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EFFECT OF INTEGRATED WEED MANAGEMENT PRACTICES ON WEED GROWTH AND YIELD OF SORGHUM IN WINTER

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Abstract

The field experiment was conducted at Agronomy Division, Bangladesh Agricultural Research Institute, Gazipur, during *Rabi* season of 2022-23 and 2023-2024 to study the effect of integration of chemical and cultural methods for weed management in sorghum. There were seven treatment viz. T_1 = Two hand weeding at 25 and 40 days after sowing (DAS), T_2 = Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 days after sowing (DAS), T_3 =Atrazine @ 2 L ha^{-1} spraying as pre-emergence + weeding by BARI weeder at 25 days after sowing (DAS), T_4 = Atrazine @ 2 L ha^{-1} spraying as post-emergence at 25 DAS + one hand weeding at 40 days after sowing (DAS), T_5 = Pendimethalin @ 3 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 days after sowing (DAS), T_6 = Pendimethalin @ 3 L ha^{-1} spraying as pre-emergence and T_7= No weeding and no herbicide were included in the experiment. Barnyard grass (*Echinochola crusgalli*), Harkuch (*Enhydra fluctuans*), Nutsedge (*Cyperus rotundus*) and Jersey cudweed (*Gnaphalium affine*) were the common and dominant weeds in the sorghum field. Results showed that the highest weed control efficiency (WCE) (84.4% at 25 days after establishment (DAE) and 90.2% at 45 DAE at 2022-23 and 85.28% at 25 DAE and 81.58% at 45 DAE at 2023-24) was found in T_2 treatment. Significantly the highest two years average yield (3.64 kg ha^{-1}) was obtained from T_5 treatment. The highest gross return of (Tk. 109300 ha^{-1}) and benefit cost ratio (BCR) (2.01) were also obtained from T_5 treatment. From the result it might be concluded that, two herbicides (Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 DAS and Pendimethalin@ 3 L ha^{-1}spraying as pre-emergence + one hand weeding at 25 DAS) were found economical by recording higher net returns and BCR compared to control.

Introduction

Sorghum (*Sorghum bicolor* L.) is considered as king of millets and extensively grown in semi- arid tracks of Africa, China and India. The area under sorghum cultivation was recorded as 6316 acres in 1996-1997 but it continuously decreased and reached to 745 acres in 2017-2018 (BBS, 2018). It has multiple uses as grain, fodder and more recently as bifo energy crop. In Asia and Africa sorghum grain is consumed by human or as animal feed, stalks are used as fodder or housing material. Sorghum has a high nutritive value, with 70-80% carbohydrate, 11-13% protein, 2-5% fat, 1-3% fibre, and 1-2% ash. Protein in sorghum grain is gluten free and thus it is specifically a food for people who suffer from celiac disease (intolerant to food with gluten), including diabetic patients.

Comparing the production potential of sorghum, the low productivity in Bangladesh is attributed to several reason. Among them weed is a major constrains. Weeds are major problems in increasing productivity of the crop. It was reported that yield loss of sorghum due to weeds ranges from 15-97%, depending on the nature and density of weeds (Thakur *et al.* 2016). Weeds germinated fast and grow rapidly at initial growth period of crops competing with the crops

severely for growth resources, viz. nutrients, moisture, sunlight and space. This affects the growth and development of crop and leads to yield losses (Freitas *et al*., 2014).

Weed management in grain sorghum is a challenge because of the limited number of herbicides available to growers, rotational crop restrictions following a number of herbicides registered for use in grain sorghum and presence of herbicide resistant weeds. Traditional hand weeding is the most efficient and widely adopted practice of weed management but it is labor intensive, time consuming and not economical due to high wage rates. Mechanical equipment can be time saving during peak operation, resulting in higher output per worker and reduction in the cost of weeding. Chemical weed control is a better supplement to conventional method however the weed emergence pattern, application timing and stage of crop are important in chemical control. Continuous use of herbicides over a prolonged time leads to development of resistance in weeds making them difficult to control.

Integrated weed management (IWM), the process of combining several single management strategies together to suppress weeds has been developed. Hence, various components of integrated weed management are to be blended in a systematic way to achieve the acceptable level of weed control. The integration of herbicides with cultural operations and use of pre-emergence and post-emergence herbicides in combination with mechanical methods will makes the crop weed free effectively and thus, improves the crop growth as well as yield. The integrated weed management is, therefore, gaining importance in management of weeds for preventing yield losses and higher input-use efficiency. Herbicide application in Bangladesh is expected to increase in future due to labor scarce situation. The present investigation was carried out to study the effect of integrated weed management practices on weed density, weed dry weight and economics in sorghum.

