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Full Length Research Paper

Effect of pre-emergence herbicides on weed infestation and productivity of sesame (*Sesamum indicum* L.) in the Sudan Savanna Zone of Nigeria

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Field trials were conducted in 2006 and 2007 cropping seasons at the University of Maiduguri Teaching and Research Farm located in Maiduguri (11°50'N; 13°10'E), Nigeria, to evaluate the effect of different pre-emergence herbicides on weed infestation and productivity of sesame (*Sesamum indicum L.*) The experiment consisted of 22 treatments, which included 4 different pre-emergence herbicides applied at 5 rates each namely butachlor, metolachlor, diuron and pendimethalin at 0.5, 1.0, 1.5, 2.0 and 2.5 kg a.i./ha, weeding at 3 and 6 weeks after sowing (WAS) and a weedy check. The treatments were laid out in randomized complete block design (RCBD) replicated 3 times. Results showed that diuron at 1.5 to 2.5 kg a.i./ha produced significantly (P<0.05) the least weed cover and dry matter at 3 and 6 WAS, which was comparable with two-hoe-weedings at harvest. Both butachlor at 2.0 kg a.i./ha and metolachlor at 1.5 kg a.i./ha produced significantly (P<0.05) low weed cover score and weed dry matter, which were comparable with the least weed cover score in both trials and their combined means at harvest. Among the herbicides tested, butachlor at 2.0 kg a.i./ha and diuron at 1.0 kg a.i./ha produced significantly (P<0.05) the highest grain yield in 2006, while metolachlor at 1.5 kg a.i./ha produced significantly (P<0.05) the highest grain yield in 2007 and the combined means. For effective weed control and higher yield, metolachlor at 1.5 kg a.i./ha and butachlor at 2.0 kg a.i./ha are recommended as an alternative to two hoe-weedings at 3 and 6 WAS for the production of sesame in the Sudan Savanna zone of Nigeria.

Key words: Pre-emergence herbicides, weed infestation, productivity, sesame, savanna, Nigeria.

INTRODUCTION

Sesame (*Sesame indicum* L.) is thought to be the oldest oil producing plant, and its seeds have the highest oil content close to 50% (Anonymous, 2006). Asia accounts for three quarters of the global production of sesame seeds. The world's total production of the crop estimated by FAO was 3 million metric tonnes in 2005 and since then, Africa's share has been rising steadily. More than 20 African countries produce this crop with Nigeria, Sudan and Uganda as the leading producers and exporters of the crop (FAO, 2006). In Nigeria, sesame is mainly grown in areas of southern Guinea savanna ecological zone, notably in Benue and Kogi States and the Federal Capital Territory, Abuja (Philips, 1977). Recent reports by Iwo and Idowu (2002), indicated that production trend of sesame in Nigeria is on the increase by 7.8%, where production has increased from 15,000 metric tonnes in 1980 to 56,000 metric tonnes in 1994. Further increase in production was seen in 1996 of 64,000 and 67,000 metric tonnes in 1997. They have projected that production will increase to 130,000 metric tonnes by the year 2010. Sesame is an annual up to 1.5 m tall (Roland, 1993). It has a strong tap root and dense, much branched lateral root system which spreads in the surface. The lower leaves are opposite, broad and palmately lobed, while the upper leaves are alternately arranged, narrow and lanceolate (Onwueme and Sinha, 1991). The stems of most varieties are branched. The flowers are white or pink. The fruit is a rectangular,

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deeply-grooved capsules up to 3 cm long with a short beak (Onwueme and Sinha, 1991) . The importance of sesame lies in its high content of oil, protein, calcium, iron and methionine, which are very important for pregnant and lactating women (Gupta et al., 1998).

Yermanos et al. (1972) reported that, the seed of sesame contains about 50 to 51% oil, 17 to 19% protein and 16 to 18% carbohydrate and that the oil is edible, odourless and semi-drying, containing oleic, stearic and palmitic acids. Sesame oil serves as antioxidant in the manufacture of margarine and salad creams, and as a fixative in the industries for making of perfumes and cosmetics. It is also used as carriers for fat-soluble substances in pharmaceuticals and insecticide manufacturing (Godin and Spensley, 1971). The traditional methods of weed control, namely, hoe-weeding, are the commonest method of weed control by farmers in the Sudan Savanna Zone of Nigeria. This method is not only labour intensive, expensive and strenuous, but can also cause mechanical damage to growing branches and roots of plants. In addition to high cost, labour availability is uncertain, thus making timeliness of weeding difficult to attain, leading to greater yield loss (Adigun et al., 2003).

Chemical weed control has revolutionized farmers approach to weed control in the world. Chemical weed control is more adapted to large scale crop production than other weed control methods and it is labour saving (Anon, 1994). Also, herbicide use has been reported to be more profitable than hoe-weeding in the production of various crops in Nigeria (Shrock and Monaco, 1980; Okereke, 1983; Usoroh, 1983; Sinha and Lagoke, 1984; Ogungbile and Lagoke, 1986; Adigun et al., 1993). Most of the work done on chemical weed control in sesame has been limited to the Southern Guinea Savanna Zone of Nigeria and other parts of the world with agro-ecology different from that of the semi-arid zone of Nigeria, characterized by low, erratic, variable and unreliable rainfall, which affect the performance of herbicides. For example, Ndarubu et al. (2003), reported highest sesame yield and effective weed control with application of herbicide mixture of metolachlor + metobromuron at 1.0 + 1.0 kg a.i./ha in the Guinea Savanna of Nigeria. As a result of the paucity of data on the use of herbicides in sesame production, it has made it necessary to evaluate some herbicides in this zone to find out not only how safe they are, but their effectiveness in the control of weeds to achieve higher yield in sesame (Imoloame, 2009).

