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Effect of *Pendimethalin* on Relative Tolerance of Sorghum in Northern Guinea Savanna Areas of Nigeria

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ABSTRACT--- ***Field trials were carried out at different location to determine the relative tolerance of sorghum to different rates of pendimethalin application during the 2012 cropping season in Mubi (Latitude 10^{0} 15^{II} N and Longitude 13^{0} 16^{II} E at an altitude of 696m above sea level) and Gombe (Latitude 11^{0} 30^{II} N and Longitude 10^{0} 20^{II} E at an altitude of 240m above sea level). The trials consisted of eight treatments; 1.0, 2.0, 3.0, 4.0. 5.0 and 6.0kg a.i/ha rates of Pendimethalin, plus weed free and weedy check. The herbicide rates were assigned to the main plot as main treatment while sorghum variety was assigned to subplots as sub treatment replicated three times in a split plot design. The following data were collected, days to 50% emergence, crop injury score, crop vigour score, plant height, leaf area index, weed cover score, weed fresh weight, weed dry weight, grain yield and 1000 grain weight in both locations respectively. Result indicates that sorghum can tolerate up to 3.0kg a.i/ha rate of Pendimethalin in both location. However, rates of Pendimethalin perform better than the weedy check but weed free was significantly superior to all treatments across the two locations. Hence it can be concluded that 3.0kg i.a/ha of Pendimethalin can be tolerated by sorghum with relatively low weed fresh and dry weights as well as higher grain yield and 1000 grain weight.***

Keywords--- Relative tolerance, sorghum, herbicide rates, location

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1. INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the commercial cereal crops with more than 40 million hectares dedicated to its cultivation globally (FAO, 2003). It is extensively used as food crop in Africa, Asia and as a major food grain in North America and South Africa (ICRISAT, 1992; ICRISAT/1AR, 1990; ICRISAT/FAO, 1996). Sorghum is a warm annual grass with demonstrated ability to produce high biomass yields per unit of land and cultivars are available that have been selected specifically for high biomass production (Venulo and Kindiger, 2008). This crop is adapted to wide range of conditions and can tolerate high temperature and low rainfall throughout its lifecycle better than any other cereal (Chapman and Carter, 1976). Cellulose, hemicelluloses and lignin are the main chemical components of sorghum biomass; as such they are the most abundant renewable resources on earth and can be used as the alternative to petroleum and other fossil resources (Habyerimane *et al*., 2004). In sorghum, weed control during the 4-5 weeks after emergence is most critical because the seedlings of sorghum grow very slowly and do not compete well with weeds until a canopy develops (Benini *et al*., 1994). As a consequence, severe uncontrolled weed infestation at the early growth stages of sorghum often cause poor crop establishment or complete crop failure. However this problem could be avoided with an effective pre-emergence weed control (Martin *et al*., 1982). Yield losses due to uncontrolled weed ranges between 40-60% (ICRISAT and IAR, 1990; Shebayan, 1992). Striga, a parasitic weed had been found to cause total crop lose where susceptible sorghum varieties have been planted in highly infested fields particularly in those soils that are poor in nutrient status (Shebayan, 1992). In order to improve the production of sorghum in the Nigerian Savannah, various weed control methods have been evaluated and found adaptable by farmers among which are the cultural and chemical methods.

Cultural weed control methods in sorghum production are: hoe weeding, mechanical weeding, mulching, crop rotation and use of resistant varieties. Manual hoe weeding is the most widely used method of weed control in sorghum among small scale farmers. Chemical weed control is a practical way of controlling weeds in medium and large scale production system. Herbicides that have proved effective in controlling weeds in sorghum include pre-emergence and post emergence herbicides such as atrazine + metolachlor, atrazine + terbutryne or atrazine + pendimethalin at 1.0+1.0kg a.i.ha^{-1} each control annual grasses and broad-leaved weeds very effectively (Besufekad, 2001). *Pendimethalin* is a selective herbicide used to control annual grasses and certain broadleaf weeds in field corn, sorghum, leguminous crops and *Solanaceous* crops. *Pendimethalin* has been found to be effective against *Rotteboelia cochinchinensis* which is a fast and aggressive growing weed in cereal farms and often followed with great loss in grain yield (Malik, 2006). Massive field infestation by such an aggressive weed would require higher rates of *Pendimethalin* application. It is therefore very necessary that relative tolerance of crops to *Pendimethalin* be evaluated. However, information on tolerances of agricultural crops to *Pendimethalin* application is very scanty, especially in Nigeria. The current work therefore is aimed at evaluating the relative tolerance of sorghum to different rates of *Pendimethalin* in two locations of the Northern Guinea Savanna of Nigeria.

