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Integrated Weed Management in Turmeric (*Curcuma longa*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was conducted at Regional Spices Research Centre, BARI, Magura during the cropping season of 2021-22 and 2022-23 to find out the best management practices for controlling the weed of turmeric. The experiment was laid out in a randomized complete block design with three replications. Nine different treatments and a control plot were studied. Significant differences regarding yield and yield attributes were observed among different treatments. The results revealed that *Cyperus rotundu*s was the major weed constituting 51% of the total weed flora. All treatments brought significant reduction in the count of weeds over control. The lowest number of these weeds was recorded in glyphosate @ 10 ml/L+ 1 HW at 70 DAP + straw mulch @ 5 t/ha treated plot. The highest fresh yield (64.63 t/ha in 2021-22 and 58.28 t/ha in 2022-23) was found from treatment T_5 (glyphosate @ 10 ml/L+ 1 HW at 70 DAP + straw mulch @ 5 t/ha) and the lowest yield (20.16 kg/ha in 2021-22 and 20.07 in 2022-23) was found from control plot $T_{10.}$ Maximum weed control efficiency (91.97%) was found from treatment T_5 (glyphosate @ 10 ml/L+ 1 HW at 70 DAP + straw mulch @ 5 t/ha). Benefit cost ratio (BCR) was highest under glyphosate @ 10 ml/L+ 1 HW at 70 DAP + straw mulch @ 5 t/ha (3.75) followed by T_6 (Paraquat @ 10 ml/L+ 1 HW (70 DAP) + straw mulch 5 t/ha (3.33).

Keywords: Turmeric; weeds; glyphosate; straw mulch; yield.

1. INTRODUCTION

Turmeric, the dried rhizome of the herbaceous perennial *Curcuma longa* L. under the family zingiberaceae, is a crop of warm-humid climate native to South Asia [1]. Among the numerous uses of turmeric, it is generally used as a spice, cosmetic, coloring agent, flavorantand preservative, and is also imputed universally for its aromatic, stimulative and carminative properties. It is also marketed as a spice, dye, oleoresin, complexion agent and source of industrial starch [2,3,4]. The principal constituent of turmeric is curcumin, which is diferuloylmethane. Other constituents are curcuminoids and an essential oil called zingiberene. The yellow coloring substances are known as curcuminoids [5]. Globally, around 1.1 million metric tons of turmeric are produced per year, and India holds the 1st position in production, consumption and export. India produces 80% of the total world's turmeric followed by China (8%), Myanmar (4%), Nigeria (3%) and Bangladesh (3%). Turmeric powder is one of the major spices in Bangladesh. Every year, Bangladesh imports around 49,522 tons of turmeric from India [6].

Though in Bangladesh, turmeric is being grown over the country but area and production are in decreasing despite f increasing yield potential [7]. Turmeric is a long-durational crop that takes 270 days from planting to harvest. During this long period, it faces high rainfall during monsoons and dry spells during pre-and post-monsoons, as well as a high abundance of weed pressure. Delayed emergence, slow initial growth of the crop and ample land space available due to wider spacing permit more sunlight to reach the soil resulting in a conducive environment for rapid weed growth and covering the ground quickly which causes enormous damage to crop yield [8,9]. Weed competition is one of the limiting factors for low crop yields. Due to improper weed management, 30-70% yield losses have been reported because of delayed emergence, slow initial growth, poor crop canopy development and long duration [10,11,12]. The successful cultivation of the crop mainly depends on weeds management. But there is no single method by which weeds can be controlled effectively below threshold level. Conventional weed management practices are costly, unavailability of labor in time and exhaustive due to different back-pulling reasons, especially in transplanted turmeric. The chemical method of weed control is not only cheaper but also feasible for timely application; however, it requires more care with reference to the appropriate selection of herbicide, its dose and time of application.

A judicious combination of chemicals and cultural control practices for weed management reduces the expenditure as well as gives benefit to the crop plants by providing proper aeration, conservation of moisture and nutrients [13]. The best practices for managing weeds in turmeric have been determined to be integrating the use of herbicides and mulches [14,15], herbicides and hand weeding/hoeing [16, 3], or applying herbicides in alpha and omega sequentially [17]. Mulch plays an important role in controlling weeds. The placement of mulch reduced the weed species and provided the congenial conditions for crops to grow and develop [18].