MATERIALS AND METHODS

Field trials were conducted during the 2006 and 2007 cropping seasons on the university Teaching and Research Farm, Faculty of Agriculture, University of Maiduguri, Maiduguri (11°51'N; 13°15'E; elevation 336 m) located in the Sudan Savanna Zone of Nigeria. The experimental site which measured 12 x 88 m was harrowed, leveled properly using a hand-hoe, and marked out. The plot size was 4 x 4 m leaving a distance of 1.0 and 0.5 m between replications and plots, respectively. NPK 15:15:15 was applied to each plot to provide 50 kg P and 75 kg N. The full rate of P was applied before sowing and incorporated into the soil. The application of N however, was done in 2 equal split dose. The first dose was applied before planting as starter dose and the second dose was applied at 6 WAS which was drilled into the soil 15 cm away from the stand in a continuous band. The experiment consisted of 22 treatments, which included 4 different pre-emergence herbicides at five rates each, namely butachlor, diuron, metolachlor and pendimethalin at 0.5, 1.0, 1.5, 2.0 and 2.5 kg a.i./ha, weeding at 3 and 6 WAS and a weedy check. The treatments were laid out in randomized complete block design (RCBD) with 3 replications. Data collected were subjected to analysis of variance (ANOVA) and the difference between means were determined using Duncan's Multiple Range Test (DMRT). Sesame var. Gwoza Local was sown on 6 August, 2006 and 26 July, 2007 by drilling the seeds at the rate of 6 kg/ha into the soil, at a spacing of 90 cm between the rows. The following day, the pre-emergence herbicides were applied using CP-15 knapsack sprayer at a pressure of 2 kg/cm^2 calibrated to deliver 250 l/ha spray volume using a green nozzle. Observations taken included the following:

Crop vigor score: This was assessed visually at 3, 6 and 9 WAS, using a scale of 1 to 9, where 1= completely dead plants and 9 = most vigorous plants. The features of the plants used for scoring were, leaf and stem size, greenness and size of the plant (Ishaya et al., 2009).

Plant height (cm): This was taken at 4, 8 and 12 WAS. This was done by selecting 5 plants randomly from a plot and then measured their heights from the soil level to the tip of the apical bud with a graduated meter ruler. The mean of the plant heights was recorded as height of plant/plot (Imoloame, 2009).

Phytotoxicity rating: This was taken at 2, 4 and 8 WAS by visual observation using a scale of 1 to 9, where 1 = no crop injury and 9 = complete crop kill (Imoloame, 2009).

Weed dry matter: This was estimated at 3, 6 WAS and at harvest. This was done by harvesting weed biomass from three (3) randomly located 1 m^2 quadrats in each experimental plot. The weeds were oven-dried and weighed. The average weight was recorded (Imoloame, 2009).

Weed cover score: This was taken at 3, 6 WAS and at harvest using a scale of 1 to 9, where 1=complete absence of weeds in the plot and 9 =complete coverage of the plot by weeds (Imoloame, 2009).

Number of pods (capsules)/plant: This was determined by counting all the pods on 5 randomly selected plants at 10 and 12 WAS and the average recorded (Imoloame, 2009).

Grain yield/ha: This was determined after harvest. After threshing the plant, the grain yield/plot was weighed and recorded. This was converted to grain yield per hectare. (Imoloame, 2009). Harvesting was done in November with only the 3 inner rows of each plot harvested (net plot) and the first and last rows were discarded.

RESULTS AND DISCUSSION

Pre-emergence herbicides had significant phytotoxic effect on sesame crop at 2, 4 and 8 WAS (Table 1). In both years and their combined means at 2, 4 and 8 WAS, all the rates of butachlor, all the rates of metolachlor except at 2.0 and 2.5 at 2 WAS in 2006 and combined means, diuron and pendimethalin at 0.5 kg a.i./ha had significantly ($P<0.01$) least phytotoxicity effect on sesame. The slight phytotoxic effect of metolachlor at the aforementioned rates in 2006 at 2 WAS could be due to the lower rainfall recorded in this year than 2007, which

Table 1. Effect of pre-emergence herbicides on sesame phytotoxicity at 2, 4 and 8 WAS in Maiduguri, 2006 and 2007.