2. MATERIALS AND METHODS

Field trials were conducted at the Teaching and Research Farm, Adamawa State University, Mubi (Latitude 10^0 15^{II} N and Longitude 13^0 16^{II} E at an altitude of 696m above sea level) and at CBADP demonstration farm of Gombe State Agricultural Development Project (Latitude 11^0 30^{II} N and Longitude 10^0 20^{II} E at an altitude of 240m above sea level). Both locations are situated in the Northern Guinea Savanna agro-ecological zone of Nigeria (Kowal and Knabe, 1972; Adebayo, 2004). Composite soil samples of the two locations were collected prior to the period of trail establishment. The land were ploughed and harrowed in both locations to obtain a fine tilt and marked into plots. Total land area used for the experiment was 392m^2 (28m × 14m) with a gross plot of 3m × 3m and net plot of 3m × 1.5m. The experiment had eight treatments which consisted of six different rates of *Pendimethalin* (1.0, 2.0, 3.0, 4.0, 5.0, 6.0kg a.i.ha^{-1}) plus two control checks (weed free and weedy check). Herbicide rates were placed in the main plots as main treatment while the sorghum variety SAMSORG 17 (SK 5912) was placed in the sub-plots as sub-treatments which were laid in a split plot design and replicated three times. 6-7 seed hole^{-1} of sorghum were sown on mid-July at a spacing of 0.75×0.25m for inter and intra row spacing respectively. However, seedlings were later thinned to one plant stand^{-1} at 2 weeks after sowing (WAS). The herbicide (*Pendimethalin*) was applied pre-emergence 1 day after sowing (DAS) using a CP3 knapsack sprayer fitted with green deflector nozzle set at a pressure of 2.1kgcm^3 and in spray liquid volume of 240Lha^{-1} .Urea was used as source of fertilizer at 120kg N ha^{-1}, were half of the N dose was applied to the sorghum stand at 2WAS and the remaining dose was top dressed to the same crop at 6 WAS. Weed free check plots (control) were kept weed free by regular weeding. Nevertheless, all agronomic practices were adequately carried out except those under investigation. Data were collected on Days to 50% emergence, crop injury score, crop vigour score, plant height, leaf area, crop growth rate, relative growth rate, days to 50% booting; weed parameters include the following weed cover score, weed fresh weight and weed dry weight. While at harvest are yield in Kg ha^{-1}, 1000 grain weight were as well determined in both locations.

2.1 Data analysis

Data collected were subjected to analysis of variance (ANOVA) according to Steel and Torrie (1980) using the General Linear Model (GLM) in SPSS version (1996) for Windows. Means of treatments were compared using Duncan Multiple Range Test (DMRT), calculated only when analysis of variance (F-test) was significant at P=0.05 (Duncan, 1955).

3. RESULTS AND DISCUSSION

A total of 1278mm and 1343mm were recorded with mean monthly distribution of 182.6mm and 191.9mm. Rainfall was at peak during the month of August and September (313.30mm and 304.40mm) and (331.50mm and 314.50mm) for Gombe and Mubi respectively. Similarly, a mean monthly temperature (minimum and maximum) of (21.30^o c and 31.90^o c) and (20.20^o c and 30.20^o c) for Gombe and Mubi respectively was equally recorded during the period of field trials with a mean monthly relative humidity of 41.7 and 42.6 for Gombe and Mubi was reported respectively. The soil textural class was sandy loam for both locations with pH slightly acidic. Organic carbon, total N and available P were slightly higher with relatively minimum of cation exchange capacity (CEC) in both locations.

All the parameters under investigation were significantly affected by rates of *Pendimethalin* in both locations. *Pendimethalin* at 5.0 and 6.0kg a.i/ha resulted in total mortality of sorghum in both location. Similarly, 4.0kg a.i/ha of *Pendimethalin* resulted significantly in highest number of days to 50% emergence of sorghum in both location. *Pendimethalin* at 3.0, 2.0, 1.0kg a.i/ha, weedy check and weed free resulted in least number of days to 50% emergence of sorghum in both locations (P=0.05). An increase number of days to 50% emergence of sorghum arises as a result of phytotoxic effect of the herbicide at higher rates which also indicates the herbicide at higher dosage rate is capable of disrupting important physiological process of the plant (Ware, 2000).

