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Full Length Research Paper

Economic assessment of some pre-emergence herbicides in the production of millet-cowpea intercrop in the Sudan Savanna Zone of Nigeria

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Field trials were conducted in 1997 and 1998 cropping seasons at the University of Maiduguri Teaching and Research Farm located in Maduguri (11° 50'N; 13° 10'E). The aim was to carry out an economic analysis of the use of some pre-emergence herbicides for the production of millet-cowpea intercrop. The experiment consisted of 14 treatments which included four different herbicides at three rates each, namely, metolachlor + metobromuron (Galex), metolachlor (Dual), atrazine, and metolachlor + atrazine (Primextra) applied at the rates of 0.5, 1.0 and 1.5 kg a.i./ha, weeding at 3 and 6 weeks after sowing (WAS) and a control plot (weedy check). The treatments were laid out in randomized complete block design (RCBD) replicated three times. Results showed that metolachlor + atrazine (Primextra) at 1.0 kg a.i./ha significantly increased individual and combined yields of cowpea and millet in the two years of study, which were comparable to hoe weeding in two years of study. Also metolachlor + atrazine at 1.0 kg a.i./ha was found to be more profitable, economical and beneficial than two hoe weeding and the other treatments in the two years of study. Therefore for higher yield and economic returns, metolachlor + atrazine (Primextra) at 1.0 kg a.i./ha is recommended to the farmers as alternative to two hoe weeding in the Sudan Savanna Zone of Nigeria.

Key words: Economic assessment, pre-emergence herbicides, millet-cowpea intercrop, Sudan Savanna, Nigeria.

INTRODUCTION

Intercropping a system of growing two or more crops simultaneously on the same piece of land in a manner that will permit the interaction of component crops in spatial and temporal context (Steiner, 1984), is commonly practiced in the savanna zone of Nigeria. Cereals that is, millet, sorghum, maize etc. and legumes that is, cowpea, groundnut etc. are commonly grown in intercropping systems. Millet-cowpea intercrop is a very common farming system among small scale farmers of the Sudan savanna zone of Nigeria. Millet is usually the main crop and cowpea the intercrop. The farmers practice intercropping because of its beneficial effects which include insurance against complete crop failure, less labour demand and increased total crop yield per hectare (Okigbo, 1979).

In Africa, weeds have caused crop losses due to uncontrolled weed growth. In the Guinea and Sudan savannas, yield losses of 44 to 53% were reported for millet, while in cowpea losses of 30 to 61% in southern Guinea savanna, and 34 to 55% in northern Guinea and Sudan savannas respectively were reported as a result of weed infestation. (Lagoke, 1983).

Hoe-weeding is a common weed control practiced by farmers in the Sudan savanna, where they weed two or three times for millet-cowpea intercrop (Shetty, 1978; Joshua and Gworgwor, 2000). However, this is labour intensive and time consuming and can lead to yield loss due to lack of timely weed control or management.

Chemical weed control has revolutionized farmers approach to weed control in the world. It is one of the recent developments in crop production and it has responded to the food production needs of all food-

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sufficient countries of the world and will play major roles in the tropics as this region moves from food deficiency to surplus food production (Akobundu, 1987). The possibility of chemical weed control in mixed cropping system had been identified by Akobundu (1987) and Joshua and Gworgwor (2001). 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; Ogungbile et al., 1982; Sinha et al., 1982; Okereke, 1983; Usoroh, 1983; Sinha and Lagoke 1984; Ogunbile and Lagoke, 1986; Adigun et al., 1993; Joshua and Gworgwor, 2002; Imoloame, 2009). Account taken of the importance of intercropping and the advantages of herbicides as a cost-effective method of weed control, the objective of this paper is to carry out an assessment of some herbicides to find out the one that will give higher yield and economic returns.

MATERIALS AND METHODS

Field trials were conducted during the 1997 and 1998 cropping seasons (June to October) on the Teaching and Research Farm of the Department of Crop Production, Faculty of Agriculture, University of Maiduguri (latitude 11° 51'N; 13° 15'E) located in the Sudan Savanna Zone of Nigeria. The soil type of the experimental site was sandy loam with high proportion of sand (80.37%) and low proportion of silt and clay, (44.07%) and (5.56%) respectively. The soil also had low organic carbon (0.67%) and a pH of 6.87. The area had been cropped with millet, sorghum and groundnut in the previous years. The experimental site, which measured 1, 512 m^2 was harrowed, leveled properly using a hand hoe, and marked out. The plot size was 4.5 × 6.0 m leaving a distance of 2 and 0.5 m between replications and plots respectively. Compound fertilizer, NPK 20:10:10 was applied to each plot to provide 60 kg N, 30 kg P and 30 kg K. The full rate of P was applied before sowing and incorporated into the soil with a hand rake. The application of N, however, was applied in two equal split doses. The first dose was applied before planting as starter dose by broadcast method and the second dose was applied at 6 WAS by band placement about 15 cm away from the millet stand.