Treatment	Rates (kg a.i./ha)	Phytotoxicity rating[1]								
		2 WAS[2]			4 WAS			8 WAS		
		2006	2007	Mean[3]	2006	2007	Mean	2006	2007	Mean
Butachlor	0.5	2.3ghi[4]	1.8fg	2.1efg	1.7e[3]	1.8c	1.8de	1.0e	1.0e	1.0f
”	1.0	2.7ghi	2.3d-g	2.5efg	2.1de	1.7c	1.9de	1.0e	1.0e	1.0f
”	1.5	2.7ghi	2.0efg	2.3efg	1.9e	2.0c	2.0de	1.0e	1.2e	1.1f
”	2.0	2.0hi	3.0d-g	2.5efg	1.6e	2.2c	1.9de	1.0e	1.3e	1.2f
”	2.5	3.0f-i	2.0efg	2.5efg	2.4de	1.8c	2.1de	1.0e	1.3e	1.2f
Metolachlor	0.5	2.5ghi	1.8fg	2.2efg	1.8e	1.7c	1.8de	1.0e	1.0e	1.0f
”	1.0	3.0f-i	1.5g	2.3efg	2.2de	1.3c	1.8de	1.0e	1.0e	1.0f
”	1.5	3.7e-i	1.8fg	2.8edg	2.5de	1.7c	2.1de	1.0e	1.0c	1.0f
”	2.0	5.0c-g	1.8fg	3.4de	2.0de	1.7c	1.8de	1.0e	1.3e	1.2f
”	2.5	5.0c-g	2.0efg	3.5de	4.8cd	1.8c	3.3cd	1.7de	1.0e	1.3f
Diuron	0.5	2.7ghi	2.3d-g	2.5efg	2.3de	2.3c	2.3de	1.3e	1.3e	1.3f
”	1.0	4.0d-h	2.2efg	3.1def	6.3bc	3.2c	4.8c	2.3cde	1.7e	2.0f
”	1.5	6.0a-e	7.0ab	6.5bc	7.8ab	6.3b	7.1b	6.0ab	5.3cd	5.7de
”	2.0	7.3abc	6.0bc	6.7ab	8.3ab	5.7b	7.0b	7.3ab	4.3d	5.8cde
”	2.5	8.7a	8.3a	8.5a	9.7a	8.8a	9.3a	9.0a	7.3bc	8.2ab
Pendimethalin	0.5	3.2f-i	2.3d-g	2.8efg	2.8de	2.0c	2.4de	1.3e	1.0a	1.2f
”	1.0	5.7b-f	3.8def	4.8cd	7.0abc	6.5b	6.8b	4.7bcd	5.0d	4.8e
”	1.5	6.7a-d	3.0d-g	4.8bcd	8.0ab	8.5a	8.3ab	6.6ab	8.0ab	7.3bcd
”	2.0	7.7abc	4.3cd	6.0bc	9.0ab	9.5a	9.3a	9.0a	9.8a	9.4a
”	2.5	8.3ab	4.0cde	6.2bc	9.3a	9.8a	9.6a	5.3bc	9.8a	7.6abc
Weeding at 3 and 6 WAS		1.0i	1.3g	1.2fg	1.0e	1.5c	1.3e	1.0e	1.0e	1.0f
Weedy check		1.0i	1.7g	1.3fg	1.0e	1.7c	1.3e	1.0e	1.0e	1.0f
SE (±		1.35	0.79	0.93	1.4	0.69	0.81	1.58	1.04	0.94

1 = On a scale of 1 to 10 where 1 = no crop injury and 10 = complete crop kill; 2 = Weeks after sowing; 3 = Combined mean for two years data; 4 = Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability according to Duncan's Multiple Range Test (DMRT).

led to the uptake of more of the desorbed herbicide at higher concentration in a sandy loam soil. Diuron at 1.5 to 2.5 kg a.i./ha and pendimethalin at 1.5 to 2.5 kg a.i./ha were significantly (P<0.01) phytotoxic to sesame in both years and combined means at 2,4 and 8 WAS (Table 1). This is similar to the findings of Grichar et al. (2001) who reported the phytotoxicity of pendimethalin at 1.2 kg a.i./ha which reduced sesame plant stands by 8 to 98% compared to untreated check.

Table 2 shows that the pre-emergence herbicides evaluated had significant effect on crop vigour of sesame in both years and the combined means. Generally, crop vigour decreased with increase in herbicide rates for all the herbicides. This could be due to increase in phytotoxicity effect with increase in herbicide rate. In both years and their combined means at 6 WAS, all the rates of butachlor, all the rates metolachlor except at 2.0 and 2.5 kg a.i./ha in 2006 produced significantly vigorous crops which were comparable to hoe-weeding. However, diuron and pendimethalin at 1.0 to 2.5 kg a.i./ha produced significantly the least vigorous crops. At 9 WAS, however diuron and pendimethalin at 1.0 and 1.5 kg a.i./ha in 2006, produced vigorous crops comparable to hoe-weeding. The depressive effect of pendimethalin and diuron at higher rates had on the crop was due to the phytotoxic effect of these herbicides. However, at 9 WAS in 2006, diuron and pendimethalin at 1.0 and 1.5 kg a.i./ha produced vigorous crops because the crops recovered from the depressive effect of these herbicides. While metolachlor at 2.0 kg a.i./ha produced the most vigorous crop in 2007 at 6 WAS, metolachlor at 1.0 and 1.5 kg a.i./ha produced the most vigorous crop in 2007 at 9 WAS.

Plant height of sesame was significantly affected by

Table 2. Effect of pre-emergence herbicides on crop vigour at 6 and 9 WAS and plant height (cm) at 8 WAS and at harvest in Maiduguri, 2006 and 2007.

