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Integrated weed management in turmeric

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ABSTRACT

Ten weed control treatments *viz.* metribuzin (700 g/ha) or pendimethalin (1000 g/ha) each followed by (*fb*) hoeing twice; metribuzin (700 g/ha), pendimethalin (1000 g/ha) or atrazine (750 g/ha) each followed by i) fenoxaprop (670 g/ha) + metsulfuron-methyl (4 g/ha) or ii) straw mulch *fb* hoeing; weed free (hand weeding thrice) and weedy check] were evaluated for weed control in turmeric on a silty clay loam soil at Palampur during 2012 and 2013. Treatment constituting of fenoxaprop + metsulfuron-methyl were phytotoxic. Pendimethalin *fb* hoeing and pendimethalin /metribuzin /atrazine *fb* mulch *fb* hoeing were comparable to weed free in reducing population of *Echinochloa colona*, *Digitaria sanguinalis*, *Panicum dicotomiflorum*, *Cyperus iria* and *Aeschynomene indica*. Metribuzin *fb* mulch *fb* hoeing significantly reduced the count of *Ageratum conyzoides* and *Galinsoga parviflora* upto 60 DAS. Metribuzin/pendimethalin *fb* hoeing and pendimethalin/ metribuzin/ atrazine *fb* mulch *fb* hoeing resulted in significantly higher plant height, leaves per plant, number of shoots per plant, plant dry matter accumulation, rhizome weightperplant and fresh rhizome yield over other treatments. Atrazine/ pendimethalin/metribuzin *fb* mulch *fb* hoeing increased fresh rhizome yield by 1.54-1.68 times over weed free. Metribuzin *fb* mulch *fb* hoeing resulted in highest gross and net returns due to weed control. Marginal benefit cost ratio (MBCR) was highest under pendimethalin *fb* mulch *fb* hoeing (54.67) followed by atrazine *fb* mulch *fb* hoeing (50.73), metribuzin *fb* mulch *fb* hoeing (46.2) and pendimethalin *fb* hoeing (24.86). Weeds in weedy check reduced rhizome yield by 78.2% over metribuzin *fb* mulch *fb* hoeing.

Key words: Integrated weed managment, Metribuzin, Metsulfuron, Mulch, Pendimethalin, Turmeric

Low and mid hills of Himachal Pradesh are important turmeric growing areas. It is an alternative to maize in *Kharif* season particularly in areas infested by wild boars, stray animals and porcupines. It has slow initial growth rate and shallow root system. As a result, it is invaded by a variety of weeds. Weeds compete with turmeric for nutrients, moisture and space and cause 35-75% yield reduction (Krishnamurthy and Ayyaswamy 2000). Generally, for the control of weeds, farmers do manual weeding, but with increase in labour cost and scarcity of labour, manual weed control has become a difficult task. Mulching with straw is another approach adopted by the farmers that conserves soil moisture and maintains soil temperature for the benefit of the crop (Mahey *et al*. 1986), besides suppressing weeds (Hossain 2005). Pre emergence herbicides, *viz*. pendimethalin (Kumar and Reddy 2000), atrazine (Singh and Mahey 1992) or metribuzin (Gill *et al*. 2000), save the crop from severe weed competition at an early stage. However, sole dependence on any single method may not provide effective weed management in a long duration crop like turmeric. The weeds need to be removed during 70 to 160 days after planting, indicating that it needs a longer weed free period than other crops. This necessitates development of an effective and economically better integrated weed control strategy for realizing higher productivity of turmeric. Keeping these points in view, the present investigation was conducted under mid–hill conditions of Himachal Pradesh.

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MATERIALS AND METHODS

The field experiment was conducted during 2012 and 2013 at Palampur in randomized block design with three replications. The experimental soil was silty clay loam, acidic (pH 6.1), medium in available N (326 kg/ha), and high in available P (25.8 kg/ha) and K (276.4 kg/ha). The treatments consisted of metribuzin 0.7 kg/ha *fb* hoeing twice, metribuzin 0.7 kg/ha *fb* fenoxaprop 67 g/ha+ metsulfuron-methyl 4 g/ha, metribuzin 0.7 kg/ha *fb* straw mulch 10 t/ha *fb* hand weeding, pendimethalin 1.0 kg/ha *fb* hoeing twice, pendimethalin 1.0 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha, pendimethalin 0.7 kg/ha *fb* straw mulch 10 t/ha *fb* hand weeding, atrazine 0.75 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron-

