

Grain yield (kg) per hectare. The maize plants' cobs were harvested when the plants were matured and fully dried. The cobs harvested on each net plot were threshed, cleaned, weighed, and expressed in kg per hectare.

100 – grain weight (g). The 100 grain weight was determined by randomly selecting 100 grains from each plot's total grains and was weighed and recorded as 100-grain weight.

Threshing percentage (%). This is the percentage of the weight of kernels per cob weight concerning total cob weight. It was calculated using the equation below:

$$\text{Threshing percentage} = \frac{\text{Weight of kernels}}{\text{Cob weight}} \times 100$$

Cob yield per hectare. The harvested cobs of each net plot were dried, de-husked, weighed, and expressed in kg per hectare.

Data analysis

The data generated from this study were subjected to a two-way Analysis of Variance (ANOVA) using Statistical Package for Social Sciences (SPSS) version 26.0. Where there was a significant difference, Duncan's Multiple Range Test (DMRT) was used in separating means.

RESULTS AND DISCUSSION

Effect of nicosulfuron and bentazone on the growth parameters of SAMMAZ 17 and SAMMAZ 37

The results showed that the post-emergence application of nicosulfuron and bentazone herbicides at different concentrations in the field of SAMMAZ 17 and SAMMAZ 37 had no significant effect on the plant height of the two (2) maize varieties sampled at 2 and 4 weeks after herbicides application. Although, the herbicides resulted in comparable values for the plant height of the 2 maize varieties, but at each of the sampling weeks after the herbicides application, the different nicosulfuron treatments resulted in lower values for the plant height of the 2 maize varieties than did the different bentazone treatments and also the hoe weeded and unweeded controls. The 3, 5 and 7 WAS times of the herbicides application on the other hand, had significant effect on the plant height of the 2 maize varieties at all the sampling weeks after application. The 3 WAS application time led to significant reduction in plant height than did the 5 and 7 WAS applications when the plants were sampled at 2 and 4 weeks sampling after application and in the overall combined data (Table 1). Similarly, it was observed that at each of the sampling weeks after the application of the 2 herbicides and at the overall combined data, the different nicosulfuron treatments led to lower leaf area index in the 2 maize varieties than bentazone treatments and hoe weeded and unweeded control treatments. The leaf area index of the 2 maize varieties due to hoe weeded and unweeded control treatments were comparable at all the sampling weeks after application. The herbicides application at 3 WAS led to lower values for the leaf area index at all the sampling weeks and overall combined data compared with that due to 5 and 7 WAS application (Table 2). Also, the values for total biomass of the 2 maize varieties due to the varied treatments of nicosulfuron were significantly similar with that due to the different treatments of bentazone as well as that of the hoe weeded and unweeded control treatments at all the sampling weeks and the overall combined data. The herbicides application at 3, 5 and 7 WAS, however, had significant effect on the 2 maize varieties total biomass at all the sampling weeks after application. The 3 WAS application led to significant reduction in the maize plants total biomass when compared with that due to 5 and 7 WAS application at all the sampling weeks after application and the overall combined data (Table 3).

The reduction in values for those growth parameters as a result of nicosulfuron treatments could be linked to the temporary interference to DNA synthesis and stoppage of cell growth caused possibly by inhibition of branched-chain amino acids as a result of stoppage to the activity of enzyme acetolactate synthase as attested to by Silva (2007). This explains why there was an increase in values for the growth parameters with an increase in sampling age. Meng et al. (2019) further reported the reduction in plant height and fresh weight of maize plants due to the application of nicosulfuron. Tianjun et al. (2018) reported that the reduction in values for plant growth parameters like leaf area, root length, root surface area, and root volume depended upon the variety of the plant, the herbicide types, and concentrations. Therefore, this could be responsible for the higher values of the growth parameters mentioned above of SAMMAZ 17 than that of SAMMAZ 37. The higher values for most of the SAMMAZ 17 and SAMMAZ 37 growth parameters as a result of bentazone treatments than that of nicosulfuron could be because nicosulfuron, especially at higher concentrations, affect some essential physiological plant processes that are involved in protein synthesis and cell growth which eventually affect normal plant growth (Agchemaccess 2022) than bentazone which only affect plants' photosynthetic rate.