The experiment consisted of 14 treatments which included 4 different pre-emergence herbicides at three (3) different rates viz: metolachlor (2-chloro-N{2-ethyl-methyl-phenyl-N} 2-methoxyl-methyl acetamide) + metobromuron (4-bromophenyl-N-methoxyl-N-methl urea) (Galex), metolachlor (Dual), atrazine (2-chlro-4 (ethylamino-6-isopromethylamino)-S-triazine) and metolachlor+atrazine (Primextra) applied at the rates of 0.5, 1.0 and 1.5 kg a.i./ha, weeding at 3 and 6 WAS and a control plot. The treatments were laid out in randomized complete block design (RCBD) with three (3) replications. The millet variety Gwagwa and cowpea variety Borno Brown were used. Millet was sown on 17 and 11, July, 1997 and 1998 respectively at a spacing of 0.75 × 0.3 m, while cowpea was sown at a spacing of 1.0 × 0.75 m three weeks after sowing millet. The millet was thinned to three plants per stand three weeks after sowing (WAS). All the herbicides were applied a day after planting pre-emergence to millet with a CP15 knapsack sprayer using a green nozzle calibrated to deliver 220 L/ha spray volume at a pressure of 1.5 kg/cm^2. Harvesting of millet and cowpea was carried out on a net plot of 16 m^2 on November, 7th and 14th respectively in 1997, while in 1998, harvesting of millet and cowpea was done on 14 and 21 November respectively. Harvesting of millet was done when the leaves turned yellow and the seeds were well formed. The heads were cut with sharp knives and spread on a mat for four weeks to allow the seeds to be well dried. This was followed by threshing and winnowing to separate the seeds from the chaff. On the other hand cowpea was harvested when majority of the pods turned yellow. The harvested pods were spread on the mat for four weeks to allow the pods to be well dried before threshing it. This was followed by winnowing to separate the seeds from the chaff.

Information on the cost of all the cultural practices from land preparation to harvesting and processing was collected from Borno State Agricultural Development Programme (BOSADP), Maiduguri, an agency responsible for extension services in Borno State, Nigeria. The current price of a big mudu measure was found out from the open market to calculate the selling price or income. The economic assessment was done for different rates compared with hoe-weeded control and weedy check to find out the most cost-effective or profitable rate for the production of millet-cowpea intercrop. The following methods (Joshua and Gworgwor, 2001) were used to produce the cost benefit ratio:

Cost of production

This includes the cost of all the cultural practices, seeds, herbicides and transportation per net plot (0.0048 ha) and later converted to per hectare.

Selling price (Income)

Yields obtained from the experiments were sold at the prevailing market prices of cowpea and millet in Maiduguri.

Profit/ loss

This was determined by subtracting the total cost of production from the income as represented by this equation.

Profit/loss = I- CP, where SP = Income (selling price) and TCP = Total cost of production.

$$\text{Cost benefit ratio} = \frac{TCP}{I}$$

where TCP is total cost of production, I, Income (selling price).

RESULTS AND DISCUSSION

Monthly rainfall and temperature figures

Table 1 shows the monthly rainfall and temperature figures during the two years of the study. It shows that 1998 recorded a higher amount of rainfall than 1997. In both years, the rainfall was fairly distributed throughout the rainy season from July to October. Generally, better crop growth and yield were observed in 1998 compared to 1997. This could have been as a result of the higher total rainfall of that year. Also, the maximum temperatures in both years of study were favourable for the rapid growth of millet and cowpea.

Table 1. Monthly rainfall and temperature figures for 1997 and 1998 at Maiduguri, Nigeria.

Month	Rainfall (mm)		Temperature (°C)			
	1997	1998	1997		1998	
			Maximum	Minimum	Maximum	Minimum
January	0.0	0.0	NIL	NIL	31.6	11.9
February	0.0	0.0	NIL	NIL	35.5	15.2
March	0.0	0.0	NIL	NIL	36.0	17.3
April	19.7	1.5	39.3	25.1	41.6	23.7
May	30.6	24.7	38.2	24.2	41.7	28.1
June	14.3	59.3	32.7	24.6	37.4	25.9
July	137.7	179.0	32.8	23.5	32.9	23.9
August	130.0	268.6	32.1	22.9	30.9	22.9
September	160.3	157.4	35.1	22.9	32.8	23.1
October	20.6	1.2	37.3	22.7	36.5	22.3
November	0.0	0.0	NIL	NIL	36.6	17.3
December	0.0	0.0	NIL	NIL	33.1	13.7
Total	513.20	691.7	247.50	166.9	427.1	245.3
Average	73.3	98.8	35.40	23.8	35.6	20.4