Materials and Methods

Field experiment was conducted at the research farm of Bangladesh Agricultural Research Institute, Gazipur during *Rabi* season of 2022-2023 and 2023-2024. The experiment site was located Chhiata Series under Agro-Ecological Zone-28 (AEZ-28) latitude $23^0$59' N and longitude $90^0$24' E. The meteorological data of the experimental site revealed that the highest temperature prevails in March-April and the lowest in December to January. Maximum rainfall was received during the months of January. The crop received 543 mm rain showers from November to March in 2023-24years. The average maximum (32.08 °C) was found in the month of March during the crop growing season (Fig. 1.) and minimum (12.77 °C) temperature in the month of January during the crop growing season (Fig. 1.). The experiment was consisted of seven treatments viz. T_1 = Two hand weeding at 25 and 40 DAS, T_2 = Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 DAS, T_3 =Atrazine @ 2 L ha^{-1} spraying as pre-emergence + weeding by BARI weeder at 25 DAS, T_4 = Atrazine @ 2 L ha^{-1} spraying as post-emergence at 25 DAS + one hand weeding at 40 DAS, T_5 = Pendimethalin @ 3 L ha^{-1}spraying as pre-emergence + one hand weeding at 25 DAS, T_6 = Pendimethalin @ 3 L ha^{-1} spraying as pre-emergence and T_7= No weeding and no herbicide. The experiment was laid out in randomized complete block design with three replications. The unit plot size was 3m × 3m. Seeds of sorghum (BARI Sorghum-1) were sown on 25 November, and harvested on 1 April, 2023 and 2nd year sown on 28 November 2023 and finally harvested on 5 April 2024. Fertilizers were applied at the rate of 120-60-50 kg ha^{-1} of NPK as urea, triple superphosphate (TSP), muriate of potash (MOP) for grain sorghum. One third N and all other fertilizers were applied as basal. Rest N was be applied at 20 and 40 DAS. Three times of irrigation were applied in field. Weed sample were collected (1 m^2 per each plot) at 25 DAS and 45 DAS and dry matter was taken after oven dry. Weed control efficiency (WCE) was calculated according to following formula:

$$\text{Weed Control Efficiency (WCE\%)} = \left(\frac{A-B}{A}\right) \times 100$$

Where, A = Dry weight of weeds in no weeding plots and B = Dry weight of weeds in treated plots. Yield and yield contributing characters were recorded and pooled data analyzed statistically with STATISTICS 10 statistical package. The means were separated by least significant difference test (LSD 0.05%).

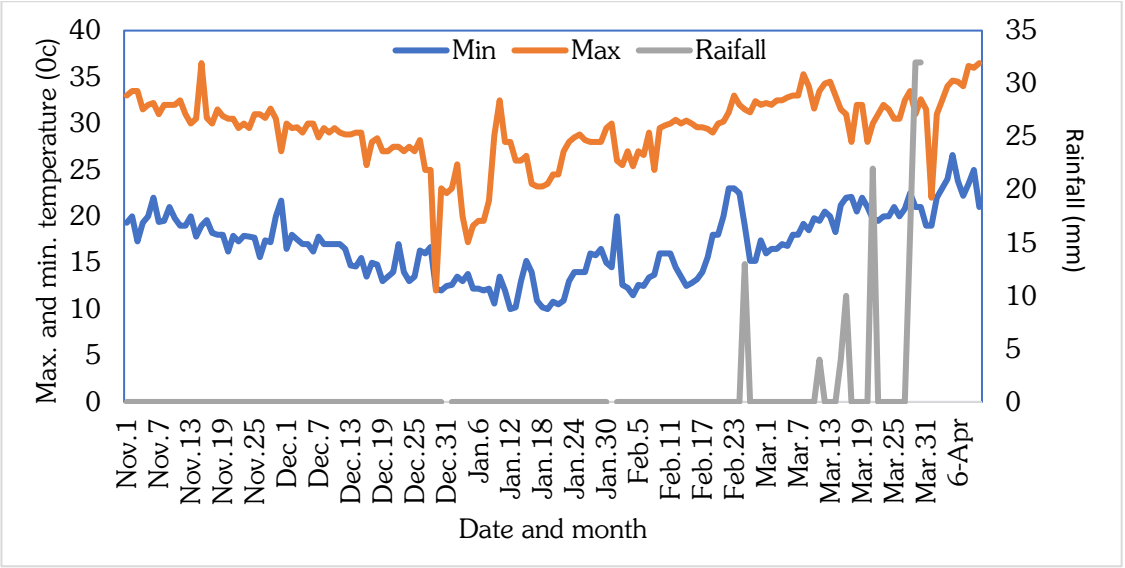

Fig. 1. Mean temperature and rainfall prevailed during sorghum growing periods at Gazipur