Pendimethalin at 1.0, 2.0 and 3.0 kg a.i/ha as well as weed free and weedy check recorded least injury score compared to *Pendimethalin* at 4.0 and 5.0 kg a.i/ha which significantly resulted in higher injury score of sorghum in

Mubi and Gombe. *Pendimethalin* at 6.0kg a.i/ha resulted significantly in highest injury score of sorghum in both locations which was an indication of phytotoxic effect of *Pendimethalin* at higher dosage rates to the crop irrespective of location. This also agrees with the findings of Imolame (2009) and (Shittu, 2013) who reported a poor performance of crops treated with *Pendimethalin* at higher rates for weed control in the Sudan savanna zone of Nigeria as a result of phytotoxicity.

Pendimethalin at 3.0, 2.0 and 1.0kg a.i/ha significantly resulted in higher vigour score compared with weedy check which had least vigour score of sorghum in Mubi. Weed free resulted significantly in highest vigour score of sorghum. A similar result was also obtained in Gombe during period of assessment. This result indicates that vigor score of sorghum is herbicidal rates dependent of *Pendimethalin* in despite of location. This shows that *Pendimethalin* is highly phytotoxic to sorghum because it only tolerates 3.0kg a.i/ha compared to maize and cowpea which tolerates and performs better at 6.0kg a.i/ha (Shittu, 2013), phytotoxicity of herbicide at certain rate of application usually results in decrease crop vigour.

Pendimethalin at 1.0, 2.0 and 3.0 kg a.i/ha resulted in a higher plant height compared to weedy check which gave significantly the least plant height of sorghum at 8 and 12WAS in Mubi. While weed free resulted significantly in highest plant height of sorghum at 8 and 12WAS in Mubi (P=0.05). A similar trend of result was also obtained in Gombe at 8 and 12 WAS respectively. Leaf area index was significantly affected by rates of *Pendimethalin*. At 8WAS, weed free significantly resulted in highest leaf area index of sorghum compared to *Pendimethalin* at 3.0, 2.0 and 1.0kg a.i/ha which had lower leaf area index (p=0.05). Weedy check resulted in least leaf area index of sorghum at 8 and 12WAS in Mubi. A similar trend of result was also obtained in Gombe at 8 and 12WAS respectively (Table 2).

Weedy check resulted significantly in highest weed cover score followed by *Pendimethalin* at 1.0, 2.0, 3.0, 4.0, 5.0 and 6.0 kg a.i./ha while weed free resulted in a least weed cover score in sorghum in both Mubi and Gombe at 8WAS. However at 12 WAS, weedy check, 1.0,2.0, 3.0 and 4.0 kg a.i/ha of *Pendimethalin* resulted in highest weed cover score in sorghum(Table 3) while *Pendimethalin* at 5.0, 6.0kg a.i/h and weed free resulted significantly in least weed cover score of sorghum in both locations.(P=0.05). These findings indicate that *Pendimethalin* gives weed control of up to 8WAS in both locations by providing a relative longer weed control regime at higher rates compared to lower rates (Shittu, 2013). This also agrees with the findings of (Anonymous, 1994; Atangs, 1997 and Malik, 2006) who earlier reported reduction in weed cover of 6-7WAS as a result of pre-emergence herbicide application.

Weedy check significantly resulted in highest fresh weight of weed compared with 1.0, 2.0, 3.0 and 4.0kg a.i/ha of *Pendimethalin*. While weed free significantly resulted in least weed fresh weight at 8 and 12WAS in Mubi. A similar result was also obtained in Gombe at 8 and 12WAS respectively (Table 3). These occur as a result of similar weed biotypes but differ in population (Shittu, personal observation). Weedy check significantly resulted in highest weed dry weight compared to weed free, 1.0, 2.0 and 3.0kg a.i/ha which resulted in lowest dry weight in that order of increase dry weight though statistically similar in Mubi at 8WAS. Similarly, weedy check significantly resulted in highest dry weight followed by 1.0, 2.0 and 3.0kg a.i/ha which resulted in lower dry weight which were at par. Weed free significantly resulted in least dry weight of weed at 12WAS (Table 4). Furthermore, weedy check significantly resulted in highest dry weight followed by 1.0, 2.0 and 3.0kg a.i/ha of *Pendimethalin* which were also at par with lower weed dry weight at 8WAS in Gombe. Weed free significantly resulted in least dry weight at 8 and 12 WAS respectively. Whereas weedy check significantly resulted in highest weed dry weight followed by 1.0, 2.0 and 3.0kg a.i/ha in that order of decreasing dry weight at 12WAS in Gombe (P=0.05).