Also, on the other growth parameters (except relative growth rate and days to 50% tasselling) of maize variety SAMMAZ 17 and 37, the nicosulfuron and bentazone treatments showed no significant effect (Table 4). The 2.0 kg a.i/ha bentazone treatment resulted in the higher values for the SAMMAZ 17 and SAMMAZ 37 growth parameters like Crop Growth Rate (CGR) and Relative Growth Rate (RGR). In contrast, the 100 g/ha nicosulfuron treatment had higher values for Net Assimilation Rate (NAR) and silking than other treatments (Table 4). Similar findings were reported by Sharara et al. (2005), Sharma et al. (2018), and El-Rokiek et al. (2022), whose studies recorded a significant increase in growth parameters of maize, rice, and wheat, respectively. They associated the increase in the growth parameters to bentazone application. Also, Akadiri et al. (2017) assessed the effect of nicosulfuron, 2,4-D, and atrazine on the growth parameters of maize plants. They discovered that nicosulfuron treatments had higher values for some of the maize growth parameters like leaves per plant and stem girth than that due to the other herbicide treatments.

Also, the interaction effect of herbicides and time of application, herbicides and variety, time of application and variety and herbicides, time of application and variety was not significant on the plant height, leaf area index and total biomass of the 2 maize varieties at all sampling time (Tables 1-3). This was similarly observed in Table 4 especially on NAR, 50% silking and tasselling. This was an indication that the interaction of herbicides, time of application and variety of the maize plants was not such that they would significantly affect the plant height, leaf area index, total biomass and some of the other growth parameters of the 2 maize varieties.

Table 1. Effect of post-emergence application of nicosulfuron and bentazone on the plant height of maize varieties SAMMAZ 17 and SAMMAZ 37 in 2019 and 2020 wet seasons in Mubi, Nigreia

Treatment	Rate	Plant height (cm)			
		Sampling week			
		2	4	6	Mean
Herbicide – (H)					
Nicosulfuron	50 g/ha	86.09a	134.02a	203.08abc	141.07a
Nicosulfuron	100 g/ha	78.88a	130.70a	201.00bc	136.86a
Nicosulfuron	150 g/ha	78.27a	127.97a	197.45bc	134.56a
Nicosulfuron	200 g/ha	77.59a	121.20a	191.96c	130.25a
Bentazone	0.5 kg a.i/ha	90.63a	151.27a	215.36ab	152.42a
Bentazone	1.0 kg a.i/ha	89.06a	152.71a	200.64bc	147.47a
Bentazone	1.5 kg a.i/ha	85.16a	150.06a	220.63a	151.95a
Bentazone	2.0 kg a.i/ha	89.72a	145.37a	215.45ab	150.18a
Hoe weeded	-	91.79a	140.28a	213.10ab	148.39a
Unweeded	-	87.81a	139.99a	202.61abc	143.47a
SE±		10.65	10.36	5.79	7.15
TA (WAS) –(T)					
3		45.42c	115.49b	194.77b	118.56c
5		82.84b	149.77a	214.22a	148.94b
7		128.24a	152.82a	209.39a	163.48a
SE±		5.83	5.67	3.17	3.91
Variety (V)					
Sammaz 17		87.57a	141.81a	215.75a	148.37a
Sammaz 37		83.43a	136.91a	196.51b	138.95b
SE±		4.76	4.63	2.59	3.20
Interaction					
H x T		NS	NS	NS	NS
H x V		NS	NS	NS	NS
T x V		NS	NS	NS	NS
H x T x V		NS	NS	NS	NS

Note: TA: Time of application, NS: Not significant. Means under each column with the same letter(s) are not significantly different at p≤0.05 using DMRT

Table 2. Effect of post-emergence application of nicosulfuron and bentazone on the leaf area index of maize varieties SAMMAZ 17 and SAMMAZ 37 in 2019 and 2020 wet seasons in Mubi, Nigeria