Results and Discussion

Weed species and their relative density and number of weeds m^{-2} in different treatments are presented in Table 1.The weeds flora infesting the sorghum field were Harkuch (*Enhydra fluctuans*), Barnyard grass (*Echinochloa crusgalli)*, Scrab grass (*Digitaria sanguinalis)*, Kanainala *(Cyanotis axillaris*), Goose grass (*Eleusine indica)*, Nutsedge (*Cyperus rotundus)*, Vetch (*Vicia sativa)*, Bitter dock (*Rumexm aritimus)*, Bermuda grass (*Cynodon dactylon)*, Lambsquarte (*Chenopodium album)*, Alligator weed (*Alternanthera philoxeroides)*, Paspalum grass (*Paspalum commersonii*), Hatishur (*Heliotropium indicum)* and pig weed (*Amaranthus viridis)*. Among the weed species, Barnyard grass (*Echinochloa crusgalli*), Harkuch (*Enhydra fluctuans*), Nutsedge (*Cyperus rotundus*), Bermuda grass *(Cynodon dactylon)* and Jersey cudweed (*Gnaphalium affine*) were the common and dominant weeds in the sorghum field. The relative density of the major weed species among the treatments ranges from 18.81-74.04, 1.78-23.33,2.96-20,2.12 -6.29 and 16.97 -33.86%, respectively. *C. dactylon*, *E.crusgalli, C. rotundus*, *G. affine* and *E. fluctuans*at 25 days after emergence (DAE). *D. sanguinalis, E. indica*, *C. rotundus*, *V. sativa* and *R. maritimus* occured in lesser number at 25 DAE. At 45 DAE, *C. dactylon*, *E. crusgalli, C. rotundus* and *G. affine* were found as major weeds with their relative density among the different treatments ranges from 7.17-45.24, 3.00-13.33, 1.63-24.39 and 2.22-25.09%, respectively. *E. fluctua, P. commersoni*, *A. viridis*, *H. indicum* and *C. album* occurred in lesser number.

Two hand weeding (HW) recorded significantly lower number of all the weed m^{-2} at 25 and 45 DAE. At 25 DAE, among the weed management plots the number of weeds ranged from 40 to 63 m^{-2}. The highest weed population (106 m^{-2}) was recorded in T_7 treatment at 25 DAE. At 45 DAE, numbers of weeds ranged from 45 to 82 m^{-2}. The highest weed population (186 m^{-2}) was recorded in T_7 treatment at 45 DAE. The number of weeds were increased in all the plots at 45 DAE than 25 DAE. Among the chemical treatments, application of Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 DAS, Pendimethalin @ 3 L ha^{-1}

spraying as pre-emergence + one hand weeding at 25 DAS and Atrazine @ 2 L ha^{-1} spraying as post-emergence at 15 DAS + one hand weeding at 40 DAS were very effective in controlling the weeds which recorded a weed density of 45 and 49, respectively (Table 1).

Table1. Effect of different of weed management method on weed species, weed number m^{-2} and weed density (%) over time average two years

Treatment	English name	Scientific name	25 DAE		45 DAE	
			Number of weed m^{-2}	Weed density (%)	Number of weed m^{-2}	Weed density (%)
T_1	Scrab grass	*Digitaria sanguinalis*	-	-	4	4.88
	Nutsedge	*Cyperus rotundus*	8	20.00	1	1.63
	Alligator weed	*Alternanthera philoxeroides*	-	-	7	8.13
	Harkuch	*Enhydra fluetuans*	8	20.00		
	Vetch	*Vicia satiua*	-		4	4.88
	Barnyard grass	*Echinochloa crusgali*	9	23.33	9	11.38
	Jersey cudweed	*Gnaphalium affine*	-		4	4.88
	Bitter dock	*Rumexm aritimus*	3	6.67	3	3.25
	Goose grass	*Eleusine indica*	3	6.67		
	Bermuda grass	*Cynodon dactylon*	9	23.33	12	14.63
	Kanai nala	*Cyanotis axillaris*	-	-	1	1.63
	Total		40		45	
T_2	Nutsedge	*Cyperus rotundus*	1	2.96	3	4.94
	Alligator weed	*Alternanthera philoxeroides*			21	39.51
	Lambsquarte	*Chenopodium album*	1	2.96		
	Harkuch	*Enhydra fluetuans*	9	20.74		
	Barnyard grass	*Echinochloa crusgali*	1	2.96	5	9.88
	Jersey cudweed	*Gnaphalium affine*			4	7.41
	Goose grass	*Eleusine indica*			4	7.41
	Bermuda grass	*Cynodon dactylon*	33	74.07	17	32.10
		Total	45		55	
T_3	Scrab grass	*Digitaria spp*			11	13.01
	Nutsedge	*Cyperus rotundus*	3	5.03		
	Alligator weed	*Alternanthera philoxeroides*			20	24.39
	Lambsquarter	*Chenopodium album*	1	2.52		
	Harkuch	*Enhydra fluetuans*	16	21.33		
	Barnyard grass	*Echinochloa crusgali*	1	1.78	7	8.13
	Jersey cudweed	*Gnaphalium affine*	-		4	4.88
	Pig weed	*Amaranthu sviridis*	-		3	3.25
	Bitter dock	*Rumex maritimus*			1	1.63
	Goose grass	*Eleusine indica*	3	3.56	5	6.50
	Bermuda grass	*Cynodon dactylon*	29	55.35	31	37.40
		Total	53		82	
T_4	Scrab grass	*Digitaria sanguinalis*			3	4.76
	Nutsedge	*Cyperus rotundus*	3	4.23	9	16.67
	Alligator weed	*Alternanthera philoxeroides*			16	28.57
	Lambs quarter	*Chenopodium album*	1	2.12		