Keeping these points in mind, the present investigation was planned to develop an effective integrated weed management strategy for turmeric.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the Regional Spices Research Center, BARI, Magura during the cropping seasons of 2021-22 and 2022-23 to find out the best integrated management practices for controlling weeds of turmeric. The experimental site belongs to the Agro-Ecological Zone (AEZ) No. 11 (High Ganges River Floodplain) and the geographic coordinates are latitude: 23º29'18.468546" N, longitude: 89˚24'8.06306" E. The soil is clay loam in texture and has a pH of 7.54.

2.2 Experimental Design and Treatment

The experiment was laid out in randomized complete block design with three replications. Nine different treatments with one control plot were studied. The treatments were T_1= Glyphosate @ 10 ml/L+ 2 HW (45, 70 DAP), T_2= Paraquat @ 10 ml/L+ 2 HW (45, 70 DAP), T_3= Oxyfluropen @ 3 ml/L + 2 HW (45, 70 DAP), T_4= Pendimethalin @ 5 ml/L +2 HW (45, 70 DAP), T5= Glyphosate @ 10 ml/L + 1 HW (70 DAP)+ Straw mulch 5 t/ha , T_6= Paraquat @ 10 ml/L+ 1 HW (70 DAP)+ Straw mulch 5t/ha, T_7= Oxyfluropen @ 3 ml/L + 1 HW (70 DAP) + Straw mulch 5t/ha, T_8= Pendimethalin @ 5 ml/L+ 1 HW (70 DAP)+ Straw mulch 5t/ha, T_9= 3 HW (25,45,70 DAP)and T_{10}= Control (Weedy/No weed control) were studied. A turmeric variety namely BARI Holud-4 was used as a planting material. A unit plot sized 3 m x 2 m with plant spacing of 50 cm × 30 cm was considered. Fingers of turmeric were used as planting material and planted on 25 April 2021 and 20 April 2022.

2.3 Intercultural Management for Growing of Crop

The land was fertilized with cow dung, N, P, K, S and Zn at rates of 10t, 100, 36, 85, 20 and 2 kg per hectare, respectively. The entire cow dung, triple super phosphate, muriate of potash, zinc sulphate and gypsum were applied at the time of final land preparation. Half of urea was applied at 50 days after planting. Remaining urea and muriate of potash were applied as top dress in two equal splits at 80 and 120 days after planting. Cultural operations like watering, weeding and plant protection measures were performed as per the needs of the crop during the season. Three irrigations at 30, 70 and 100 DAP were provided. For controlling leaf spot and leaf blotch disease of turmeric fungicides were sprayed at 95, 110 and 125 DAP, respectively. The crop from the experimental plots was harvested when the leaves turned yellow or dry. The rhizomes were uprooted from the soil in such a way that they were not cut or damaged. The rhizomes were then cleaned to remove soil then air dried for an hour in a shady place and weighed for fresh yield. The weed count was recorded at 90, 120, 150 DAP, respectively and at harvest by randomly throwing a quadrat in the plot.

2.4 Data Collection and Analysis

Data on days to germination (d), plant height (cm), number of leaves per clump, number of tillers per clump, number of mother rhizomes, weight of mother rhizome per clump (g), number of primary fingers, weight of primary fingers (g), number of secondary fingers per clump, weight of secondary fingers (g), weight of rhizome per clump, rhizome yield (t/ha) and weed per square meter were recorded. The recorded data on different parameters were statistically analyzed by using Statitix10 software to find out the significance of variation resulting from the experimental treatments. To determine the cost-efficiency of the treatments, the Benefit Cost Ratio (BCR) was calculated based on the local market price of turmeric chunks and input costs. The BCR was measured by the following formula:

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross return}}{\text{Total cost of production}}$$

3. RESULTS

3.1 Weed Species

Different grassy and broadleaf weed species were identified in the experimental field of turmeric (Table 1). All these perennials and annul weed species were abundantly growing in the experimental site. *Cyperus rotundus* (51%) was the most dominant weed observed in the experimental plots (Table 1). The other weed species recorded in the field area were *Amaranthus spinosus (*11%), *Echinochloa colonum (*7%), *Eleusine indica (*6%), *Dactyloctenium aegyptium (5%), Leptochola chinensis (*4%), *Amaranthus viridis (*3%), *Digitaria ischaemum (*3%), *Cynodon dactylon (*2%) and others weed (8%).