methyl 4 g/ha, atrazine 0.75 kg/ha *fb* straw mulch 10 t/ha *fb* hand weeding, weed free and weedy check. Turmeric variety '*Pitamber'* was planted on 2 June, 2012 and 5 June, 2013 in rows 30 cm apart using a seed rate of 2.5 t/ha. The crop was fertilized with 60 kg N, 180 kg P and 100 kg K/ha. through urea (46%), single super phosphate (16% P_2O_5) and muriate of potash (K_2O), respectively, at the time of planting. The herbicides and interculture operations were applied as per the treatments to different plots. Metribuzin/ pendimethalin/atrazine were applied as pre- emergence, fenoxaprop + metsulfuron-methyl as post emergence. Straw mulch was applied immediately after spray and hoeing were done at 25-35 and 45-55 DAP. Herbicides were applied with knapsack power sprayer using 600 L water per hectare. Mulching was done after the herbicides were sprayed on second day as per treatment. Care was taken to ensure uniform thickness of the mulch and coverage of whole area of the plot. The rest of the management practices were adopted in accordance with the recommended package of practices. Data on density and dry weight of weeds were recorded at 60 DAS and at harvest. The weed count and dry weight data were subjected to square root transformation ($\sqrt{x+1}$). When the leaves turned yellow and dry, the crop from net plots was harvested. The rhizomes were dug taking care that they were not cut or damaged, then cleaned to remove soil and weighed for fresh weight. The crop was harvested on 4 January 2013 and 30 December 2013. Economics of the treatments was computed based on the prevalent market prices of the inputs used and rhizomes produced.

RESULTS AND DISCUSSION

Effect on weeds

The major weeds of the experimental field were *Cyperus iria* (41.9%), *Ageratum conyzoides* (14.1%), *Echinochloa colona* (12.9%), *Panicum dichotomiflorum* (12.5%), *Digitaria sanguinalis* (5.2%), *Aeschynomene indica* (5.2%), *Commelina benghalensis* (4.6%), *Galinsoga parviflora* (3.2%) and *Polygonum* sp. (0.6%). *Physallis minima* had also shown its sporadic appearance.

Weed control treatments brought about significant variation in the population of *E. colona* (Table 1). All the weed control treatments except pendimethalin 1.0 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha during 2012 and atrazine 750 g/ha *fb* fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha during 2013 had significantly reduced the population of *E. colona* over weedy check.

Table 1. Effect of treatments on species-wise weed count (no./m^2) at 60 DAS in turmeric