Treatment	English name	Scientific name	25 DAE		45 DAE	
			Number of weed m^{-2}	Weed density (%)	Number of weed m^{-2}	Weed density (%)
	Harkuch	*Enhydra fluetuans*	21	33.86		
	Barnyard grass	*Echinochloa crusgali*	11	16.93	2	3
	Jersey cudweed	*Gnaphalium affine*	1	2.12	3	4.76
	Goose grass	*Eleusine indica*	1	2.12		
	Bermuda grass	*Cynodon dactylon*	25	40.21	25	45.24
		Total	63		56	
T_5	Scrab grass	*Digitaria sanguinalis*			7	11.11
	Nutsedge	*Cyperus rotundus*			4	6.67
	Alligator weed	*Alternanthera philoxeroides*			25	42.22
	Lambs quarter	*Chenopodium album*	3	5.44		
	Harkuch	*Enhydra fluetuans*	12	24.49		
	Barnyard grass	*Echinochloa crusgali*	3	5.44	8	13.33
	Jersey cudweed	*Gnaphalium affine*			1	2.22
	Goose grass	*Eleusine indica*	4	8.16		
	Bermuda grass	*Cynodon dactylon*	27	54.42	15	24.44
		Total	49		60	
T_6	Scrab grass	*Digitaria spp*			5	9.36
	Nutsedge	*Cyperusrotundus*	5	9.70	5	9.36
	Alligator weed	*Alternantheraphiloxeroides*			11	18.71
	Lambs quarter	*Chenopodium album*	1	2.42		
	Harkuch	*Enhydra fluetuans*	9	16.97		
	Vetch	*Vicia satiua*			4	7.02
	Barnyard grass	*Echinochloa crusgali*	7	12.12	3	4.68
	Jersey cudweed	*Gnaphalium affine*			3	4.68
	Bitter dock	*Rumexm aritimus*			7	11.70
	Goose grass	*Eleusineindica*	5	7.27	4	7.02
	Bermuda grass	*Cynodon dactylon*	27	48.48	15	25.73
		Total	55		57	
T_7	Scrab grass	*Digitaria sanguinalis*	4	3.77	21	11.47
	Nutsedge	*Cyperus rotundus*	11	10.06	4	2.15
	Alligator weed	*Alternanthera philoxeroides*			28	15.05
	Hatisur	*Heliotra piumindicum*			7	3.58
	Paspalum grass	*Paspalum commergonii*			3	1.43
	Harkuch	*Enhydra fluetuans*	23	21.38		
	Vetch	*Vicia Satiua*			4	2.15
	Barnyard grass	*Echinochola crusgali*	15	13.84	17	9.32
	Jersey cudweed	*Gnaphalium affine*	7	6.29	47	25.09
	Pig weed	*Amaranthus viridis*	4	3.77	3	1.43
	Wild radish	*Raphanus rahanistrum*	4	3.77		
	Bitter dock	*Rumex maritimus*	4	3.77	25	13.62
	Goose grass	*Eleusine indica*	7	6.29	11	5.73
	Bermuda grass	*Cynodon dactylon*	20	18.87	13	7.17
	Lambs quarter	*Chenopodium album*	7	6.29	3	1.43
		Total	106		186	

T_1 = Two hand weeding at 25 and 40 days after sowing (DAS), T_2 = Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 days after sowing (DAS), T_3 =Atrazine @ 2 L ha^{-1} spraying as pre-emergence +weeding by BARI weeder at 25 days after sowing (DAS), T_4 = Atrazine @ 2 L ha^{-1} spraying as post-emergence at 25 DAS + one hand weeding at 40 days after sowing (DAS), T_5 = Pendimethalin @ 3 L ha^{-1}spraying as pre-emergence +one hand weeding at 25 days after sowing (DAS), T_6 = Pendimethalin @ 3 L ha^{-1} spraying as pre-emergence and T_7= No weeding and no herbicide

The present results are in agreement with the earlier findings of Priya and Kubsad (2013). Sorghum in very early stages of crop development grows slowly and competes weakly with weeds. This is the critical time and a small amount of weed in the field will cause a substantial reduction in yield (Saini *et al*., 2018). Hence the above treatments were effective in controlling the weeds in the earlier stages of the crop producing very low weed density. The weeds were very densely populated in the control plot. Herbicides in combination with good cultural practices would effectively reduce the density of the weed population in crop production (Greer and Denman, 1983).

The dry matter of the weeds was influenced by different weed control strategies (Table 2). As the level of herbicides or weed control practices increases there was a great decrease in the dry matter accumulation by weeds (Shakoor *et al*., 2000). The treatment atrazine @ 2 L ha^{-1} as pre-emergence + one hand weeding at 25 DAS producing comparatively lower weed dry weight (21.0 g m^{-2} at 25 DAE and 30.7 g m^{-2} at 45 DAE at 2022-23 and 5.10 g m^{-2}at 25 DAE and 63 g m^{-2} at 45 DAE at 2023-24). Other than the above treatments, dry matter accumulation by the weed was controlled effectively by two hand weeding @ 25 and 40 DAS, atrazine @ 2L ha^{-1} as post emergence + one hand weeding at 45 DAS and Pendimethalin @ 3L ha^{-1} as pre-emergence + one hand weeding at 25 DAS. The reason for the low dry matter accumulation by the weed in different weed management practices is because of their effectiveness in suppressing the weeds. These results were in similarity with the findings of Shakoor *et al*., (2000). On the other hand, highest weed dry matter was accumulated in the (T_7) weeded plots (128.7 g m^{-2} at 25 DAE 314.7 g m^{-2} at 45 DAE at 2022-23 and 34.67 g m^{-2} at 25 DAE 342 g m^{-2} at 45 DAE at 2023-24) as the crops in the treatment was completely competed by the weeds because of the non-interference in the growth of weeds utilizing maximum resources (Deshmukh and Usadadia, 2017).