3.2 Weed Control Efficiency

Significant variation was observed among the different treatments for controlling weeds of turmeric (Table 2). The lowest number of weeds per meter square (37.67 in 2021-22 and 49.33 in 2022-23) was found from treatment T_5 (glyphosate @ 10 ml/L + 1 HW (70 DAP) + straw mulch @ 5 t/ha) and the highest number of weeds per meter square (470.00 in 2021-22 and 500.00 in 2022-23)) was found from the control plot. The maximum weed control efficiency (91.97 % in 2021-22 and 89.98 % in 2022-23) was found from T_5 treatment compared to control treatment.

3.3 Effect of Different Treatments on Growth and Yield of Turmeric

The growth characters of turmeric as influenced by different treatments are presented in Table 3. The tallest plant height (125.27 cm in 2021-22 and 119.27 cm in 2022-23), maximum number of leaves per clump (35.00 in 2021-22 and 31.67 in 2022-23) and maximum number of tillers per clump (4.33 in 2021-22 and 3.67 in 2022-23) were recorded from the treatment T_5 (glyphosate @ 10 ml/L + 1 HW (70 DAP)+ straw mulch @ 5 t/ha) while the lowest plant height (94 cm in 2021-22 and 88.00 in 2022-23), minimum number of leaves/clump (21.66 in 2021-22 and 18.67 in 2022-23) and minimum number of tillers per clump (2.67 in 2021-22 and 2.60 in 2022-23) were found from control plot.

The yield and yield contributing characters of turmeric significantly influenced by the treatments (Table 4). The maximum number of mother rhizomes per plant (3.33 in 2021-22 and 3.00 in 2022-23), weight of mother rhizome per clump (165.95g in 2021-22 and 155.28g in 2022-23), number of primary fingers (14.67 in 2021-22 and 12.67 in 2022-23), weight of primary fingers (703.26 g in 2021-22 and 643.26 g in 2022-23), number of secondary fingers per clump (22.33 in 2021-22 and 19 in 2022-23), weight of secondary fingers (605.00 g in 2021-22 and 548 g in 2022-23) and weight of rhizome per clump (1500 g in 2021-22 and 1331.2 g in 2022-23) were recorded from the treatment T_5 (glyphosate @ 3kg/ha + straw mulch 10 t/ha + 1 HW at 70 DAP). The minimum number of mother rhizomes (2.33 in 2021-22 and 2.00 in 2022-23), weight of mother rhizome per clump (53.17 g in 2021-22 and 43.5 g in 2022-23), number of primary fingers (7.00 in 2021-22 and 6.00 in 2022-23), weight of primary fingers (226.59 g in 2021-22 and 181.59 g in 2022-23) , number of secondary fingers per clump (10.33 in 2021-22 and 8.00 in 2022-23), weight of secondary fingers (188.17 g in 2021-22 and 138.17 g in 2022-23) and weight per clump (483.3 g in 2021-22 and 338 in 2022-23) were recorded from the control plot.

Effect of different treatments on yield of turmeric is presented in Table 5. Significantly the highest fresh rhizome yield (64.63 t/ha), dry yield (9.70 t/ha) and maximum yield increase over control were recorded from the treatment T_5 (glyphosate @ 10 ml/L + straw mulch @5t/ha + 1 HW at 70 DAP). Lowest fresh rhizome yield (20.16 t/ha), dry yield (3.02 t/ha) were found in control treatment.