Effect of some pre-emergence herbicides on weed infestation agronomic characters of millet in millet-cowpea intercrop

Table 2, shows the effect of pre-emergence herbicides on weed cover scores, plant height, 1000-seed weight and grain yield of millet. It shows that atrazine and metolachlor + atrazine (Primextra) at 1.0 and 1.5 kg a.i./ha significantly reduced weed cover which was comparable to hoe-weeding in the two years of study. However, all the rates of metolachlor, metolachlor + metobromuron (Galex) and control plot produced higher and comparable weed cover with the control plot. The significant reduction of weeds by atrazine and Primextra for the rates given previously could be as a result of their efficacy to control broad spectrum weeds effectively as reported by Joshua (2001). All the treatments produced comparable tall plants at 10 WAS in the two years of study, except atrazine and metolachlor at 1.5 kg a.i./ha in 1997 and 1998 respectively which significantly depressed plant height (Table 2). The suppressed plant height observed under atrazine for the rates given previously could be due to the phytotoxicity of the herbicide, while the suppressed plant height resulting from the application of metolachlor for the rates given previously could be due to its inability to control weeds which led to weed competition, resulting in poor crop growth. Pre-emergence herbicides had significant effect on both 1000-seed weight and grain yield of millet (Table 2). Hoe weeding at 3 and 6 WAS produced significantly heavier seeds of millet in both years of the study which was comparable to all the herbicide treatments except metolachlor + metobromuron (Galex) at 0.5 and 1.0 kg a.i./ha, metolachlor at 0.5 kg a.i./ha and the control plot in 1997 and metolachlor at 0.5 and 1.0 kg a.i./ha and the control plot in 1998, which produced significantly lighter seeds. This could be due to the inability of these herbicides for the rates given previously control weeds effectively, which resulted in competition between the crop and the weeds for growth resources of moisture, nutrients and sunlight which resulted in lighter seeds.

In 1997, metolachlor + atrazine (Primextra) at 0.5 and 1.0 kg a.i./ha produced significantly highest yield of millet which was comparable to hoe-weeding at 3 and 6 WAS but significantly higher than other treatments and the control plot except metolachlor + atrazine (Primextra) at 1.5 kg a.i./ha. All the rates of metolachlor + metobromuron (Galex), metolachlor and the control plot produced significantly lower yield of millet. However in 1998, atrazine at 0.5 kg a.i./ha produced significantly the maximum yield which was comparable to the other treatments except metolachlor + metobromuron (Galex) at 0.5 and 1.0 kg a.i./ha, all the rates of metolachlor and the control plot. Metolachlor + atrazine (Primextra) at 1.0 and 1.5 kg a.i./ha produced maximum yield comparable to two hoe weedings as a result of their low phytotoxic effect and ability to control weeds effectively which led to reduced weed competition. This allowed the uptake of enough nutrients and moisture by the crop, resulting in significantly heaviers seeds and higher yield. All the rates of metolachlor + metobromuron (Galex) and the control plot resulted in significantly lower yield probably due to their inability to control weeds which led to intense weed competition with the crop causing lower yield. Atrazine at all rates significantly produced lower yield, despite their ability to significantly reduce weed infestation. This could have resulted from the phytotoxic effect of this herbicide on millet which was pronounced in 1997 due to lower

Table 2. Effect of some pre-emergence herbicides on weed cover score at 10 WAS, leaf area at 8WAS, 1000-seed weight and grain yield of millet in millet-cowpea intercrop at Maiduguri, 1997 and 1998.