Treatment	**Rates (kg a:i./ha)**	**Crop vigour**						**Plant height**					
		6 WAS[2]			**9WAS**			**8 WAS**			**Harvest**		
		2006	**2007**	**Mean[3]**	**2006**	**2007**	**Means**	**2006**	**2007**	**Mean**	**2006**	**2007**	**Mean**
Butachlor	0.5	7.7ab[4]	7.7abc	7.7ab	8.5a	7.3abc	7.9ab	79.6a-d	91.1a-e	85.4abc	122.0abc	134.5c-f	128.2abc
”	1.0	6.7a-d	8.2ab	7.4ab	8.0ab	8.0a	8.0ab	83.0ab	107.7a	95.4a	125.0ab	139.3b-f	132.2abc
”	1.5	7.7ab	7.5abc	7.6ab	8.2ab	7.2abc	7.2abc	80.4a-d	87.1b-f	83.8abc	135.6a	144.5a-d	140.0a-d
”	2.0	7.7ab	6.8abc	7.3ab	7.7abc	7.0a-d	7.3a-d	83.8a-d	98.1a-d	87.9abc	127.2ab	144.0a-e	135.6abc
”	2.5	7.0abc	7.3abc	7.2ab	7.5abc	7.0a-d	7.3a-e	77.3a-d	82.8def	80.1abc	120.1abc	141.9a-f	131.0abc
Metolachlor	0.5	7.7ab	8.0ab	7.8a	7.8ab	7.5abc	7.7abc	76.9a-d	102.0ab	89.5ab	111.4bc	133.1c-f	122.3cd
”	1.0	6.7a-d	8.2ab	7.4ab	7.5ab	8.0a	7.7abc	73.5a-d	104.8ab	89.1ab	124.0abc	141.2a-f	132.6abc
”	1.5	6.3a-e	8.0ab	7.2ab	7.8ab	8.0a	7.9ab	81.7abc	105.7ab	93.7ab	128.7ab	146.1a-d	137.4abc
”	2.0	5.3bf	8.3a	6.8abc	7.8ab	7.7ab	7.8abc	62.8a-g	99.1a-d	81.0abc	129.5ab	146.0a-d	137.8abc
”	2.5	4.0efg	7.0abc	5.5cd	7.0abc	7.0a-d	7.0a-e	62.2a-f	92.1a-e	79.2abc	119.3abc	126.5f	122.9cd
Diuron	0.5	6.7a-d	6.8abc	6,8abc	8.1ab	6.8a-d	7.5abc	70.2a-e	83.5c-f	76.8bcd	129.6ab	139.4b-f	134.5abc
”	1.0	4.3d-g	4.3d	4.3de	7.3abc	6.3c-f	6.8a-e	52.1c-g	70.1fg	61.1de	118.7abc	144.5a-d	131.6abc
”	1.5	2.8fgh	3.0de	2.9ef	7.0abc	5.5efg	6.3b-e	41.1e-h	57.1gh	49.1ef	116.3bc	151.7ab	134.0abc
”	2.0	3.0fgh	3.3de	3.2ef	5.2c	5.8d-g	5.5ef	36.9fgh	41.9hi	39.4fg	118.7abc	156.8a	137.8abc
”	2.5	1.8gh	2.0e	1.9fg	5.8bc	5.3fg	5.6def	34.9gh	34.7i	34.8fg	105.0c	141.5a-f	123.2bcd
Pendimethalin	0.5	6.0a-e	6.3c	6.2bc	8.0ab	6.7b-e	7.3a-d	64.8a-g	77.1ef	71.0cd	119.07abc	139.7b-f	129.4abc
”	1.0	4.7c-f	2.3e	3.5ef	7.5abc	4.7gh	6.1cde	54.2b-g	43.8hi	49.0ef	116.4bc	127.1ef	121.8cd
”	1.5	3.0fgh	1.8ef	2.4f	7.5abc	3.7h	5.6def	50.4d-g	30.6i	40.5fg	115.4bc	104.9g	110.2de
”	2.0	1.0h	0.3f	0.7g	7.2abc	0.7i	3.9f	36.6fgh	10.9j	23.8gh	113.3bc	93.0g	102.2e
”	2.5	0.7h	0.3f	0.5g	2.3d	0.7i	1.5g	16.2h	9.4j	12.8h	36.1d	26.4g	31.2f
Weeding at 3 and 6 WAS		8.3a	7.3abc	7.8a	9.0a	8.0a	8.5a	85.6a	99.5a-d	92.6ab	137.1a	146.8abc	142.0a
Weedy check		7.0abc	6.7bc	6.8abc	6.8abc	7.3abc	7.1a-e	76.5a-d	75.9efg	76.2bcd	113.6bc	129.6def	121.6cd
SE (±		1.23	0.37	0.80	1.32	0.58	0.90	10.54	12.04	9.53	14.50	12.58	12.22

1 = On a scale of 1-10 where 1 = completely retarded growth and 10 =Most vigorous plant growth. 2 = Weeks after sowing; 3 = Combined means for two years data. 4 = Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability according to Duncan’s Multiple Range Test (DMRT).