Table 1. Different weed species found in turmeric experiment field in RSRC, BARI, Magura

Sl. No.	Bengali name	Common name /English name	Scientific name	Proportion of total weeds (%)
01	Mutha	Nutsedge	*Cyperus rotundus*	51
02	Kanta notae	Spiny pig weed	*Amaranthus spinosus*	11
03	Choto shama	Jungle rice	*Echinochloa colonum*	7
04	Chapra	Goose grass	*Eleusine indica*	6
05	Kakpaya	Crow foot weed	*Dactyloctenium aegyptium*	5
06	Fulka ghash	Leptochola grass	*Leptochola chinensis*	4
07	Shak notae	Pig weed	*Amaranthus viridis*	3
08	Anguli ghash	Scrab grass	*Digitaria ischaemum*	3
09	Durba	Bermuda grass	*Cynodon dactylon*	2
10	Others weed species			8

Table 2. Effect of different treatments for controlling weeds of turmeric field at the RSRC, BARI, Magura

Treatment	Number of weeds/m^2		Weed control efficiency (%)	
	2021-22	2022-23	2021-22	2022-23
T_1	175.00 c	192.33 c	62.74 e	61.07 d
T_2	97.33 e	113.33 d	79.28 c	77.12 c
T_3	161.67 cd	178.00 c	65.58d e	63.91 d
T_4	92.67 e	108.67 d	80.28 c	78.06 bc
T_5	37.67 g	49.33 e	91.97 a	89.98 a
T_6	67.67 f	84.00 de	85.59 b	83.00 b
T_7	96.67 e	112.67 d	79.42 c	77.17 c
T_8	151.67 d	167.00 c	67.71 d	66.14 d
T_9	253.33 b	272.67 b	46.03 f	44.53 e
T_{10}	470.00 a	500.00 a	0	0.00
CV (%)	5.35	12.43	2.76	4.76
L.S.	**	**	**	**

*(Note: Mean followed by the same letter did not differ significantly. CV= Coefficient of variation, L. S. = Level of significance, significant, * *= 1% level of significance. T1= Glyphosate @ 10 ml/L + 2 HW (45, 70 DAP), T2= Paraquat @ 10 ml/L + 2 HW (45, 70 DAP), T3= Oxyfluropen @ 3 ml/L + 2 HW (45, 70 DAP), T4= Pendimethalin @ 5 ml/L +2 HW (45, 70 DAP), T5= Glyphosate @ 10 ml/L + 1 HW (70 DAP)+ Straw mulch @ 5t/ha, T6= Paraquat @ 10 ml/L + 1 HW (70 DAP)+ Straw mulch @ 5t/ha, T7= Oxyfluropen @ 3 ml/L + 1 HW (70 DAP) + Straw mulch @ 5t/ha, T8= Pendimethalin @ 5 ml/L + 1 HW (70 DAP)+ Straw mulch @ 5t/ha, T9= 3 HW (25,45,70 DAP), T10= Control.*

Table 3. Effect of different treatments of the experiment on growth characters of BARI Holud-4 during the cropping seasons of 2021-22 and 2022-23 at the RSRC, BARI, Magura

Treatments	Plant height (cm)		No. of leaves/clump		No. of tillers/clump	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T_1	107.67 c	101. d	30.67 c	28.00 b	3.00 bc	3.00 abc
T_2	109.33 cd	102.67 cd	29.67 d	26.33 c	3.00 bc	2.67 bc
T_3	102.67 e	96.00 e	30.67 c	27.33 bc	3.33 bc	3.33 ab
T_4	107.33 d	101.00 d	29.33 d	26.33 c	3.33 bc	3.00 abc
T_5	125.27 a	119.27 a	35.00 a	31.67 a	4.33 a	3.67 a
T_6	118.42 b	112.76 b	34.00 b	31.00 a	3.67 ab	3.67 a
T_7	111.67 c	105.33 c	29.67 d	27.00 bc	3.00 bc	3.00 abc
T_8	119.6 b	113.93 b	29.33 d	26.67 bc	2.67 c	2.33 c
T_9	108.33 d	102.33 cd	31.33 c	28.00 b	3.33 bc	3.00 abc
T_{10}	94.00 f	88.00 f	21.67 e	18.67 d	2.67 c	2.60 bc
CV (%)	1.55	2.00	1.46	3.09	14.21	13.75
L.S.	**	**	**	**	**	**