Weed control efficiency (WCE) denotes the magnitude of weed reduction due to weed control treatment (Mani *et al*., 1973). The WCE was affected by different treatment. The highest WCE (84.4% at 25 DAE and 90.2% at 45 DAE at 2022-23 and 85.28% at 25 DAE and 81.58% at 45 DAE at 2023-24) was found in T_2 (Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 DAS) treatment. Priya and Kubsad (2013), Pandey *et al*., 2001 and Thakur *et al*., 2016 have also obtained similar effect of various weed control treatments on WCE.

Table 2. Weed dry weight (g m^{-2}) and weed control efficiency at 25 DAE and 45 DAE as affected by different treatments during *rabi* seasons of 2022-23 and 2023-24

Treatment	Dry weight of weed (g m^{-2})				Weed control efficiency (%)			
	2022-23		2023-24		2022-23		2023-24	
	25 DAE	45 DAE	25 DAE	45 DAE	25 DAE	45 DAE	25 DAE	45 DAE
T_1	21.3	36.7	8.69	84.70	83.5	88.2	74.92	75.23
T_2	21.0	30.7	5.10	63.00	84.4	90.2	85.28	81.58
T_3	24.7	52.7	6.29	77.76	80.7	83.2	81.86	77.26
T_4	25.3	38.7	6.78	81.00	80.4	87.5	80.44	76.32
T_5	23.0	44.7	6.67	76.50	82.1	85.6	80.77	77.63
T_6	25.7	37.3	6.10	94.50	80.2	87.9	82.40	72.37
T_7	128.7	314.7	34.67	342.00	00	00	00	00

T_1 = Two hand weeding at 25 and 40 days after sowing (DAS), T_2 = Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 days after sowing (DAS), T_3 =Atrazine @ 2 L ha^{-1} spraying as pre-emergence + weeding by BARI weeder at 25 days after sowing (DAS), T_4 = Atrazine @ 2 L ha^{-1} spraying as post-emergence at 25 DAS + one hand weeding at 40 days after sowing (DAS), T_5 = Pendimethalin @ 3 L ha^{-1}spraying as pre-emergence +one hand weeding at 25 days after sowing (DAS), T_6 = Pendimethalin @ 3 L ha^{-1}spraying as pre-emergence and T_7= No weeding and no herbicide

Leaf Area Index

Leaf area index (LAI) varied as influenced by different weed management practices (Fig. 2). Leaf area index did not differ at 30 DAE among the different weed management treatment but markedly differed at 60 DAE and up to 75 DAE. Treatment T_2 (Atrazine @ 2 L ha^{-1} spraying as pre-emergence +one hand weeding at 25 DAS) and T_5(Pendimethalin @ 3 L ha^{-1}spraying as pre-emergence + one hand weeding at 25 DAS) gave the maximum LAI of 3.38 and 3.31 at 75 DAE followed by T_1 and T_4. Treatment T_7 gave the lowest LAI of 1.89. Similar findings were obtained by Suseendran *et al*., (2019).