Treatment	Rate kg a.i./ha	Plant height at 10 WAS[1] (cm)		Weed cover score[3] at 8 WAS (cm)		1000-seed weight (g)		Grain yield (kg/ha)	
		1997	1998	1997	1998	1997	1998	1997	1998
Metolachlor + Metobromuron	0.5	174.7^{a2}	183.4^{ab}	8.5^{a}	6.0^{a}	6.8^{b}	8.8^{a}	262.0^{fg}	913.0^{bc}
	1.0	194.5^{a}	188.6^{ab}	8.0^{ab}	5.8^{a}	7.7^{b}	6.6^{b}	301.0^{e-g}	623.0^{bc}
	1.5	189.8^{a}	188.8^{ab}	9.3^{a}	6.3^{a}	8.9^{ab}	9.5^{ab}	352.0^{e-g}	913.0^{a-c}
Metolachlor	0.5	167.2^{a}	190.9^{ab}	8.3^{ab}	6.0^{a}	7.1^{b}	7.9^{ab}	244.0^{g}	543.0^{c}
	1.0	168.2^{a}	182.0^{ab}	8.0^{ab}	7.3^{a}	9.0^{ab}	9.0^{ab}	94.0^{h}	650.0^{c}
	1.5	190.3^{a}	165.1^{b}	9.0^{a}	5.8^{a}	8.7^{ab}	9.0^{ab}	74.0^{h}	814.0^{bc}
Atrazine	0.5	171.4^{a}	193.8^{ab}	3.0^{c}	2.3^{bc}	10.9^{ab}	8.9^{ab}	875.0^{d}	1756.0^{a}
	1.0	129.8^{ab}	191.8^{ab}	1.5^{d}	1.5^{bc}	11.1^{ab}	9.9^{ab}	860.0^{ef}	1103.0^{a-c}
	1.5	68.9^{b}	180.6^{ab}	0.8^{d}	1.3^{c}	11.1^{ab}	10.8^{ab}	254.0^{g}	1436.0^{a-c}
Metolachlor + Atrazine	0.5	187.1^{a}	172.1^{ab}	5.8^{b}	3.0^{b}	9.9^{ab}	10.9^{ab}	1400.0^{a-c}	1253.o^{a-c}
	1.0	134.9^{ab}	187.1^{ab}	2.5^{cd}	1.3^{c}	12.4a^{b}	10.0^{ab}	1400.0^{ab}	1395.0^{a-c}
	1.5	173.0^{a}	205.7ab	1.5^{d}	2.0^{bc}	12.5^{ab}	10.1^{ab}	1174.0^{b-d}	1513.0ab
Hoe weeding at 3 and 6 WAS	-	184.8^{a}	175.9^{ab}	0.5^{d}	0.8^{c}	13.1^{a}	13.6^{a}	1656.0^{a}	1241.0^{a-c}
Control plot	-	170.0^{ab}	218.3^{a}	8.5^{a}	6.5^{a}	6.3^{b}	7.4^{b}	247.9^{g}	828.8^{bc}
SE(±)		27.62	16.25	1.0	0.64	5.56	5.63	207.82	333.64

Weeks after sowing. (1) All means within a column followed by the same letters are not significantly different at p = 0.05 according to Duncan's Multiple Range Test (DMRT).
(2) Weed cover score on a scale of 1-10 where 1= no weed cover and 10=complete weed cover.

rainfall which suppressed crop growth and yield. However, in 1998, atrazine at 0.5 kg a.i./ha produced the highest grain yield which was comparable to all the treatments except all the rates of metolachlor + atrazine and metolachlor. This good performance of atrazine at 0.5 kg a.i./ha could be due to its efficacy to control weeds more effectively and the leaching of most of the herbicide molecules from the root zone due to higher rainfall. This freed the plants to utilize more growth resources for better growth and yield.

Table 3 shows the effect of pre-emergence herbicides on number of branches at 8 WAS, number of pods at harvest and grain yield of cowpea in millet-cowpea intercrop. It shows that metolachlor + atrazine (Primextra) at 1.5 kg/ha produced significantly the highest number of branches/plant which was comparable to other treatments except atrazine at 1.5 kg a.i./ha. In 1998, atrazine at 1.5 kg a.i./ha produced the highest branches/plant which was comparable to the other treatments except all the rates of metholachlor + metobromuron (Galex) and metolachlor. The poor performance of Galex and metolachlor was due to their inability to control weeds which led to competition between weeds and crop which reduced the number of branches/plant.

Metolachlor + atrazine (Primextra) at 1.0 kg a.i./ha produced the highest number of pods which was comparable to the other treatments and two hoe weeding except all the rates of metolachlor + metobromuron, atrazine at 1.0 and 1.5 kg a.i./ha, metolachlor and atrazine at 0.5 kg a.i./ha and the control plot. However in 1998, all the herbicide treatments produced higher and comparable number of pods with two hoe-weedings except, metolachlor and metolachlor + metobromuron (Galex) at 0.5 kg a.i./ha and control plot. However, in 1998, all herbicide treatments produced higher and the comparable

Table 3. Effect of some pre-emergence herbicides on number of branches at 8 WAS, number of pods/plant and grain yield of cowpea.