Treatment	Dose g/ha	*Echinochloa* sp.		*Digitaria* sp.	*Panicum* sp.		*Cyperus** sp.	*Ageratum* sp.		*Aeschyno-mene** sp.	*Galinsoga* sp.
		2012	2013	2012	2012	2013	2012	2012	2013	2012	2013
Metribuzin *fb* hoeing	700 g	2.2 (4.0)	3.2 (12.0)	1.0 (0.0)	1.7 (2.7)	2.1 (4.0)	4.4 (18.7)	2.2 (4.7)	5.1 (26.7)	1.0 (0.0)	3.2 (14.7)
Metribuzin *fb* fenoxaprop + metsulfuron-methyl	700 g *fb* 67+4 g	1.7 (2.7)	2.9 (9.3)	1.7 (2.7)	2.1 (4.0)	4.0 (22.0)	2.7 (6.7)	1.4 (1.3)	1.0 (0.0)	2.5 (6.7)	1.0 (0.0)
Metribuzin *fb* straw mulch *fb* hoeing	700 g *fb* 10 t/ha	1.8 (2.7)	1.7 (2.7)	1.8 (2.7)	1.8 (2.7)	1.0 (0.0)	3.0 (8.0)	2.4 (4.7)	1.7 (2.7)	1.0 (0.0)	1.4 (1.3)
Pendimethalin *fb* hoeing	1000 g	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	4.0 (14.7)	2.1 (4.0)	8.6 (73.3)	1.0 (0.0)	3.2 (18.7)
Pendimethalin *fb* fenoxaprop + metsulfuron-methyl	1000 g *fb* 67+4 g	2.7 (6.7)	1.7 (2.7)	1.7 (2.7)	1.7 (2.7)	1.0 (0.0)	3.1 (9.3)	2.4 (4.7)	1.0 (0.0)	2.3 (5.3)	1.0 (0.0)
Pendimethalin *fb* straw mulch *fb* hoeing	1000 g *fb* 10 t/ha	1.7 (2.7)	1.0 (0.0)	1.4 (1.3)	1.0 (0.0)	1.0 (0.0)	2.5 (6.7)	2.1 (4.0)	4.3 (18.7)	1.0 (0.0)	1.7 (2.7)
Atrazine *fb* fenoxaprop + metsulfuron-methyl	750 g *fb* 67 + 4 g	1.7 (2.7)	4.6 (21.3)	2.1 (4.0)	2.5 (5.3)	4.5 (21.3)	3.0 (8.0)	2.1 (4.0)	1.0 (0.0)	1.4 (1.3)	1.0 (0.0)
Atrazine *fb* straw mulch *fb* hoeing	750 g *fb* 10 t/ha	1.0 (0.0)	1.9 (4.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	4.0 (16.0)	2.7 (6.7)	4.2 (17.3)	1.0 (0.0)	1.4 (1.3)
Weed free (3 hand weeding)	-	1.7 (2.7)	1.0 (0.0)	1.4 (1.3)	1.7 (2.7)	1.0 (0.0)	4.1 (16.0)	2.9 (8.0)	5.5 (36.0)	1.0 (0.0)	1.0 (0.0)
Weedy check	-	3.6 (12.0)	4.8 (22.7)	3.2 (9.3)	3.2 (9.3)	3.4 (17.3)	5.5 (29.3)	4.1 (16.0)	5.8 (33.3)	4.1 (16.0)	2.9 (14.7)
LSD (P=0.05)		1.3	1.2	1.3	1.3	2.3	1.3	1.3	2.4	1.2	1.3

Values in the parentheses are the original means *fb* = followed by, DAS= days after sowing; * at harvest. Metribuzin/ pendimethalin/ atrazine applied as pre- emergence, fenoxaprop + metsulfuron-methyl applied as post emergence, straw mulch applied immediately after spray and hoeings at 25-35 DAP and 45-55 DAP.

Table 2. Effect of different treatments on total weed count and dry weight in turmeric

Treatment	Dose/ha	Total weed count (no./m^2)				Total weed dry weight (g/m^2)			
		2012		2013		2012		2013	
		60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest
Metribuzin *fb* hoeings	700 g	4.7 (22.0)	6.1 (37.3)	9.5 (94.7)	6.4 (42.7)	3.4 (11.0)	3.9 (14.5)	4.5 (19.8)	4.8 (22.6)
Metribuzin *fb* fenoxaprop + metsulfuron-methyl	700 g *fb* 67+4g	4.3 (18.0)	6.0 (38.0)	7.2 (50.7)	5.7 (33.3)	2.8 (7.6)	4.0 (15.8)	4.7 (25.3)	4.6 (20.2)
Metribuzin *fb* straw mulch *fb* hoeing	700 g *fb* 10 t/ha	4.7 (23.3)	5.0 (25.3)	3.9 (14.7)	2.9 (9.3)	3.9 (18.3)	3.4 (13.4)	5.6 (41.1)	8.7 (88.1)
Pendimethalin *fb* hoeing	1000 g	3.6 (12.0)	5.2 (26.7)	10.7 (114.7)	6.2 (38.7)	2.3 (5.2)	3.2 (9.6)	3.6 (12.6)	3.1 (8.6)
Pendimethalin *fb* fenoxaprop + metsulfuron-methyl	1000 g *fb* 67+ 4g	5.7 (32.7)	7.4 (56.0)	6.3 (40.0)	5.6 (33.3)	4.4 (19.5)	4.7 (21.8)	3.6 (12.1)	5.6 (31.3)
Pendimethalin *fb* straw mulch *fb* hoeing	1000 g *fb* 10 t/ha	3.1 (11.3)	4.1 (16.0)	6.1 (38.7)	5.8 (44.0)	2.5 (6.1)	2.7 (7.1)	3.8 (14.1)	5.6 (32.3)
Atrazine *fb* fenoxaprop + metsulfuron-methyl	750 g *fb* 67 + 4g	5.0 (24.7)	6.1 (37.3)	8.0 (66.7)	5.5 (29.3)	3.4 (10.9)	4.1 (15.5)	8.7 (84.2)	7.9 (74.2)
Atrazine *fb* straw mulch *fb* hoeing	750 g *fb* 10 t/ha	3.6 (12.0)	5.4 (29.3)	6.2 (38.7)	4.4 (25.3)	2.4 (4.8)	2.9 (7.7)	3.4 (13.1)	5.1 (26.5)
Weed free (3 hand weeding)	-	4.8 (23.3)	6.6 (42.7)	6.6 (45.3)	6.7 (46.7)	3.2 (10.4)	4.2 (18.1)	1.5 (1.2)	2.8 (7.1)
Weedy check	-	8.7 (76.0)	10.8 (116.7)	15.6 (244.0)	5.7 (32.0)	5.9 (34.1)	7.7 (58.3)	11.1 (120.6)	6.1 (37.2)
LSD (P=0.05)		1.9	2.2	2.0	NS	1.7	1.7	4.0	NS