Treatment	Rate	Leaf Area Index (cm)			
		Sampling week			
		2	4	6	Mean
Herbicide – (H)					
Nicosulfuron	50 g/ha	0.63a	0.73a	1.12cd	0.83bc
Nicosulfuron	100 g/ha	0.57a	0.71a	1.09d	0.79c
Nicosulfuron	150 g/ha	0.57a	0.75a	1.19cd	0.84bc
Nicosulfuron	200 g/ha	0.61a	0.73a	1.14cd	0.83bc
Bentazone	0.5 kg a.i/ha	0.59a	0.82a	1.56a	0.99ab
Bentazone	1.0 kg a.i/ha	0.62a	0.90a	1.40abc	0.97abc
Bentazone	1.5 kg a.i/ha	0.60a	0.85a	1.52ab	0.99ab
Bentazone	2.0 kg a.i/ha	0.71a	0.92a	1.59a	1.07a
Hoe weeded	-	0.59a	0.83a	1.40bcd	0.94abc
Unweeded	-	0.72a	0.77a	1.26abc	0.92abc
SE±		0.08	0.07	0.10	0.06
TA (WAS) –(T)					
3		0.21c	0.38b	1.24b	0.61c
5		0.39b	0.99a	1.43a	0.94b
7		1.26a	1.03a	1.31ab	1.20a
SE±		0.05	0.04	0.05	0.03
Variety (V)					
Sammaz 17		0.66a	0.87a	1.40a	0.98a
Sammaz 37		0.58a	0.73b	1.25b	0.86b
SE±		0.04	0.04	0.04	0.03
Interaction					
H x T		NS	NS	NS	NS
H x V		NS	NS	NS	NS
T x V		NS	NS	NS	NS
H x T x V		NS	NS	NS	NS

Note: TA: Time of application, NS: Not significant. Means under each column with the same letter(s) are not significantly different at p≤0.05 using DMRT

The 3, 5, and 7 WAS application times of nicosulfuron and bentazone herbicides had a significant effect on the plant height, leaf area index, total biomass, and other growth parameters like CGR, RGR, NAR and days to 50% tasselling and silking of both the SAMMAZ 17 and SAMMAZ 37 (Tables 1-4). The 3 WAS application resulted in the significantly lowest values for the plant height, leaf area index, and total biomass of the two maize varieties than the 5 and 7 WAS applications, resulting in higher values for the growth parameters (Tables 1-3). It was also observed that applying the herbicide at 3 WAS inflicted some physical injuries on the maize plants, especially the higher concentrations of the herbicides than applications at 5 and 7 WAS. On the other growth parameters, however, the application at 5 and 7 WAS resulted in the lowest days to 50% tasselling and silking and RGR and NAR, respectively, while that at 3 WAS led to the lowest value for CGR compared to that due to other periods of application (Table 4). The reduction in values for most of the maize growth parameters due to herbicide application at 3 WAS could be associated with the physical injuries sustained by the plants due to the herbicide application at that age. It could still be linked to the interference of DNA synthesis and cell growth caused by the inhibition of branched chained amino acids biosynthesis due to the stoppage of the activity of the enzyme acetolactate synthase as a result of the nicosulfuron application (Silva 2007). The higher values for some of the SAMMAZ 17 and SAMMAZ 37 growth parameters at especially 5 WAS application than that due to 3 WAS application could be due to the ability of the maize plant to tolerate and convert the higher concentrations of the herbicides into a harmless compound at that stage than at 3 WAS application. A study by Eynollahi et al. (2017) reported a significant increase in values for maize growth parameters like plant height, leaf area index, and total biomass due to the application of 60 g a.i/ha of nicosulfuron at 2-4 leaf stage of maize than that treated with 40, 80 and 100 g a.i/ha of nicosulfuron at 4-6 and 6-8 leaf stages of the maize plant. Therefore, the age of the plant at which herbicides are applied determines the magnitude of the effect of the herbicides on the plant's growth parameters. Ali et al. (2021) agreed with this when they reported the effect of bentazone application at different developmental stages on the growth parameters of soybean cultivars.

The varietal data showed that SAMMAZ 17 and SAMMAZ 37 treated with nicosulfuron and bentazone were not significantly different in plant height, leaf area index, and total biomass, especially at 2 and 4 weeks of sampling after application (Tables 1-3). Similarly, on the other growth parameters, the two maize varieties did not differ significantly except on the days to 50% tasselling and silking. However, the maize variety SAMMAZ 17 had higher values for most growth parameters than SAMMAZ 37 (Table 4). This might be due to varietal differences as plant variety affects its response to herbicides, as Robinson et al. (2017) reported.

Table 3. Effect of post-emergence application of nicosulfuron and bentazone on the total biomass of maize varieties SAMMAZ 17 and SAMMAZ 37 in 2019 and 2020 wet seasons in Mubi, Nigeria