Treatment	Rate (kg a.i/ha)	Number of plant branches/plant 8 WAS[1]		Number of pods/ plant at harvest		Grain yield (kg/ha)	
		1997	1998	1997	1998	1997	1998
Metolachlor + metobromur	0.5	3.8^{ab2}	3.8^{de}	5.0^{e1}	11.2^{bc}	20.0	15.0^{de}
	1.0	4.0^{ab}	3.9^{c-e}	10.5^{c-e}	23.7^{a-c}	38.0^{cd}	55.0^{c-e}
	1.5	3.5^{ab}	3.5^{dc}	12.5^{c-e}	24.1^{ab}	50.0^{cd}	63.0^{b-e}
Metolachlor	0.5	3.6^{ab}	3.3^{e}	6.7^{e}	7.7^{e}	43.0^{cd}	14.0^{de}
	1.0	4.9^{a}	4.8^{cd}	16.5^{be}	20.2^{a-c}	101.0^{b-d}	44.0^{c-e}
	1.5	5.1^{a}	5.2^{bc}	17.3^{b-e}	20.1^{a-c}	79.0^{b-d}	52.0^{c-e}
Atrazine	0.5	4.0^{ab}	5.1^{bc}	27.9^{a-d}	33.8^{a}	129.0^{bc}	136.0^{ab}
	1.0	3.6^{ab}	6.5^{ab}	12.2^{c-e}	24.0^{a-c}	60.0^{b-d}	85.0^{a-e}
	1.5	1.8^{b}	6.7^{a}	8.8^{c-e}	29.2^{a}	46.0^{cd}	90.0^{a-e}
Metolachlor + atrazine	0.5	4.5^{ab}	6.1^{ab}	7.9^{de}	31.2^{a}	44.0^{cd}	121.0^{a-c}
	1.0	4.2^{a}	6.2^{ab}	46.7^{a}	32.3^{a}	310.0^{a}	160.0^{a}
	1.5	5.9^{a}	4.6^{cd}	29.3^{a-c}	31.7^{a}	135.0^{bc}	115.0^{a-d}
Hoe weeding at 3 and 6 WAS	-	5.5^{a}	6.0^{ab}	34.4^{cb}	36.9^{a}	217.0^{ab}	1140^{a-d}
Control plot	-	3.5^{ab}	3.7^{e}	7.4^{de}	11.3^{cd}	25.0^{cd}	12.0^{e}
SE(±)		1.24	0.44	8.86	7.26	52.43	34.78

(1) Weeks after sowing. (2) Means followed by the same letters within the column are not significantly different at 5% level of probability according to Duncan's Multiple Range Test (DMRT).

number of pods/plant except metolachlor and metolachlor + metobromuron (Galex) at 0.5 kg a.i./ha and the control plot which produced significantly lower number of pods/plant. The poor performance of all the rates of metolachlor and metolachlor + metobromuron and the control plot in 1998 could be due to their inability to control weeds which led to weed competition with the crops and the resulting poor performance. Atrazine at 1.0 and 1.5 kg a.i./ha gave significantly low number of pods which could have been due to its phytotoxic effect on the cowpea resulting from lower rainfall in 1997. In 1998, metolachlor and Galex at lower rates of 0.5 kg a.i./ha gave significantly lower number of pods probably as a result of the fact that the rates given previously was sub-lethal dose. However, atrazine at higher rates produced significantly high number of pods compared with the maximum, probably because of the ability of this herbicide to control weed effectively and the easy leaching of the herbicide for the rates given previously by higher rainfall on the sandy-loam soil. These conditions freed the crop to utilize more growth resources to achieve good performance. The higher number of pods in 1998 than 1997 could be due to higher rainfall recorded.

Grain yield of cowpea was significantly highest under metolachlor + atrazine at 1.0 kg a.i./ha in both years of the study which was comparable to hoe-weeding and other herbicide treatments except all the rates of metolachlor, metolachlor + metobromuron (Galex), atrazine and the control plot which produced significantly lower yields. Metolachlor + atrazine (Primextra) at 1.0 kg a.i./ha produced significantly highest yield in both years of the study comparable to hoe weeding probably as a result of the non-phytotoxic effect of the foregoing herbicide for the rates given previously and its ability to control weeds effectively which minimized weed competition with the crop and allowed it to take up more nutrients, water and sunlight to achieve better growth and yield. All the rates of metolachlor, metholachlor + metobromuron (Galex) and the control plot gave significantly lower yields in both years of the study probably due to their failure to control weeds which led to weed completion with the crop leading to poor yield.

Table 4 shows the effect of some pre-emergence herbicides on the combined yield of millet and cowpea in millet-cowpea intercrop by treatments. In 1997, two hoe weeding produced the highest combined yield of millet and cowpea, followed by metolachlor + atrazine (Primextra) at 1.0 kg a.i./ha. However, in 1998, atrazine at 0.5 kg a.i./ha produced the highest combined yield of millet and cowpea followed by metolachlor + atrazine (Primextra) at 1.5 and 1.0 kg a.i./ha. The previous result show that metolachlor + atrazine at 1.0 kg a.i./ha was more consistent in producing higher combined yields in the two years of study compared to the rest of the treatments and therefore can be recommended as alternative to two hoe weedings in the production of millet cowpea intercrop in the Sudan savanna zone of Nigeria.