Weed free resulted significantly in highest grain yield of sorghum compared to *Pendimethalin* at 3.0, 2.0, 1.0kg a.i/ha and weedy check which resulted in lower grain yield of sorghum, with the weedy check resulted in least grain yield of sorghum in both locations (P=0.05). Similarly, weed free, 3.0, 2.0 kg a.i/ha of *Pendimethalin* resulted in higher 1000 grain weight of sorghum compared to *Pendimethalin* at 1.0kg a.i/ha and weedy check which had lower 1000 grain weight of sorghum in Mubi and Gombe (Table 4). Weedy check resulted significantly in least 1000 grain weight of sorghum in both locations respectively. Furthermore, it was equally observed that the grain yield as well as 1000 grain weight of sorghum in Gombe was relatively higher compared with that obtained in Mubi, though they did not vary significantly location wise (P=0.05). These occur as result of variability in rain fall intensity and probably nature of the biodegradable micro fauna that acts upon the herbicide (Besufekad, 2001; Shittu, 2013).

4. CONCLUSION AND RECOMMENDATION

The results from the present works reveals that sorghum can tolerate application of *Pendimethalin* herbicide up to 3.0 kg rate of a.i/ha in both locations. Therefore, this maximum rate of 3.0 kg a.i/ha of *Pendimethalin* can be recommended for areas with noxious weed biotypes such as *Rotteboelia cochinchinensis, Imperata cylindrical, Digitaria ciliaris* and sedges which often required high rates of herbicides for effective weed control and higher grain yield of sorghum in the Northern Guinea Savanna areas of Nigeria.

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Table 1: Effect of Pendimethalin on 50% emergence, crop injury score and crop vigour score of sorghum in Mubi and Gombe during the 2012 cropping season

Treatment	50% Emergence		Crop injury score		Crop vigour score			
	Mubi	Gombe	Mubi	Gombe	Mubi		Gombe	
	Days after sowing (DAS)							
	14		14		4	8	4	8
Pendimethalin (kg a.i/ha)								
1.0	4.00d	4.00d	0.33ef	0.33d	7.67a	7.00b	7.67ab	6.33b
2.0	5.00c	4.67c	1.33e	1.00d	7.33ab	7.00b	7.00bc	6.67b
3.0	6.00b	5.67b	4.33d	4.00c	6.33bc	7.67b	6.33cd	7.33b
4.0	7.33a	7.00a	6.67c	6.00b	0.00d	0.00d	0.00e	0.00d
5.0	0.00e	0.00e	8.33b	8.33b	0.00d	0.00d	0.00e	0.00d
6.0	0.00e	0.00e	9.67a	9.67a	0.00d	0.00d	0.00e	0.00d
Weed free	4.00d	4.00d	0.00f	0.00d	8.33a	9.33a	8.33a	8.33a
Weedy check	4.00d	4.00d	0.00f	0.00d	5.67c	5.67c	5.67d	5.00c
LS	*	*	*	*	*	*	*	*
SE±	0.12	0.13	0.29	0.36	0.26	0.21	0.25	0.25

LS= Level of significance; * Significant at 0.05%
Mean followed by common letter(s) are not significantly different at 5% probability level (DMRT)
Crop injury score scale of 0-10; where 0 represents plants free of injury, while 10 represent most severe injured crop that can lead to mortality.
Crop vigor score scale of 0-10; with 0 as weak plants and 10 as most vigorous plant.