Values given in the parentheses are the original means *fb* = followed by, DAS= days after sowing

Metribuzin *fb* straw mulch *fb* hoeing, pendimethalin *fb* hoeing, pendimethalin *fb* fenoxaprop + metsulfuron-methyl, pendimethalin *fb* straw mulch *fb* hoeing and atrazine *fb* straw mulch *fb* hoeing were as good as weed free in reducing the population of *E. colona* upto 60 DAS during both the year. Weed suppressing efficiency of straw mulch has also been reported by Mahey *et al.* (1986). Similarly, all the weed control treatments except atrazine *fb* fenoxaprop + metsulfuron-methyl behaved statistically alike and resulted in significantly lower count of *D. sanguinalis* during 2012-13. The count of *P. dichotomiflorum* was significantly lower under all the treatments except metribuzin 700 g/ha *fb* fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha and atrazine 0.75 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha over weedy check during both years. Effectiveness of pendimethalin 1.0 kg/ha (Kumar and Reddy, 2000), metribuzin 0.70 kg/ha (Gill *et al.* 2000) and atrazine 2.0 kg/ha (Mishra and Mishra 1982) against weeds in turmeric has been established. Count of *C. iria* was effectively reduced by different weed control treatments except metribuzin 0.7 kg/ha *fb* hoeing at harvest during 2012. Pendimethalin *fb* straw mulch + hoeing was on par with metribuzin/atrazine/pendimethalin *fb* fenoxaprop + metsulfuron, while metribuzin *fb* straw mulch *fb* hoeing was superior to other treatments in curtailing *C. iria* upto harvest.

Metribuzin, pendimethalin and atrazine each *fb* fenoxaprop 67 g/ha + metsulfuron and metribuzin + mulch + hoeing significantly reduced the count of *Ageratum* upto 60 DAS during both the years. In these treatments as well as in others, *Ageratum* appeared in large numbers after 60 DAS, resulting in a count equal or higher than in weedy check. The activity of metsulfuron-methyl and pendimethalin against *A. conyzoides* has been established (Kumar *et al*. 2013). All treatments were significantly superior to weedy check in reducing the count of *Aeschynomene indica* upto harvest during 2012. Except pendimethalin/metribuzin *fb* fenoxaprop + metsulfuron-methyl, all treatments were at par in reducing its count. Except metribuzin/pendimethalin *fb* hoeing all treatments were equally effective in reducing the count of *G. parviflora* over weedy check at 60 DAS during 2013. The activity of metsulfuron-methyl alone or in combination with other herbicides has also been well established against broad-leaf weeds (Kurchania *et al.* 2000, Sharma and Pahuja 2001, Kumar *et al*. 2010).

Owing to reduction in species-wise weed count, all the weed control treatments resulted in significant reduction in total weed count as compared to weedy check upto harvest during 2012 and upto 60 DAS during 2013 (Table 2). All the treatments during 2012 and metribuzin (700 g/ha) *fb* straw mulch (10 t/ha) *fb* hoeing during 2013 were comparable to weed free in

Table 3. Effect of different treatments on plant height, leaves/plant, shoots, crop dry weight and rhizome yield of turmeric