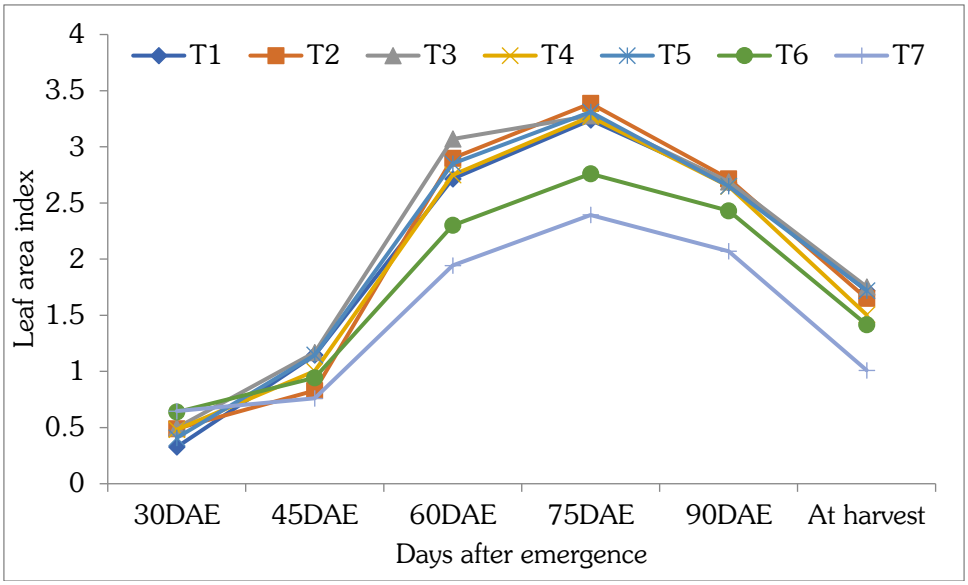

Fig 2. Leaf area index (LAI) of sorghum at different DAE as influenced by different weed management. Here,T_1 = Two hand weeding at 25 and 40 days after sowing (DAS), T_2 = Atrazine @ 2 L ha^{-1} spraying as pre-emergence +one hand weeding at 25 days after sowing (DAS), T_3 =Atrazine @ 2 L ha^{-1} spraying as pre-emergence +weeding by BARI weeder at 25 days after sowing (DAS), T_4 = Atrazine @ 2 L ha^{-1} spraying as post-emergence at 25 days after sowing (DAS) + one hand weeding at 40 days after sowing (DAS), T_5 = Pendimethalin @ 3 L ha^{-1}spraying as pre-emergence +one hand weeding at 25 days after sowing (DAS), T_6 = Pendimethalin @ 3 L ha^{-1}spraying as pre-emergence and T_7= No weeding and no herbicide

Total dry matter production

Total dry matter (TDM) accumulation in sorghum increased over time as influenced by different weed management methods (Fig.3). Difference in TDM production per unit area among the treatments started sharply from 60 DAE then increased rapidly up to 90 DAE and then increased slowly up to harvest. The maximum amount (1987 gm^{-2}) of TDM per unit area was recorded in T_2 (Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 DAE) followed by T_5, T_4 and T_1 treatment and it was higher than other treatments throughout the growing period. The lowest TDM was observed in T_7 (no weeding and no herbicide) treatment followed by T_6 treatment. It might be due to better utilize the growth resources for growth and development as compared to other treatments and produced maximum TDM and T_7 treatment produced the minimum TDM (1163 g m^{-2}). Similar findings were also observed by BARI (2008).

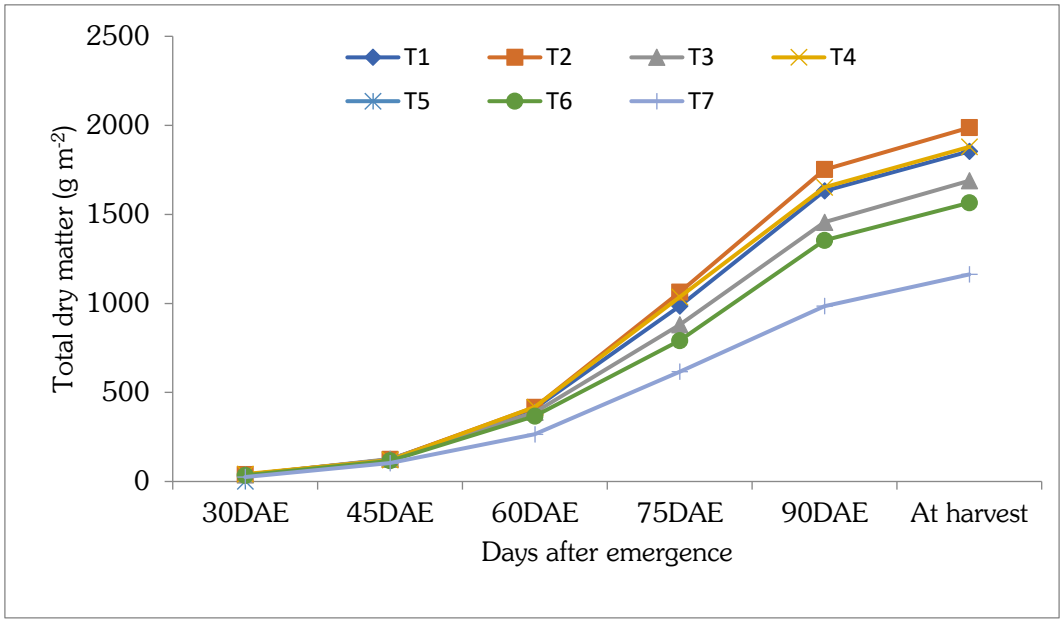

Fig. 3. Total dry matter accumulation of sorghum at different DAE as influenced by different weed management. Here, T_1 = Two hand weeding at 25 and 40 days after sowing (DAS), T_2 = Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 days after sowing (DAS), T_3 =Atrazine @ 2 L ha^{-1} spraying as pre-emergence + weeding by BARI weeder at 25 days after sowing (DAS), T_4 = Atrazine @ 2 L ha^{-1} spraying as post-emergence at 25 days after sowing (DAS) + one hand weeding at 40 days after sowing (DAS), T_5 = Pendimethalin @ 3 L ha^{-1}spraying as pre-emergence +one hand weeding at 25 days after sowing (DAS), T_6 = Pendimethalin @ 3 L ha^{-1} spraying as pre-emergence and T_7= No weeding and no herbicide

Crop growth rate

Crop growth rate (CGR) values of sorghum increased progressively with time in different weed management methods (Fig.4) except T_7 (No weeding and no herbicide). The CGR values declined from 90 DAE in T_7 because of maximum crop weed competition. Treatment T_2 (Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 DAS)gave the maximum CGR values of 45.89 gm^{-2} day^{-1} at 90-75 DAE, which was followed by T_1(43.13g m^{-2} day^{-1}), T_4 (44.49 g m^{-2} day^{-1}) and T_5 (44.12 g m^{-2} day^{-1}) treatment. Leaf area index, TDM and CGR values of sorghum under different weed management methods indicate that application of Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 DAS and Pendimethalin @ 3 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 days after sowing (DAS) had no adverse effect on sorghum. The results are in agreement with the reports of BARI (2008).