Table 2: Effect of Pendimethalin on plant height and leaf area index of sorghum in Mubi and Gombe during the 2012 cropping season

Treatment	Plant height (cm)				Leaf area index			
	Mubi		Gombe		Mubi		Gombe	
	8 WAS	12 WAS	8 WAS	12 WAS	8 WAS	12 WAS	8 WAS	12 WAS
Pendimethalin (kg a.i/ha)								
1.0	97.80b	137.37b	97.67b	135.70d	0.50c	0.50b	0.60b	0.60b
2.0	96.67b	139.67b	96.67b	141.00c	0.60b	0.50b	0.60b	0.60b
3.0	94.80b	140.10b	94.33b	145.33b	0.60b	0.50b	0.60b	0.60b
4.0	0.00c	0.00c	0.00c	0.00f	0.00d	0.00c	0.00d	0.00d
5.0	0.00c	0.00c	0.00c	0.00f	0.00d	0.00c	0.00d	0.00d
6.0	0.00c	0.00c	0.00c	0.00f	0.00d	0.00c	0.00d	0.00d
Weed free	102.67a	174.67a	102.80a	176.00a	0.70a	0.70a	0.70a	0.70a
Weedy check	69.93c	82.03c	69.33c	84.60e	0.40d	0.40c	0.40c	0.40c
LS	*	*	*	*	*	*	*	*
SE±	1.01	2.28	0.76	0.99	0.02	0.02	0.01	0.01

LS= Level of significance; * Significant at 0.05%
Mean followed by common letter(s) are not significantly different at 5% probability level (DMRT)

Table 3: Effect of Pendimethalin on weed cover score and weed fresh weight in sorghum in Mubi and Gombe during the 2012 cropping season.

Treatment	Weed cover score				Weed fresh weight (kg/ha)			
	Mubi		Gombe		Mubi		Gombe	
	8WAS	12 WAS	8WAS	12 WAS	8WAS	12 AWS	8 WAS	12 AWS
Pendimethalin (kg a.i/ha)								
1.0	7.00b	9.67a	7.00b	9.67a	3.387b	3.033b	3.203b	3.100b
2.0	6.67b	9.33a	6.67b	9.33a	2.867c	2.567c	2.707c	2.567c
3.0	6.00b	8.67ab	6.00b	8.67ab	2.380d	2.233d	2.447d	2.300d
4.0	4.67c	8.00b	4.67c	8.00b	0.00f	0.00f	0.00f	0.00f
5.0	3.67cd	6.67c	3.67cd	6.67c	0.00f	0.00f	0.00f	0.00f
6.0	2.67de	6.33cd	2.67de	6.33cd	0.00f	0.00f	0.00f	0.00f
Weed free	1.67e	2.67e	1.67e	2.67e	1.043e	0.977e	1.027e	0.993e
Weedy check	9.67a	10.00a	9.67a	10.00a	4.387a	4.267a	4.223a	4.170a
LS	*	*	*	*	*	*	*	*
SE±	0.30	0.29	0.30	0.29	0.22	0.24	0.32	0.32

LS= Level of significance; * Significant at 0.05%
Mean followed by common letter(s) are not significantly different at 5% probability level (DMRT)
Weed cover score scale 0-10; 0.No weed cover; 10. Full weed cover (infestation) as in un-weeded control.

Table 4: Effect of Pendimethalin on weed dry weight, grain yield and 1000 grain weight of sorghum in Mubi and Gombe during the 2012 cropping season.

Treatment	Weed dry weight (kg/ha)				Grain yield (Kg/ha)		1000 grain weight	
	Mubi		Gombe		Mubi	Gombe	Mubi	Gombe
	8WAS	12 WAS	8WAS	12 WAS	8WAS	12 WAS	8WAS	12 WAS
Pendimethalin (kg a.i/ha)								
1.0	1.310b	1.133b	1.317b	1.367b	1731.64d	1740.37c	32.81c	32.86c
2.0	1.267b	1.037bc	1.203bc	1.200c	1807.01c	1831.68b	34.57b	34.70b
3.0	1.243b	0.893c	1.083c	0.990d	1894.55b	1904.27b	34.64ab	34.76b
4.0	0.000c	0.000e	0.000e	0.000f	0.0000e	0.0000d	00.00e	00.00e
5.0	0.000c	0.000e	0.000e	0.000f	0.0000e	0.0000d	00.00e	00.00e
6.0	0.000c	0.000e	0.000e	0.000f	0.000e	0.0000d	00.00e	00.00e
Weed free	0.980b	0.503d	0.550d	0.547e	1983.33a	2003.44a	36.67a	36.83a
Weedy check	2.343a	2.033a	2.180a	2.100a	1666.66d	1677.00c	31.05d	31.10d
LS	*	*	*	*	*	*	*	*
SE±	0.105	0.403	0.030	0.040	17.89	18.33	0.36	0.074

LS= Level of significance; * Significant at 0.05%
Mean followed by common letter(s) are not significantly different at 5% probability level (DMRT)