Economic assessment of some pre-emergence herbicides in millet-cowpea intercrop

The cost-benefit analysis for the production of millet in

Table 4. Effect of some pre-emergence herbicides on combined yield of millet and cowpea in millet-cowpea intercrop.

Treatment	Rate kg a.i./ha	Grain yield (kg/ ha)					
		1997			1998		
		Millet	Cowpea	Combined	Millet	Cowpea	Combined
Metolachlor + metobromuron	0.5	262.0	20.0	282.0	913.0	15.0	928.0
	1.0	301.0	38.0	339.0	623.0	55.0	678.0
	1.5	352.0	50.0	402.0	913.0	63.0	976.0
Metolachlor	0.5	244.0	43.0	287.0	543.0	14.0	557.0
	1.0	94.0	101.0	195.0	650.0	44.0	694.0
	1.5	74.0	79.0	153.0	814.0	52.0	866.0
Atrazine	0.5	875.0	129.0	1004.0	1756.0	136.0	1892.0
	1.0	860.0	60.0	920.0	1103.0	85.0	1188.0
	1.5	254.0	46.0	300.0	1436.0	90.0	1526.0
Metolachlor+ atrazine	0.5	1400.0	44.0	1440.0	1253.0	121.0	1374.0
	1.0	1400.0	310.0	1710.0	1395.0	160.0	1555.0
	1.5	1174.0	135.0	1309.0	1513.0	115.0	1628.0
Hoe weeding at 3 and 6 WAS	-	1656.0	217.0	1873.0	1241.0	114.0	1355.0
Control plot	-	248.0	25.0	273.0	829.0	12.0	841.0

millet-cowpea intercrop system with the use of some pre-emergence herbicides in Maiduguri is presented in Table 5. Yield of millet was highest (1656.0 kg/ha) under hoe-weeding and lowest (74 kg/ha) under metolachlor at 1.5 kg a.i./ha in 1997. In 1998, however, highest yield (1756.0 kg/ha) was recorded under atrazine at 0.5 kg a.i./ha and lowest (543.0 kg/ha) under metolachlor at 0.5 kg a.i./ha. In 1998, the highest income (N105,378.00) was recorded under atrazine at 0.5 kg a.i./ha while the lowest (N32,550.00) was recorded under metolachlor at 0.5 kg a.i./ha. Profit was highest (N43,166.42) under a tank mixture of metolachlor + atrazine (Primextra) at 0.5 kg a.i./ha followed by metolachlor + atrazine at 1.0 kg a.i./ha (N42,838.83), compared with 2 hoe-weeding and other treatments, while the lowest profit (-N37,122.00) was recorded under metolachlor at 1.5 kg a.i./ha in 1997. In 1998, profit was highest (N64,628.00) under atrazine at 0.5 kg a.i./ha, followed by a tank mixture of metolachlor + atrazine (Primextra) at 1.5 kg a.i/ha (N49,231.25), atrazine at 1.5 kg a.i./ha (N44,928.00) and metolachlor+atrazine at 1.0 kg a.i./ha (N42,520.83) compared with two hoe-weedings and the rest of the treatments. The cost-benefit ratio was highest (1:9.383) under metolachlor at 1.5 kg a.i./ha and lowest (1:0.486 and 1:0.490) under metolachlor + atrazine (Primextra) at 0.5 and 1.0 kg a.i./ha respectively, compared to 2 hoe-weedings and the other treatments in 1997. However, in 1998, cost-benefit ratio was highest (1:1.255) under metolachlor 0.5 kg a.i./ha and lowest (1:0.387) under atrazine at 0.5 kg a.i./ha followed by metolachlor + atrazine (Primextra) at 1.5 kg a.i./ha (1:0.458), atrazine at1.5 kg a.i./ha (1:0.479), metolachlor + atrazine (Primextra) at 1.0 kg a.i./ha (1:0.492), metolachlor + atrazine (Primextra) at 0.5 kg a.i./ha (1:0.543), atrazine at 1.0 kg a.i./ha (1:0.620), metolachlor + metobromuron (Galex) at 0.5 kg a.i./ha (1:0.746) and at 1.5 kg a.i./ha (1:0.759), compared to hoe-weeding (1:0.769) respectively.