Treatment	Rate	Total biomass (g)			
		Sampling week			
		2	4	6	Mean
Herbicide – (H)					
Nicosulfuron	50 g/ha	32.17ab	49.68a	107.76a	63.20a
Nicosulfuron	100 g/ha	25.06ab	55.73a	84.17b	54.98a
Nicosulfuron	150 g/ha	30.16ab	54.36a	94.84ab	59.79a
Nicosulfuron	200 g/ha	27.57ab	50.82a	86.96b	55.12a
Bentazone	0.5 kg a.i/ha	28.68ab	55.17a	89.12ab	57.66a
Bentazone	1.0 kg a.i/ha	34.60a	54.85a	104.32ab	64.59a
Bentazone	1.5 kg a.i/ha	31.94ab	54.09a	92.73ab	59.59a
Bentazone	2.0 kg a.i/ha	34.00ab	44.93a	91.96ab	56.96a
Hoe weeded	-	33.86ab	60.49a	98.23ab	64.19a
Unweeded	-	24.06b	56.74a	87.92ab	56.24a
SE±		3.08	4.99	6.33	4.02
TA (WAS) –(T)					
3		9.88c	21.30b	68.22c	33.14c
5		19.11b	71.15a	115.72a	68.66b
7		61.64a	68.60a	97.46b	75.90a
SE±		1.68	2.73	3.47	2.20
Variety (V)					
Sammaz 17		30.90a	55.12a	95.25a	60.42a
Sammaz 37		29.52a	52.26a	92.35a	58.04a
SE±		1.38	2.23	2.83	1.80
Interaction					
H x T		NS	NS	NS	NS
H x V		NS	NS	NS	NS
T x V		NS	NS	NS	NS
H x T x V		NS	NS	NS	NS

Note: TA: Time of application, NS: Not significant. Means under each column with the same letter(s) are not significantly different at p≤0.05 using DMRT

Effect of nicosulfuron and bentazone on the yield parameters of SAMMAZ 17 and SAMMAZ 37

Table 5 shows the effect of nicosulfuron and bentazone treatments on SAMMAZ 17 and SAMMAZ 37 yield parameters significantly affected most yield parameters. It was observed that although the nicosulfuron treatments had higher values for most of the SAMMAZ 17 and SAMMAZ 37 yield parameters, the values for almost all of the yield parameters due to the two herbicide concentrations were comparable. The hoe-weeded control treatment had higher values for yield parameters like cob weight [CW (148.00 g)], cob length [CL (17.75 cm)], cob yield/hectare [CY/H (921.08 kg/ha)], kernel depth [KD (1.17)], and grain yield/hectare [GY/H (809.90 kg/ha)], which were significantly similar with that due to the two herbicides treatments, but significantly higher than that due to unweeded control treatment. However, the two control treatments (hoe weed and unweeded) had a comparable value for most other yield parameters (Table 5). The higher values for most of the yield parameters of SAMMAZ 17 and SAMMAZ 37 as a result of the nicosulfuron treatments than that due to bentazone treatments could be attributed to the effective weed control recorded that eventually led to less weed competition for available soil nutrients, water, and space. Akadiri et al. (2017) also found an increase in yield parameters of maize plants due to nicosulfuron application. The highest values for almost all the yield parameters (including CY/H and GY/H) of the two maize varieties due to hoe-weeded control treatment could be a result of the effective weed control with less phytotoxicity compared with that due to the herbicides treatments. Nosratti et al. (2007) reported similar significantly higher values for GY/H and other yield parameters due to hoe-weeded control compared to nicosulfuron concentrations and other herbicides. Felix et al. (2019) also found that the highest GY/H due to hoe-weeded control was comparable to pre and post-emergence herbicides studied. The lowest values for most of the yield parameters (including CY/H, GY/H, HGW, WKC) due to unweeded control treatment was a result of high weed infestation/density that led to high maize/weeds competition for available essential environmental resources required for plant growth and development thus causing a reduction in values for most of the yield parameters of the two maize varieties.

The 3, 5, and 7 WAS application times of nicosulfuron and bentazone treatments were also significant on the yield parameters (except CL and KD) of the SAMMAZ 17 and SAMMAZ 37. The 3 WAS application resulted in higher values for all the yield parameters (except KD and HGW) of the maize varieties compared with that due to 5 and 7 WAS applications (Table 5). This confirmed that the time herbicide is applied determines its effect on the plant's yield or yield attributes (Soltani et al. 2007). Hence, the highest values for virtually all the maize variety SAMMAZ

17 and SAMMAZ 37 yield parameters due to 3 WAS application might be due to the early and effective weed control recorded at that stage. A similar finding was reported by Anderson et al. (1974) when they applied bentazone at the unifoliate, first trifoliate, and second trifoliate stages of soybean development and thus discovered that the bentazone application resulted in effective weed control and an increase in soybean yield at the first trifoliate stage of growth than it did at other stages of development. The finding also agreed with that of Sharara et al. (2005) who found that the single application of bentazone and other herbicides like fluroxypyr at two weeks after sowing maize plant effectively control weeds and thus significantly increase the yield parameters of the maize plant by about 52-74% when compared with that due to other period of application.