pre-emergence herbicides at 8 WAS and at harvest. Generally, plant height decreased with increase in the herbicide rate irrespective of herbicide (Table 2). This could be due to the phytotoxic effect of the herbicides at higher rates, which might have caused a depressive effect on crop growth. All the treatments produced significantly tall plants which were comparable to hoe-weeding in 2006 at 8 WAS, except diuron and pendimethalin at 1.0 to 2.5 kg a.i./ha which produced significantly the shortest plants. In 2007 and combined means all the rates of pendimethalin and diuron and the weedy check produced significantly the shortest plants (Table 2). The phytotoxic effect of diuron and pendimethalin and the inability of pendimethalin to control weeds effectively suppressed crop growth resulting in significantly short plants. This is similar to the findings of Ndarubu (1997), that the application of a mixture of simazine+ametryn at 0.75+0.75 kg a.i./ha and 1.0+1.0 kg a.i./ha resulted in stunted crop growth probably as a result of the phytoxic effect of this herbicide at the stated rates on sesame. At harvest, similar trend as at 8 WAS was observed; however, diuron at 1.0 and 2.0 kg a.i./ha in both trials and combined means and diuron at 1.0 to 2.5 kg a.i./ha in 2007 produced plant height comparable to the hoe-weeding. This showed that sesame plants were able to overcome the phytotoxicity effect of diuron at the above rates with time, possibly as the herbicide became degraded or leached out (Ashton and Klingman, 1975). Also, diuron at 1.5 and 2.0 kg a.i./ha produced the tallest plants in 2007 at harvest, as a result of the low plant population and the significantly low weed infestation, under this treatments which minimized weed competition for growth resources and allowed the few plants to take up enough moisture and nutrients for better growth.

Among the herbicides, while butachlor at 1.0 and metolachlor at 1.5 kg a.i./ha produced the tallest plants in both years and the combined means at 8 WAS, butachlor at 1.5 kg a.i./ha and metolachlor at 2.0 kg a.i./ha produced the tallest plants in 2006 and combined means at harvest. The pre-emergence herbicides evaluated significantly ($P<0.01$) affected weed cover scores in both trials at 3, 6 WAS and at harvest (Table 3). All the herbicide treatments resulted in significantly lower weed cover score compared to the weedy check in both years and their combined means at 3, 6 WAS and at harvest, except pendimethalin at 0.5 to 2.0 kg a.i./ha in 2007 at 6 WAS and at 1.0 to 2.5 kg a.i./ha in both years and combined means at harvest which gave poor weed control comparable to unweeded check (Table 3). The progressive loss of efficacy of pendimethalin herbicide over time resulting in poor control of weeds could be due to the volatile nature of dinitroanaline herbicides of which pendimenthalin is a member (Akobundu, 1987; Rao, 2000) and the faster degradation of the herbicide through the action of microorganisms in the soil (Zimdahl and Gwynm, 1977). Compared to other treatments at 3 WAS, application of diuron at 1.5 to 2.5 kg a.i./ha consistently resulted in significantly the least weed cover score which is comparable with diuron at lower rate and pendimethalin at 1.5 to 2.5 kg, a.i/ha in both years and combined means, metolachlor at 1.5 kg a.i./ha in 2006, butachlor at 1.5 to 2.5 kg a.i./ha and metolachlor at 2.0 and 2.5 kg a.i./ha in 2007. The ability of diuron to provide season-long effective weed control, could be due to the persistence of this herbicide in the soil and the fact that it is more effective on broad- leaved weeds than grasses (Akobundu, 1987) which were predominant at the site. Generally, at 3, 6 WAS, the weed cover scores were higher in 2007 compared with 2006. This could be due to higher amount of rainfall received in 2007 which might have solubilised the herbicides resulting to leaching. Similarly, weed cover score were higher in 2007 and combined means at 6 WAS compared with that in 2007 and combined means at harvest, possibly as a result of the ability of the sesame crop to suppress and smother weeds due to early canopy closure which shaded off the weeds, depriving them of growth factors of sunlight, moisture and mineral nutrients (Imoloame, 2004). Table 4 shows that pre-emergence herbicides significantly ($P<0.01$) affected weed dry matter in both years and combined means at 3, 6 WAS and at harvest.

All the herbicide treatments reduced significantly the weed dry matter in both years and their combined means compared to the weedy check at 3, 6 WAS and at harvest, except metolachlor at 0.5 and 1.0 kg a.i./ha and pendimethalin at 2.5 kg a.i./ha at 6 WAS in 2006 and 2007, butachlor at 1.5 kg a.i./ha, diuron at 2.0 kg a.i./ha and pendimethalin at 0.5, 1.0, 1.5 and 2.5 kg a.i./ha in 2007 and combined means, which produced high and comparable weed dry matter to the weedy check. In the combined means also at 6 WAS; all the herbicide treatments produced lower weed dry matter except metolachlor at 0.5 and 1.0 kg a.i./ha, pendemethalin at 0.5, 1.0, 1.5 and 2.5 kg a.i./ha which were comparable to the weedy check. At harvest, all the herbicide rates did not differ significantly from the weedy check in 2006. All the rest of the herbicide treatments in 2007 and the combined means significantly produced lower weed dry matter compared to the weedy check but comparable to hoe-weeded control. The effectiveness of metolachlor and diuron at all rates except at 2.0 kg a.i./ha in 2007 at harvest is an indication that, these herbicides can be used in weed control alternative to two hoe-weedings at 3 and 6 WAS. This agrees with the findings of Ibrahim et al. (2008) that pre- emergence application of diuron at 0.960 kg a.i./ha gave excellent broad-leaved weed control in sesame in Egypt. It also agrees with Grichar et al. (2001) who reported that metolachlor among all the herbicides evaluated, provided the best control of weeds and least sesame injury.