*(Note: Mean followed by the same letter did not differ significantly. CV= Coefficient of variation, L. S. = Level of significance, significant, * *= 1% level of significance.) T1= Glyphosate @ 10 ml/L+ 2 HW (45, 70 DAP), T2= Paraquat @ 10 ml/L + 2 HW (45, 70 DAP), T3= Oxyfluropen @ 3 ml/L + 2 HW (45, 70 DAP), T4= Pendimethalin @ 5 ml/L +2 HW (45, 70 DAP), T5= Glyphosate @ 10 ml/L + 1 HW (70 DAP)+ Straw mulch @ 5t/ha, T6= Paraquat @ 10 ml/L + 1 HW (70 DAP)+ Straw mulch @ 5t/ha, T7= Oxyfluropen @ 3 ml/L + 1 HW (70 DAP) + Straw mulch @ 5t/ha, T8= Pendimethalin @ 5 ml/L + 1 HW (70 DAP)+ Straw mulch @ 5t/ha, T9= 3 HW (25,45,70 DAP), T10= Control.*

3.4 Cost Benefit Analysis

The economic performance of turmeric as influenced by different weed management practices are presented in the Table 6. The highest (3.9) BCR was found from the treatment T_5 (glyphosate @ 10 ml/L + straw mulch @ 5t/ha + 1 HW at 70 DAP) and the lowest (1.40) BCR was recorded from control plot.

Table 4. Yield and yield contributing characters of BARI Holud-4 influenced by different weed management practices during the cropping seasons of 2021-22 and 2022-23 at the RSRC, BARI, Magura

Treatment	No. of mother rhizome (nos.)		Wt. of mother rhizome (g)		No. of primary Fingers (nos.)		Wt. of primary fingers (g)		No. of secondary Fingers (nos.)		Wt. of secondary Fingers (g)		Wt. of rhizome/ clump (g)	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T_1	3.0 ab	2.6 ab	94.2 c	83.2c	10.0 c	8.3cd	397.8c	350.5c	15.3d	12.6de	338.5c	285.5c	850.0c	703.9c
T_2	3.3 a	3.0 a	80.2 d	70.2d	10.0c	8.3cd	342.1d	292.4d	16.6c	14.0c	287.9d	245.2d	726.7d	592.6d
T_3	2.6 bc	2.6 ab	66.5 e	55.5e	8.6d	7.6d	284.2e	233.8e	15.0de	12.6de	238.7e	178.7e	606.7e	452.9e
T_4	2.6 bc	2.3 ab	87.6 cd	76.6cd	9.0d	7.6d	372.7d	326.0d	16.6c	14.0c	315.2cd	259.2cd	793.3cd	646.7cd
T_5	3.3 a	3.0 a	165.9 a	155.2a	14.6a	12.6a	703.2a	643.2a	22.3a	19.0a	605.0a	548.0a	1500.0a	1331.a
T_6	3.0 ab	3.0 a	142.2 b	132.2b	11.6b	10.0b	604.9b	554.9b	18.6b	15.6b	520.2b	460.6b	1293.3b	1132.b
T_7	3.0 ab	3.0 a	79.0 d	69.7d	11.0b	9.6b	335.2d	291.2d	14.0f	12.0e	282.4d	229.4d	713.3d	575.1d
T_8	2.6 bc	2.6 ab	94.9 c	84.9c	11.3b	9.3bc	404.5c	356.2c	14.3ef	11.6e	343.9c	290.6c	863.3c	716.5c
T_9	2.6 bc	2.6 ab	66.9 e	57.9e	11.6b	9.6b	282.8e	239.2e	15.6d	13.6cd	237.3e	183.3e	603.3e	465.3e
T_{10}	2.3c	2.0 b	53.1f	43.5f	7.0e	6.0e	226.5f	181.5f	10.3g	8.0f	188.1f	138.1f	483.3f	348.0f
CV %	12.20	17.31	6.03	6.41	4.88	8.50	6.08	6.94	3.36	5.08	6.21	8.18	6.43	7.28
L.S.	**	**	**	**	**	**	**	**	**	**	**	**	**	**