The varietal data showed that the maize varieties SAMMAZ 17 and SAMMAZ 37 treated with nicosulfuron and bentazone treatments significantly differed in yield parameters, including GY/H, CY/H, WKC, and CW (Table 5). SAMMAZ 17 had higher values for all the yield parameters (except NKRC, KD, T% and HGW) than SAMMAZ 37. This could be due to varietal differences or the effect of the herbicides. Wilson et al. (2010) attested to these findings when they reported that the tolerance of maize to herbicides was based on factors like variety type, herbicide application dose, and environmental factors. Also, Soltani et al. (2007) observed the sensitivity of some sweet corn hybrids to herbicides that involved nicosulfuron, bentazone, mesotrione, primisulfuron, foramsulfuron, and isoxaflutole and associated their response to herbicides and variety of the maize.

The study concluded that the nicosulfuron treatments resulted in reduced values for most growth parameters of SAMMAZ 17 and SAMMAZ 37 than bentazone treatments. On the yield parameters of the 2 maize varieties, however, the 2 herbicides treatments had a comparable values for majority of the yield parameters. For higher yield performance of SAMMAZ 17 and SAMMAZ 37, the application of nicosulfuron and bentazone treatments should be at 3 WAS than at 5 and 7 WAS.

Table 4. Effect of post-emergence application of nicosulfuron and bentazone on the CGR, RGR, NAR, days to 50% tasselling and silking of maize varieties SAMMAZ 17 and SAMMAZ 37 in 2019 and 2020 wet seasons in Mubi, Nigeria

Treatment	Rate	Growth parameters				
		CGR ($g/m^2/wk$)	RGR (g/g/wk)	NAR (gcm^2/wk)	50% Tasselling	50% Silking
Herbicide (H)						
Nicosulfuron	50 g/ha	0.52a	0.061ab	0.003a	60.25cd	63.39a
Nicosulfuron	100 g/ha	0.48a	0.075ab	0.004a	61.22abc	64.28a
Nicosulfuron	150 g/ha	0.46a	0.061ab	0.003a	61.58ab	63.89a
Nicosulfuron	200 g/ha	0.47a	0.067ab	0.002a	61.72a	64.19a
Bentazone	0.5 kg a.i/ha	0.56a	0.046b	0.002a	60.17cd	63.33a
Bentazone	1.0 kg a.i/ha	0.50a	0.057ab	0.003a	60.69abcd	63.81a
Bentazone	1.5 kg a.i/ha	0.51a	0.068ab	0.003a	60.33cd	63.19a
Bentazone	2.0 kg a.i/ha	0.56a	0.100a	0.002a	59.81d	62.97a
Hoe weeded	-	0.48a	0.068ab	0.003a	60.64abcd	63.75a
Uweeded	-	0.52a	0.093a	0.003a	60.50bcd	63.69a
SE±		0.07	0.014	0.001	0.38	0.44
TA (WAS) (T)						
3		0.31c	0.069ab	0.003b	60.94a	63.46b
5		0.74a	0.089a	0.004a	60.08b	62.98b
7		0.47b	0.051b	0.002c	61.06a	64.52a
SE±		0.04	0.008	0.00	0.21	0.24
Variety (V)						
Sammaz 17		0.51a	0.062a	0.003a	61.84a	64.70a
Sammaz 37		0.50a	0.078a	0.003a	59.54b	62.60b
SE±		0.03	0.006	0.000	0.17	0.20
Interaction						
HxT		*	*	NS	NS	NS
HxV		NS	*	NS	NS	NS
TxV		NS	NS	NS	NS	NS
HxTxV		NS	NS	NS	NS	NS

Note: TA: Time of application, WAS: Week after Sowing, NS: Not significant, *: Statistically significantly different. Means under each column with the same letter(s) are not significantly different at $p \leq 0.05$ using DMRT

Table 5. Effect of post-emergence application of nicosulfuron and bentazone on the yield parameters of maize varieties SAMMAZ 17 and SAMMAZ 37 in 2019 and 2020 wet seasons in Mubi, Nigeria