The pre- emergence herbicides significantly affected the number of capsules/plant of sesame (Table 5). In 2006, metolachlor at 2.0 and 2.5 kg a.i./ha produced

Table 3. Effect of pre-emergence herbicides on weed cover score at 3, 6 WAS and at harvest in Maiduguri, 2006 and 2007.

Treatment	Rates (kg a.i./ha)	Weed cover score[1]								
		3WAS[2]			6WAS			Harvest		
		2006	2007	Mean[3]	2006	2007	Mean	2006	2007	Mean
Butachlor	0.5	3.3cd[4]	6.0cd	4.7bc	4.7bc	7.0a-d	5.8b-f	4.8d-h	3.7c	4.3c-f
”	1.0	3.3cd	4.7d-g	4.0bc	4.5bc	5.7b-e	5.1b-f	5.5d-g	2.8cde	4.2c-f
”	1.5	3.0cde	3.7e-i	3.3c-f	3.8cde	5.8b-e	4.8c-f	4.7d-i	2.5c-f	3.6c-h
”	2.0	3.0cde	3.7e-i	3.3c-f	3.7cde	6.3a-e	5.0b-f	3.3f-j	2.3def	2.8d-h
”	2.5	3.7cd	3.7e.i	3.7cde	4.7bc	5.7b-e	5.2b-f	6.0def	2.2ef	4.1c-g
Metolachlor	0.5	4.3bc	5.0def	4.7bc	5.0bc	7.5abc	6.3b-e	5.7d-g	2.5c-f	4.1c-g
”	1.0	3.0cde	5.3cde	4.2bcd	3.7cde	5.5b-f	4.6d-f	6.0def	2.7c-f	4.3cde
”	1.5	2.7c-f	4.0d-h	3.3c-f	3.8bcd	5.0c-f	4.4efg	5.5d-g	1.8ef	3.7c-h
”	2.0	3.3cd	3.0f-j	3.2c-g	4.2bcd	6.0b-e	5.1b-f	6.7cde	2.5c-f	4.6cde
”	2.5	3.7cd	3.2f-j	3.4cde	4.0bcd	4.0efg	4.0fg	7.0bcd	2.7c-f	4.8cd
Diuron	0.5	2.6c-f	2.7g-j	2.3d-h	4.3bc	4.2d-g	4.3efg	3.0g-j	2.3def	2.7d-h
”	1.0	1.3ef	1.8ij	1.6gh	2.0def	2.7fg	2.3gh	3.8e-j	2.0ef	2.9d-h
”	1.5	1.3ef	1.7ij	1.5h	1.5ef	2.0g	1.8h	2.1hj	2.2ef	2.1fgh
”	2.0	1.0f	1.7ij	1.3h	1.2f	1.8g	1.5h	1.8ij	2.0ef	1.9gh
”	2.5	1.0f	1.5j	1.3h	1.1f	1.8g	1.5h	3.2f-j	1.8ef	2.5e-h
Pendimenthalin	0.5	3.3cd	7.3bc	5.3b	4.3bc	9.0a	6.7bcd	7.5a-d	3.5cd	5.5bc
”	1.0	3.0cde	3.7e-i	3.3c-f	5.3bc	8.3ab	6.8bc	9.3abc	8.8a	9.1a
”	1.5	2.0def	2.8g-j	2.4e-h	6.0b	7.5abc	6.8bc	9.5abc	8.0a	8.8a
“	2.0	2.0def	3.5e-j	2.8d-h	6.0b	8.0ab	7.0ab	9.8ab	7.8a	8.8a
”	2.5	1.3ef	2.2hij	1.8fgh	5.0bc	4.7c-g	4.8c-f	9.8ab	8.0a	8.9a
Weeding at 3 and 6WAS		6.0ab	9.7a	7.8a	2.0def	6.7a-e	4.4efg	1.4j	1.5f	1.5h
Weedy check		6.3a	9.0ab	7.7a	9.7a	8.3ab	9.0a	10.0a	5.3b	7.7ab
SE (±)		0.98	1.07	0.83	1.11	1.41	1.06	1.44	0.65	1.10

1 = On a scale of 1-10 where 1 = no weed cover and 10 = complete weed cover; 2 = Weeks after sowing; 3= Combined mean for two years data; 4 = Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability according to Duncan's Multiple Range Test (DMRT).

significantly the highest number of capsules/plants which were comparable with butachlor at 2.0 kg a.i./ha, diuron at 1.5 and 2.5 kg a.i./ha, pendimethalin at 0.5 and 1.5 kg a.i./ha but significantly higher than the rest of the treatments. This could be due to the phytotoxic effect which the stated herbicide rates had on sesame crop which reduced the plant population and reduced the inter and intra plant competition leading to the utilization of more growth factors for better growth. However, in 2007 and combined means, pendimethalin at 2.0 and 2.5 kg a.i./ha produced significantly, the least number of capsules/plant probably due to the phytotoxicity of this herbicide at the aforementioned rates and its inability to effectively control weeds which competed for nutrients, moisture and other growth resources with sesame resulting in poor performance.