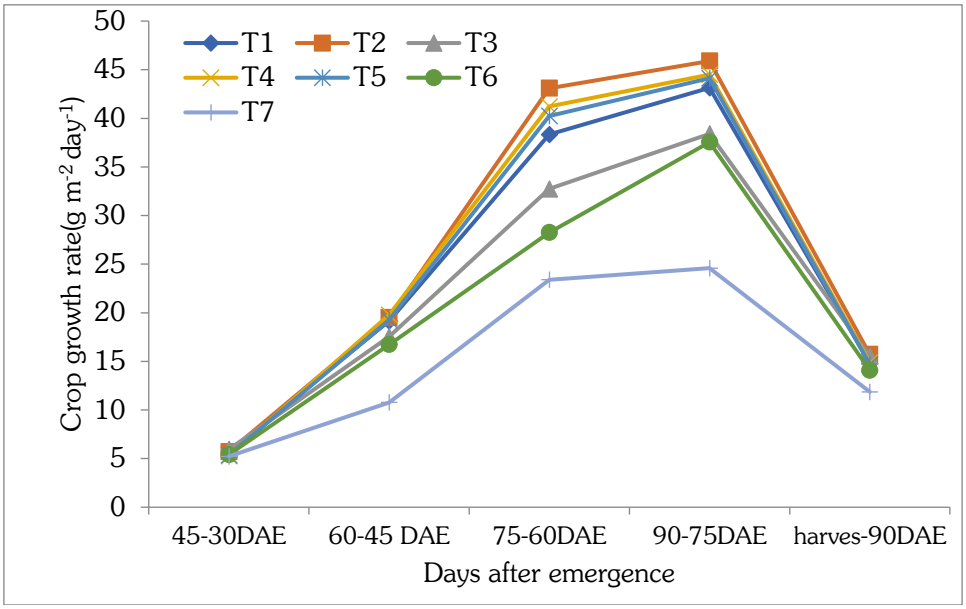

Fig.4. Crop growth rate of sorghum at different DAE as influenced by integrated weed management. Here, T_1 = Two hand weeding at 25 and 40 days after sowing (DAS), T_2 = Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 days after sowing (DAS), T_3 =Atrazine @ 2 L ha^{-1} spraying as pre-emergence + weeding by BARI weeder at 25 days after sowing (DAS), T_4 = Atrazine @ 2 L ha^{-1} spraying as post-emergence at 25 days after sowing (DAS) + one hand weeding at 40 days after sowing (DAS), T_5 = Pendimethalin @ 3 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 days after sowing (DAS), T_6 = Pendimethalin @ 3 L ha^{-1} spraying as pre-emergence and T_7= No weeding and no herbicide

Plant height, yield and yield component of sorghum

Plant population m^{-2}, plant height at harvest, yield and yield components of sorghum were significantly affected by different weed management methods (Table 3). Plant population per unit area varied from 12 to 16 m^{-2}. The highest population (16 m^{-2}) was recorded from treatment T_3, T_4, T_1, T_5 and T_6 which were identical to treatment T_2. The lowest population (12 m^{-2}) recorded in T_7 treatment. The highest plant height (134.32 cm) was found in T_5 (Pendimethalin @ 3 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 DAS) treatment which was followed by T_1, T_2, T_3 and T_4 treatments. The height of the plants was high on the above treatments is because that these treatments are effective in controlling the weeds hence offering less competition to the crop and the lowest plant height (109.67 cm) was observed in T_7 (No weeding and no herbicide) treatment. This might be due to severe crop weed competition throughout the crop growth period, which adversely hampered the normal expansion of the crop (Patel *et al.*, 2014). The longest (17.97 cm) panicle was observed in T_2 (Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 DAS) treatment which was followed by T_1, T_3, T_4, T_5 and T_6 treatments and the shortest (14.50 cm) was in T_7 treatment. Long panicle had higher number of grains $panicle^{-1}$. The highest number of grain $panicle^{-1}$ (948) was found in T_2 (Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 DAS) treatment which was statistically similar to T_1 and T_5 treatments and the lowest number of grain $panicle^{-1}$ (680) was observed in T_7 treatment. The highest 1000-grain weight (35.34 g) was obtained in T_5 (Pendimethalin @ 3 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 DAS) treatment which was satistically similar to T_1 and T_2 treatments and the lowest (29.12g) was observed in T_7 treatment. Similar findings was observed in Kumar *et al.,* (2012).