		Yield parameter											
Treat.	**Rate**	**CW (g)**	**CL (cm)**	**CDBS (cm)**	**NKRC**	**NKC**	**WKC (g)**	**CDAS (cm)**	**CY/H (Kg/ha)**	**KD**	**T%**	**GY/H (Kg/ha)**	**HGW (g)**
Her (H)													
Nico.	50 g/ha	139.83ab	15.66b	5.31a	13.93abcd	472.59a	115.01bc	3.05ab	62.22ab	1.12ab	81.34a	50.83b	25.07b
Nico.	100 g/ha	151.79a	15.60b	5.25ab	13.60cd	448.00ab	115.91bc	3.19a	66.23a	1.17a	78.10ab	51.65b	26.10b
Nico.	150 g/ha	137.72ab	15.65b	5.30a	13.68bcd	470.48a	109.05c	3.01abc	61.21ab	1.18a	79.16ab	50.44b	33.75a
Nico.	200 g/ha	136.61ab	15.30b	5.23ab	13.65bcd	428.64b	109.92c	2.75d	61.51ab	1.27a	80.14ab	48.66b	26.67b
Bent.	0.5 kg a.i/ha	143.49ab	15.57b	5.19ab	14.20ab	472.76a	118.63abc	2.86bcd	65.10a	1.13ab	76.30b	52.06b	24.38b
Bent.	1.0 kg a.i/ha	139.82ab	15.63b	5.18ab	13.85bcd	456.79ab	114.92bc	2.84bcd	63.31ab	1.16a	82.88a	51.94b	25.15b
Bent.	1.5 kg a.i/ha	139.09ab	15.24b	5.18ab	14.03abc	478.49a	143.10a	2.80cd	60.50ab	1.19a	80.98ab	48.65b	25.57b
Bent.	2.0 kg a.i/ha	142.99ab	15.06b	5.25ab	13.36d	455.12ab	141.31ab	2.80cd	63.14ab	1.11ab	79.40ab	49.58b	25.68b
Hoe W.	-	148.00a	17.75a	5.15ab	14.47a	473.33a	118.02abc	2.93bcd	65.28a	1.17a	81.51a	58.60a	25.89b
Uweeded	-	127.67b	15.09b	4.95b	14.23ab	441.41ab	104.96c	2.96abcd	56.76b	1.00b	82.10a	46.65b	24.13b
SE±		5.33	0.64	0.10	0.18	12.62	8.46	0.08	2.37	0.05	1.54	2.16	1.29
TA (T)													
3 WAS		151.94a	15.93a	5.35a	14.12a	488.11a	140.68a	3.00a	67.42a	1.16a	81.97a	55.01a	25.85ab
5 WAS		133.61b	15.75a	5.10b	13.56b	442.96b	106.50b	2.87b	58.71b	1.13a	80.42ab	47.46b	27.71a
7 WAS		136.55b	15.29a	5.14b	14.01a	448.21b	110.07b	2.89ab	61.45b	1.16a	78.18b	50.25b	25.16b
SE±		2.92	0.35	0.05	0.10	6.91	4.64	0.04	1.30	0.03	0.84	1.18	0.71
Vari (V)													
Sam. 17		148.23a	15.79a	5.29a	13.86a	462.71a	130.09a	2.99a	65.43a	1.14a	79.36a	53.05a	25.74a
Sam. 37		133.17b	15.52a	5.11b	13.94a	456.81a	108.07b	2.85b	59.62b	1.16a	81.02a	48.77b	26.73a
SE±		2.39	0.29	0.04	0.08	5.64	3.79	0.03	1.06	0.02	0.69	0.97	0.58
Inter.													
HxT		NS	NS	NS	NS	NS	*	*	NS	NS	*	NS	NS
HxV		NS	NS	NS	*	NS	*	NS	*	NS	*	NS	*
TxV		NS	NS	NS	*	NS	*	NS	NS	NS	*	NS	NS
HxTxV		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: TA: Time of application, WAS: Week after Sowing, NS: Not significant, *: Statistically significantly different, Her: Herbicide, Nico.: Nicosulfuron, Bent.: Bentazone, Hoe W: Hoe weeded, Vari: Variety, Treat.: Treatment, Inter.: Interaction, CW: Cob weight, CL: Cob length, CDBS: Cob diameter before shelling, NKRC: Number of kernel row/cob, NKC: Number of kernel/cob, WKC: Weight of kernel/cob, CDAS: Cob diameter after shelling, CY/H: Cob yield/hectare, KD: Kernel depth, T%: Threshing percentage, GY/H: Grain yield/hectare, HGW: Hundred grain weight, Sam.: Sammaz. Means under each column with the same letter(s) are not significantly different at $p \leq 0.05$ using DMRT

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