Grain yield was significantly affected by pre-emergence herbicides in both years and combined means (Table 5). In 2006, butachlor at 2.0 kg a.i./ha and diuron at 1.0 and 1.5 kg a.i./ha produced significantly the highest sesame yield which was comparable to hoe- weeded control and other treatments except butachlor at 0.5, 1.0 and 2.5 kg a.i./ha, metolachlor at 0.5, 2.0 and 2.5 kg a.i./ha, diuron at 2.0 and 2.5 kg a.i./ha, pendimethalin at all the rates and weedy check which produced significantly the lowest grain yield. However, in 2007 and combined means, metolachlor at 1.5 kg a.i./ha produced significantly, the highest yield but comparable with hoe-weeded control and other herbicide treatments except butachlor at 0.5 kg a.i./ha, metolachlor at 0.5, 2.0 and 2.5 kg a.i./ha, diuron at 0.5, 1.5, 2.0 and 2.5 kg a.i./ha, pendimethalin at 1.0-2.5 kg a.i./ha and weedy check which produced significantly, the lowest grain yield (Table 5).

Butachlor and diuron at 2.0 and 1.0 kg a.i./ha, respectively produced significantly, the highest yield; although, not significantly different from some other herbicide treatments and hoe-weeded control in 2006, probably due to the low phytotoxicity of butachlor at

Table 4. Effect of pre-emergence herbicides on weed dry matter in sesame at 3, 6 WAS and at harvest in Maiduguri, 2006 and 2007.

Treatment	Rates (kg a.i./ha)	Weed dry matter (kg/ha)								
		3 WAS[1]			6 WAS			Harvest		
		2006	2007	Mean[2]	2006	2007	Mean	2006	2007	Mean
Butachlor	0.5	7.1c[3]	6.2cd	6.6bc	34.1b-g	26.2bcd	30.1b-e	21.9a	80.0bcd	51.0cde
”	1.0	20.2bc	5.0cd	12..6bc	15.3e-h	31.8bcd	23.5c-f	28.1a	42.2d	35.7cde
”	1.5	15.9c	5.2cd	10.5bc	17.1d-h	35.0a-d	26.1c-f	35.4a	67.3cd	51.4b-e
”	2.0	21.2bc	9.7bc	15.4bc	28.6b-h	25.8bcd	27.2c-f	35..0a	50.4d	42.7cde
”	2.5	14.5c	1.8cd	8.1bc	22.9c-h	22.3cd	22.6c-f	27.7a	103.5bcd	65.3b-e
Metolachlor	0.5	42.6b	5.0cd	23.8b	48.9a-d	33.7bcd	41.3abc	42.7a	96.1bcd	69.4b-e
”	1.0	11.6c	4.9cd	8.1bc	58.2ab	37.7abc	48.0ab	65.6a	56.3d	61.0b-e
”	1.5	3.9c	6.2cd	5.1c	31.8b-h	26.0bcd	28.9b-f	26.1a	40.2d	33.1cde
”	2.0	9.5c	2.5cd	6.0c	14.2e-h	28.7bcd	21.4c-f	65.6a	56.3d	61.0b-e
”	2.5	11.5c	4.4cd	8.0bc	21.4c-h	18.0cd	19.7def	36.0a	28.2d	32.5cde
Diuron	0.5	11.1c	2.4cd	6.7bc	16.3e-h	21.6cd	18.9def	41.7a	32.7d	37.3cde
”	1.0	5.1c	3.6cd	4.4c	9.6fgh	26.4bcd	18.0def	44.8a	29.7d	37.3cde
”	1.5	13.0c	3.9cd	8.4bc	6.3fgh	16.5cd	11.4ef	15.6a	22.7d	19.2de
”	2.0	4.7c	2.4cd	3.6c	1.6h	34.8a-d	18.2def	17.7a	156.5ab	87.1abc
”	2.5	1.0c	0.6d	0.8c	2.6gh	15.2d	8.9f	33.3a	41.2d	37.3cde
Pendimethalin	0.5	17.1c	6.8cd	11.9bc	24.0c-h	49.9ab	35.4a-d	41.5a	98.2bcd	69.8a-e
”	1.0	18.2c	4.9cd	11.6bc	44.5a-e	36.5a-d	40.5abc	32.3a	225.2a	128.7a
”	1.5	9.1c	3.3cd	6.2bc	36.9b-f	44.8ab	40.9abc	67.9a	75.6bcd	71.7a-d
”	2.0	7.5c	6.4cd	7.0bc	30.2b-h	29.1bcd	29.7bc	59.4a	72.2bcd	65.8b-e
”	2.5	7.1c	2.4cd	4.7c	71.3a	35.3a-d	53.3a	74.0a	39.4d	56.7b-e
Weeding at 3 and 6WAS		16.6c	15.5ab	16.1bc	24.3c-h	46.0ab	35.2a-d	6.7a	17.6d	12.1e
Weedy check		90.6a	22.4a	56.5a	52.7abc	56.3a	54.5a	72.9a	147.7abc	110.3ab
SE (±)		11.17	4.13	8.89	15.8	10.85	10.10	21.96	43.4	29.92

1 = Weeks after sowing; 2 = Combined means for two years data; 3 = Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability according to Duncan’s Multiple Range Test (DMRT).