Although two hoe-weedings recorded the highest grain yield, and income, it was less profitable, economical and beneficial than metolachlor + atrazine at 0.5 and 1.0 kg a.i./ha because the foregoing herbicide at the previous respective rates had lower cost-benefit ratio compared to 2 hoe-weedings and other treatments in 1997. However, in 1998, highest yield and income was recorded under atrazine at 0.5 kg a.i./ha which was also most profitable, economical and beneficial, followed by metolachlor + atrazine at 1.5 kg a.i./ha, atrazine at 1.5 kg a.i./ha, metolachlor + atrazine at 1.0 kg a.i./ha and metolachlor + atrazine (Primextra) at 0.5 kg a.i./ha compared to two hoe-weedings and the rest of the treatments. This is because the aforementioned herbicides at the previous respective rates had lower cost-benefit ratio than two hoe-weedings. This confirms the report of Shrock and Monaco (1980), Okereke (1983), Usoroh (1983), Sinha and Lagoke (1984), Ogungbile and Lagoke (1986), Adigun et al. (1993) and Joshua and Gworgwor (2001, 2002) that herbicide use is more profitable than hoe-weeding in the production of various crops in Nigeria. It is also similar to the work of Nazeer et al. (2004) that a very lucrative cost-effective gain was recorded due to the application of Butil-M on wheat and Imoloame (2009) who reported higher profitability of some herbicides than two hoe weedings in the production of sesame per hectare. Also weeding at 3 and 6 WAS proved to be most expensive weeding method as it resulted in highest total

Table 5. Cost-benefit analysis of the production of millet with some pre-emergence herbicides in Maiduguri in 1997 and 1998.

Herbicides	Rate kg a.i./ha	Yield (kg/ha)		Total cost of production/ ha		Income/ selling price (N)/ ha		Profit/ loss/ ha (N)		Cost: benefit ratio	
		1997	1998	1997	1998	1997	1998	1997	1998	1997	1998
Metolachlor+ Metobromuron	0.5	262.0	913.0	40,850.00	40,850.00	15,726.00	54,750.00	-25,124.00	13,900.00	1:2.598	1:0.746
	1.0	301.0	623.0	41,200.00	41,200.00	18,036.00	37,350.00	-23,164.00	-3,850.00	1:2.284	1:1.103
	1.5	352.0	913.0	41,550.00	41,550.00	21,120.00	54,750.00	-20,430.00	13,200.00	1:1.967	1:0.759
Metolachlor	0.5	244.0	543.0	40,850.00	40,850.00	14,658.00	32,550.00	-26,192.00	-8,300.00	1:2.787	1:1.255
	1.0	94.0	650.0	41,200.00	41,200.00	5,658.00	39,000.00	-35,542.00	-2,200.00	1:7.282	1:1.056
	1.5	74.0	814.0	41,550.00	41,560.00	4,438.00	48,822.00	-37,122.00	7,322.00	1:9.383	1:0.851
Atrazine	0.5	875.0	1756.0	40,750.00	40,750.00	52,500.00	105,378.00	11,750.00	64,628.00	1:0.776	1:0.387
	1.0	860.0	1103.0	41,000.00	41,000.00	51,588.00	66,150.00	10,588.00	25,150.00	1:0.795	1:0.620
	1.5	254.0	1436.0	41,250.00	41,250.00	15,228.00	86,178.00	-26,022.00	44,928.00	1:2.709	1:0.479
Metolachlor + Atrazine	0.5	1400.0	1253.0	40,839.58	40,839.58	84,006.00	75,150.00	43,166.42	-34,310.42	1:0.486	1:0.543
	1.0	1400.0	1395.0	41,179.17	41,179.17	84,018.00	83,700.00	42,838.83	42,520.83	1:0.490	1:0.492
	1.5	1174.0	1513.0	41,518.75	41,518.75	70,434.00	90,750.00	28,915.25	49,231.25	1:0.589	1:0.458
Weeding at 3, 6 cm		1656.0	1241.0	57,300.00	57,300.00	99,372.00	74,478.00	42,072.00	17,178.00	1:0.577	1:0.769
Weedy check		248.0	829.0	39,300.00	39,300.00	14,874.00	49,728.00	-24,426.00	10,428.00	1:2.642	1:0.790

Cost: benefit ratio is based on N60.00 per kg (small mudu measure), the prevailing cost of millet in Maiduguri.

cost of production in both years of the study. This confirms the report of Adigun and Lagoke (2003) that hoe weeding is expensive.

The cost-benefit analysis for the production of cowpea in millet-cowpea intercrop system with the use of some pre-emergence herbicides in Maiduguri is presented in Table 6. Yield of cowpea was highest (310.0 kg/ha) under metolachlor + atrazine (Primextra) at 1.0 kg a.i./ha and lowest (20.0 kg/ha) under metolachlor + metobromuron (Galex) at 0.5 kg a.i./ha in 1997. Similarly, in 1998, highest yield (160.0 kg/ha) was recorded under metolachlor + atrazine at 1.0 kg a.i./ha but the lowest (14.0 kg/ha) was recorded under metolachlor at 0.5 kg a.i./ha.