*(Note: Mean followed by the same letter did not differ significantly. (CV= Coefficient of variation, L. S. = Level of significance, significant, * *= 1% level of significance.) T_1= Glyphosate @ 10 ml/L + 2 HW (45, 70 DAP), T_2= Paraquat @ 10 ml/L + 2 HW (45, 70 DAP), T_3= Oxyfluropen @ 3ml/L + 2 HW (45, 70 DAP), T_4= Pendimethalin @ 5 ml/L +2 HW (45, 70 DAP), T_5= Glyphosate @ 10 ml/L + 1 HW (70 DAP)+ Straw mulch @ 5t/ha, T_6= Paraquat @ 10 ml/L + 1 HW (70 DAP)+ Straw mulch @ 5t/ha, T_7= Oxyfluropen @ 3 ml/L + 1 HW (70 DAP) + Straw mulch @ 5t/ha, T_8= Pendimethalin @ 5 ml/L + 1 HW (70 DAP)+ Straw mulch @ 5t/ha, T_9= 3 HW (25,45,70 DAP), T_{10}= Control.*

Table 5. Effect of different treatments on yield of turmeric

Treatments	Fresh yield (t/ha)		Yield increase over control %	
	2021-22	2022-23	2021-22	2022-23
T_1	34.08 f	31.33 d	69.49 f	57.55 c
T_2	40.15 de	37.28 cd	100.47de	88.40 bc
T_3	37.33 e	34.52 cd	84.91 ef	72.91 bc
T_4	42.65 d	33.99 cd	112.49 d	76.42 bc
T_5	64.63 a	58.28 a	222.7 a	193.28 a
T_6	56.72 b	52.78 ab	183.51 b	169.77 a
T_7	42.44 d	39.40 c	110.48 d	98.94 b
T_8	52.20 c	51.14 b	159.09 c	162.05a
T_9	34.06 f	31.37 d	69.76 f	60.35 bc
T_{10}	20.16 g	20.07 e	0	0
CV (%)	4.00	10.46	6.77	8.42
L.S.	**	**	**	**

(Note: Mean followed by the same letter did not differ significantly. CV= Coefficient of variation, L. S. = Level of significance, significant, * *= 1% level of significance.)

Table 6. Cost benefit analysis of different weed management practices employed in the turmeric experiment during the cropping seasons of 2021-22 and 2022-23 at the RSRC, BARI, Magura

Treatment	Total cultivation cost (tk)	Yield (t/ha)	Unit price (tk/kg)	Gross return (tk)	BCR
T_1	290370.00	34.08	20.00	681660	2.34
T_2	290370.00	40.15	20.00	803000	2.76
T_3	292570.00	37.34	20.00	746780	2.55
T_4	291970.00	42.65	20.00	853000	2.92
T_5	340370.00	64.63	20.00	1292660	3.79
T_6	340370.00	56.72	20.00	1134440	3.33
T_7	342570.00	42.44	20.00	848880	2.47
T_8	341970.00	52.21	20.00	1044120	3.05
T_9	362370.00	34.06	20.00	681220	1.88
T_{10}	287370.00	20.17	20.00	403320	1.40

Urea-Tk. 22/kg, TSP-Tk. 22/kg, MoP-Tk.15/kg, Gypsum- Tk. 30/kg, Zinc sulphate –Tk.225/kg, Boric acid-Tk. 300/kg, Labour- Tk. 500/man/day, Irrigation- 3000/ha/irrigation, Leas value- Tk. 70000/ha for 12 months, Seed-1500/kg, Sale price-Tk. 20 taka/kg rhizome.

4. DISCUSSION

4.1 Weed Species

Numerous perennials and annul weed species were proliferating in the study area. The most harmful, disturbing, virulent, and noticeable of them all was Mutha (*Cyperus rotundus*), which could have a negative impact on crop growth and productivity. In addition, mutha is one of the most obnoxious weeds in the world [19]. Similar to this, [8,9] analogously showed that *Cyperus rotundus*, *Digitaria* spp., and *Eclipta prostrata*, among grasses, were the prevalent weeds in the experimental fields of turmeric.