Significantly the maximum grain yield (3.64 tha^{-1}) was found in T_5 (Pendimethalin @ 3 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 DAS) treatment. However, it was

statistically similar with Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 DAS (3.55 t ha^{-1}), atrazine @ 2 L ha^{-1}spraying as post-emergence at 25 DAS + one hand weeding at 40 DAS (3.36 t ha^{-1}) and two hand weeding at 25 and 40 DAS (3.37 t ha^{-1}), respectively and the minimum grain yield (1.74 t ha^{-1}) was observed in T_7 treatment. Vigorous weed growth and severe crop weed competition drastically reduced crop yield of the control plots. However, the reduction of yield under T_7 treatment was 48% in compared with weed free throughout the growing period (T_1) followed by the reduction of 52% from T_5 treatment. The highest grain yield was attributed by the highest number of grain $panicle^{-1}$ and 1000- grain weight (Table 3). The higher yields obtained on the above treatments was due to the fact that there was reduced crop weed competition as lesser or no weeds had been observed on the above treatments. Because of that reason the availability of soil moisture, nutrients, light and other resources to the plants was very high and hence promoted higher yields. These results are in corroboration with the earlier findings of Mishra *et al*. (2012), Ramakrishna *et al*. (1991) and Thakur *et al.* (2016).

Table 3. Plant population m^{-2}, plant height, yield and yield components of sorghum as affected by different weed management methods during *Rabi* season of 2022-24

	Number of plant population m^{-2}	Plant height at harvest (cm)	Length of panicle (cm)	. Grains $panicle^{-1}$(No)	1000-grain weight (gm)	Grain yield (t ha^{-1})
T_1	14	127.77	17.00	895	34.40	3.37
T_2	16	134.32	17.97	948	34.55	3.55
T_3	15	128.34	17.22	827	31.88	2.73
T_4	15	126.11	17.56	870	34.19	3.36
T_5	17	124.45	18.11	943	35.34	3.64
T_6	15	114.56	16.35	813	29.93	2.58
T_7	13	109.67	14.50	680	29.12	1.74
LSD $_{(0.05)}$	2.20	10.54	1.79	50.16	0.27	2.74
CV (%)	8.05	4.79	5.94	3.30	4.71	5.01

T_1 = Two hand weeding at 25 and 40 days after sowing (DAS), T_2 = Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 days after sowing (DAS), T_3 =Atrazine @ 2 L ha^{-1} spraying as pre-emergence + weeding by BARI weeder at 25 days after sowing (DAS), T_4 = Atrazine @ 2 L ha^{-1} spraying as post-emergence at 25 day after sowing (DAS) + one hand weeding at 40 days after sowing (DAS), T_5 = Pendimethalin @ 3 L ha^{-1}spraying as pre-emergence + one hand weeding at 25 days after sowing (DAS), T_6 = Pendimethalin @ 3 L ha^{-1}spraying as pre-emergence and T_7= No weeding and no herbicide

Cost return performance

Economic analysis of different weed management practices on sorghum production was done (Table 4). From the cost and return analysis it was found that the highest gross return (Tk. 109300 ha^{-1}) and gross margin (Tk. 54370 ha^{-1}) was recorded in T_5 (Pendimethalin @ 3 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 DAS). The highest average yield with highest gross return was obtained from T_5 treatment and this was followed by application of Atrazine 2 L ha^{-1} + one hand weeding at 25 DAS (T_2). The lowest gross margin was in T_7 treatment (Tk. 5485 ha^{-1}). The highest BCR was obtained from T_5 (Pendimethalin @ 3 L ha^{-1} as pre-emergence + one hand weeding at 25 DAS) (2.01) followed by T_2 (1.96) treatment and the lowest benefit cost ratio was in T_7 (No weeding and no herbicide) (1.12) treatment. Hence, both the treatments (Pendimethalin @ 3 L ha^{-1} and Atrazine 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 DAS) gave the highest return and BCR.

Table 4. Cost and return analysis of sorghum as affected by different weed management method in 2022-23 and 2023-24

Treatment	Yield (t ha^{-1})	Gross return (Tk. ha^{-1})	Cost of cultivation (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR
T_1	3.37	101220	62730	38490	1.61
T_2	3.55	106525	54380	52145	1.96
T_3	2.73	81910	55345	26565	1.48
T_4	3.36	100760	56325	44435	1.79
T_5	3.64	109300	54370	54930	2.01
T_6	2.58	77275	52230	25045	1.48
T_7	1.74	52265	46780	5485	1.12

T_1 = Two hand weeding at 25 and 40 days after sowing (DAS), T_2 = Atrazine @ 2 L ha^{-1} spraying as pre-emergence + one hand weeding at 25 days after sowing (DAS), T_3 =Atrazine @ 2 L ha^{-1} spraying as pre-emergence + weeding by BARI weeder at 25 days after sowing (DAS), T_4 = Atrazine @ 2 L ha^{-1} spraying as post-emergence at 25 day after sowing (DAS) + one hand weeding at 40 days after sowing (DAS), T_5 = Pendimethalin @ 3 L ha^{-1}spraying as pre-emergence + one hand weeding at 25 days after sowing (DAS), T_6 = Pendimethalin @ 3 L ha^{-1}spraying as pre-emergence and T_7= No weeding and no herbicide. Sorghum-30 Tk.kg^{-1}

Conclusion

From the present investigation it can be concluded that pre-emergence application of Atrazine @ 2 L ha^{-1}+ one hand weeding at 25 DAS and Pendimethalin @ 3 L ha^{-1} + one hand weeding at 25 DAS proved practically more convenient and economically best feasible integrated weed management practice for sorghum considering the present condition of scarcity and high cost of labors, quality weed control, yield and money invested of cultivation of sorghum.

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