The income was highest (N43,456.00) under metolachor + atrazine at 1.0 kg a.i./ha and lowest N2,730.00) under metolachlor + metobromuron at 0.5 kg a.i./ha in 1997. Similarly, in 1998, the highest income (N22,428.00) was recorded under metolachlor + atrazine and lowest (N1,638.00) under control plot. Profit was highest (N12,206.00) under a tank mixture of metolachlor + atrazine at 1.0 kg a.i./ha and lowest (-N28,520.00) under metolachlor + metobromuron at 0.5 kg a.i./ha in 1997. In 1998, the highest profit/loss (-N8,822.10) was recorded under metolachlor + atrazine at 1.0 kg a.i./ha, while the lowest profit/loss (-N29,612.00) was recorded under control plot.

The cost:benefit ratio was highest (1:11.447) under metolachlor + metobromuron at 0.5 kg a.i./ha and lowest (1:0.719) under a tank mixture of metolachlor + atrazine at 1.0 kg a.i./ha in 1997. In 1998, the highest cost-benefit ratio (1:19.078) was recorded under control plot while the lowest (1:1.393) was recorded under metolachlor + atrazine (Primextra) at 1.0 kg a.i./ha.

A tank mixture of metolachlor + atrazine at 1.0 kg a.i./ha not only recorded the highest cowpea yield, and income it was more profitable, economical and beneficial than two hoe-weedings at 3 and 6 WAS than the rest of the treatments in the two years the experiment was conducted. This was because the herbicides at the previous rate had lower cost:benefit ratio compared to all the other treatments. This agrees with the findings of Joshua and Gworgwor (2001) that herbicide use was more beneficial and economical for cowpea

Table 6. Cost-benefit analysis of the production of cowpea with some pre-emergence herbicides in Maiduguri in 1997 and 1998.

Herbicides	Rates (kg a.i./ha)	Yield (kg/ha)		Total cost of production/ ha		Income/ Selling price (N)/ ha		Profit/ Loss/ ha		Cost: benefit ratio	
		1997	1998	1997	1998	1997	1998	1997	1998	1997	1998
Metolachlor + Metobromuron	0.5	20.0	15.0	31,250.00	31,250.00	2,730.00	2,128.00	-28,520.00	-29,122.00	1:11.447	1:14.685
	1.0	38.0	55.0	”	”	5,348.00	7,672.00	-25,902.00	-23,578.00	1:5.843	1:4.733
	1.5	50.0	63.0	”	”	7,000.00	8,862.00	-24,250.00	-22,388.00	1:4.464	1.3.526
Metolachlor	0.5	43.0	14.0	”	”	6,020.00	1,974.00	-25,250.00	-29,276.00	1:5.191	1:15.831
	1.0	101.0	44.0	”	”	14,098.00	6,202.00	-17,152.00	-25,048.00	1:2.217	1:5.039
	1.5	79.0	52.0	”	”	11,120.00	7,224.00	-20,130.00	-24,026.00	1:2.810	1:4.326
Atrazine	0.5	129.0	136.0	”	”	18,018.00	18,984.00	-13,232.00	-12,266.00	1:1.734	1:1.646
	1.0	60.0	85.0	”	”	8,358.00	11,872.00	-22,892.00	-19,378.00	1:3.740	1:2.632
	1.5	46.0	90.0	”	”	6,398.00	12,572.00	-24,852.00	-18,678.00	1:4.884	1:2.486
Metolachlor + Atrazine	0.5	44.0	121.0	31,250.00	31,250.00	6,132.00	16,884.00	-25,118.00	-14,336.00	1:5.096	1:1.851
	1.0	310.0	160.0	31,250.00	31,250.00	43,456.00	22,428.00	12,206.00	-8,822.10	1:0.719	1:1.393
	1.5	135.0	115.0	”	”	18,942.00	16,030.00	-12,308.00	-15,220.00	1:1.650	1:1.950
Weeding at 3 and 6 WAS		217.0	114.0	”	”	30,436.00	15,988.00	-814.00	-15,262.00	1:1.027	1:1.955
Weedy check		25.0	12.0	”	”	3,500.00	1,638.00	-27,750.00	-29,612.00	1:8.930	1:19.078

Cost: benefit ratio is based on N140.00/ kg, the prevailing cost of cowpea in Maiduguri.

and sorghum production than hoe-weeding in the Sudan savanna zone of Nigeria.

It can be concluded that metolachlor + metobromuron at 1.0 kg a.i./ha did not only significantly promote agronomic growth of millet and cowpea, but it significantly increased their individual or combined yields comparable to two hoe weedings in the two years of the study. Also the foregoin herbicides at the previous rate was found to be more profitable, economical and beneficial than two hoe weedings which was found to be most expensive weeding method in the two years of study compared with the other treatments. Therefore for higher yield, profitability and economic returns metolachlor + atrazine at 1.0 kg/ha is recommended as alternative to two hoe weeding in the production of millet-cowpea mixture in the Sudan savanna zone of Nigeria.

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