4.2 Weed Control Efficiency

More than 150 weed species, including annual and perennial mono- and dicotyledonous plants, are known to be controlled by the nonselective post-emergence herbicide glyphosate. The foliar portions of weeds are typically treated with it. Different possible entry points for glyphosate allow it to penetrate plants, and it can also inhibit the action of particular enzymes and stop the formation of aromatic amino acids. No plant parts are capable of surviving [20,21,22]. Treatment T_5 (glyphosate at 10 ml/L plus one HW (70 DAP) + straw mulch at 5 t/ha) in this experiment had the lowest weed density per square meter reported. It can be a good blend of several weed management techniques and treatment times. For up to 60 DAP, the treated plot is weed-free thanks to the application of glyphosate @ 10 ml/L at 25 DAP. Because straw mulch spreads on top of the soil to retain soil moisture, delay weed emergence, and inhibit weed growth, the treated plot is weed-free for up to 170 days after employing straw mulch at 75 DAP [23,24]. Straw mulching, which restricts weed development by limiting resources, has been shown to dramatically reduce weed growth by Erenstein [25,26]. The application of glyphosate at 25 DAP followed by two hand weedings at 45 and 75 DAP considerably reduced total weed density, as reported by Bharty et al. [27,28,29].

4.3 Yield and Yield Contributing Character

The treatment T_5 (glyphosate @ 3 kg/ha + straw mulch @ 10 t/ha + 1 HW at 70 DAP) yielded the highest number of mother rhizomes per plant, weight of mother rhizome per clump, number of primary fingers, weight of primary fingers, number of secondary fingers per clump, weight of secondary fingers, and weight of rhizome per plant. Significantly, treatment T_5 (glyphosate @ 10 ml/L + 1 HW @ 70 DAP + straw mulch @ 5 t/ha) recorded the highest fresh rhizome yield (64.63 t/ha), dry yield (9.70 t/ha), and maximum yield increase above control. A considerable increase in the fresh weight of rhizomes per plant was also noted by Swain et al. [30] when paddy straw mulch was used as opposed to no mulch. Large temperature swings in the soil are reduced and erosion is reduced with mulch. Mulch alters the microclimate of the soil where the plants are growing. Additionally, it limits water that is allowed to flow freely, replenishes the soil profile, and lengthens the persistence of soil water repellency. Mulching with 6.25 t/ha of rice straw was advantageous for growing turmeric since it increased rhizome productivity and quality [31,32]. The control had the lowest fresh rhizome yield (20.16 t/ha) and dry yield (3.02 t/ha). Weeds compete with turmeric for nutrients, moisture and space and cause severe output decline to the extent of 35-75 percent [12]. Weed growing out of control 80 percent decreased turmeric rhizome production. Weeds caused yield losses in turmeric rhizomes that ranged from 63.9 to 76.5 percent [33,15].

4.4 BCR

Gross returns and benefit cost ratio (BCR) were highest in the T_5 (glyphosate @ 10 ml/L + straw mulch @ 5t/ha + 1 HW at 70 DAP) treated plot due to increased rhizome yield. The control plot had the lowest yield and minimal gross return, and as a result, its BCR was likewise the lowest. According to Bharty et al. [34], chemical herbicides produced the highest net return and BCR, followed by straw mulch and hand weeding. Similar findings were made by Anshuman et al. [35] who discovered that paddy straw mulching at a rate of 10 t/ha produced the highest gross return (Rs 3,29,000/ha).

5. CONCLUSION

From the above study it may be concluded combination of cultural practices and use of chemical herbicides in proper time can reduced weed significantly in turmeric field. Application of post emergence herbicide glyphosate @ 10 ml/L at 25 DAP, one hand weeding at 70 DAP and finally straw mulch @ 5 t/ha showed maximum weed control efficiency and increased yield of turmeric.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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