Table 5. Effect of pre-emergence herbicides on number of capsules at 12WAS, and grain yield of sesame in Maiduguri in 2006 and 2007.

Treatment	Rates	Number of capsules/plant 12 WAS[1]			Grain yield (kg/ha)		
	(kg a.i./ha)	2006	2007	Mean[2]	2006	2007	Mean
Batachlor	0.5	35.8cde[3]	64.1a	49.9abc	105.2f-i	210.9def	158.0ghi
”	1.0	30.7de	43.9a-d	37.3b-e	128.0efg	392.7abc	260.4c-g
”	1.5	31.8de	32.8bcd	32.3cde	295.9ab	443.4ab	369.6abc
”	2.0	43.9a-d	48.9a-d	46.4a-e	330.4a	464.2ab	397.3ab
”	2.5	39.5cd	29.1d	34.3cde	182.7def	410.3ab	292.0b-f
Metolachlor	0.5	40.3cd	57.0ab	48.7a-d	202.7b-f	311.8b-e	257.3c-g
”	1.0	40.2cd	36.5bcd	38.4a-e	263.1a-d	456.4ab	359.8abc
”	1.5	34.1cde	54.4abc	44.3a-e	286.6ab	529.7a	408.2ab
”	2.0	65.5a	46.3a-d	55.9a	195.2c-f	225.2c-f	210.2e-h
”	2.5	65.2ab	45.3a-d	55.3ab	189.4c-f	189.6ef	189.5fgh
Duiron	0.5	38.3cd	45.1a-d	41.7a-e	239.6a-d	227.0c-f	233.3d-g
”	1.0	39.8cd	57.1ab	48.5a-d	330.4a	374.1abc	352.3a-d
”	1.5	42.3a-d	47.1a-d	44.7a- e	317.5a	302.1b-e	309.8b-f
”	2.0	28.9de	29.7cd	29.3ef	68.7ghi	207.6def	138.1ghi
”	2.5	41.5a-d	48.0a-d	44.8a- e	115.0fgh	201.1def	158.1ghi
Pendimethalin	0.5	43.5a-d	25.8d	34.7cde	214.4b-e	430.0ab	322.2a-e
”	1.0	31.1de	27.5d	29.3ef	110.0fgh	64.1fg	87.1hij
”	1.5	57.5abc	28.6d	43.0a-e	66.0ghi	7.9g	36.9ij
”	2.0	25.0de	1.0e	13.0fg	19.9hi	1.0g	10.5j
”	2.5	11.7e	1.0e	6.4g	12.1i	1.0g	6.6j
Weeding at 3 and 6WAS		40.7bcd	43.1a-d	41.9a-e	331.4a	543.7a	437.58a
Weedy check		23.9de	38.8bcd	31.4de	197.3c-f	198.5ef	197.9e-h
SE (±)		12.18	12.28	9.21	1.36	86.14	62.92

1 = Weeks after sowing; 2 = Combined means for two years data; 3 = Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability according to Duncan's Multiple Range Test (DMRT).

2.0 kg a.i./ha and its ability to control weeds effectively throughout the season, which prevented weed competition for growth resources leading to better growth and high yield. Similarly, diuron at 1.0 kg a.i./ha significantly produced high yield, probably as a result of its low phytotoxicity on the crop at 8 WAS, coupled with its ability to significantly reduce both weed cover and weed dry matter throughout the season, preventing weed competition and allowing the crop to utilize more growth resources resulting in higher yield. However, in 2007 and the combined means, metolachlor at 1.5 kg a.i./ha, butachlor at 2.0 and 1.5 kg a.i./ha produced significantly, the highest yield which was comparable to hoe-weeded control and other herbicide treatments, while metolachlor at 2.0 and 2.5 kg a.i./ha, diuron at 1.5 to 2.5 kg a.i./ha, pendimethalin at 1.0 to 2.5 kg a.i./ha and weedy check produced significantly the lowest yield. The significantly higher yields produced by the aforementioned herbicides at the stated respective rates could be due to their little or no phytotoxic effect on sesame, coupled with its high selectivity to weeds. This resulted in better uptake of plant nutrients and moisture which resulted in better growth and higher yield. This is similar to the findings of Grichar et al. (2001) who reported that metolachlor at 3.36 kg a.i./ha increased yield up to 80% over the untreated check. Diuron at 1.5 to 2.5 kg a.i./ha and pendemethalin at 1.0 to 2.5 kg a.i./ha produced significantly low yields due to their phytotoxic effect on sesame.

From this research, it can be recommended that metolachlor at 1.5 kg a.i./ha and butachlor at 2.0 kg a.i./ha, were the best among the herbicides and can be used as an alternative to two-hoe weedings for effective weed control and higher grain yield in sesame in the

Sudan Savanna Zone of Nigeria.

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