Treatment	Dose/ha	Plant height (cm)		Leaves /plant*	Shoots /m^2	Crop dry weight* (g/m^2)	Fresh rhizomes /plant (g)	Rhizome yield (t/ha)	
		2012	2013	2013	2013	2013	2013	2012	2013
Metribuzin *fb* hoeing	700 g	48.4	26.7	6.3	15.0	64.8	26.0	5.4	7.6
Metribuzin *fb* fenoxaprop + metsulfuron-methyl	700 g *fb* 67 + 4 g	25.2	12.7	2.0	3.3	48.2	10.7	2.8	4.9
Metribuzin *fb* straw mulch *fb* hoeing	700 g *fb* 10 t/ha	50.6	29.7	5.7	16.3	111.5	54.0	13.7	14.3
Pendimethalin *fb* hoeing	1000 g	46.7	29.3	6.3	15.3	63.4	28.7	6.3	8.8
Pendimethalin *fb* fenoxaprop + metsulfuron-methyl	1000 g *fb* 67+ 4 g	26.4	12.0	2.0	4.1	42.2	33.3	2.8	4.6
Pendimethalin *fb* straw mulch *fb* hoeing	1000 g *fb* 10 t/ha	50.1	36.7	5.7	17.4	82.8	42.3	13.4	14.3
Atrazine *fb* fenoxaprop + metsulfuron-methyl	750 g *fb* 67 + 4 g	24.3	11.0	2.0	5.6	55.0	38.0	2.3	4.2
Atrazine *fb* straw mulch *fb* hoeing	750 g *fb* 10 t/ha	51.4	41.0	6.0	16.6	85.4	63.7	12.0	13.8
Weed free (3 hand weedings)	-	49.4	26.7	6.3	12.0	71.7	48.0	7.0	9.7
Weedy check	-	42.3	38.0	5.0	9.7	43.6	22.7	2.9	3.2
LSD (P=0.05)		7.4	7.9	0.9	3.1	11.5	12.2	2.4	1.0

affecting total weed count. All treatments except pendimethalin/atrazine *fb* fenoxaprop + metsulfuron were significantly superior to weedy check in affecting total weed dry weight upto harvest during 2012 and 60 DAP during 2013. The effectiveness of pre-emergence application of pendimethalin (Kumar and Reddy 2000), atrazine (Singh and Mahey 1992) and metribuzin (Gill *et al*. 2000) against weeds in turmeric has also been reported.

Effect on crop

Weed control treatments significantly influenced plant height (Table 3). Atrazine (750 g/ha) *fb* straw mulch (10 t/ha) *fb* hoeing was at par with metribuzin/ pendimethalin *fb* mulch *fb* hoeing, metribuzin/ pendimethalin *fb* hoeing and weed free during 2012 and weedy check and pendimethalin (1000 g/ha) *fb* straw mulch (10 t/ha) *fb* hoeing during 2013 resulted in significantly taller plants compared to other treatments. Early emergence in plots under mulch might have favored growth in terms of plant height. Favorable soil temperature and more available soil moisture for crop growth may also be responsible for taller plants in mulched plots. Weed free, atrazine *fb* mulch *fb* hoeing, metribuzin *fb* hoeing and pendimethalin (1000 g/ha) *fb* hoeing had significantly higher number of leaves/plant over weedy check. Metribuzin (700 g/ha) *fb* straw mulch (10 t/ha) *fb* hoeing, atrazine (750 g/ha) *fb* straw mulch (10 t/ha) *fb* hoeing were statistically at par with these treatments in influencing number of leaves/plant. This may be due to the early emergence of the crop in mulched plots. Metribuzin (700 g/ha) *fb* 2 hoeing, metribuzin (700 g/ha) *fb* straw mulch (10 t/ha) *fb* hoeing, pendimethalin (1000 g/ha) *fb* 2 hoeing, pendimethalin (1000 g/ha) *fb* straw mulch (10 t/ha) *fb* hoeing, atrazine (750 g/ha) *fb* straw mulch (10 t/ ha) *fb* hoeing had significantly higher number of shoots in comparison to other treatments. This might be due to more available moisture and weed free condition in the mulched treatments. Plant height, number of leaves/plant and number of shoots/plant were significantly lower where fenoxaprop + metsulfuron-methyl was included,

Metribuzin *fb* mulch *fb* hoeing resulted in significantly higher dry matter accumulation followed by atrazine *fb* mulch *fb* hoeing. The positive effect of mulch might be due to increase in crop growth parameters like plant height and number of leaves/plant. Mulch also suppressed the weeds for longer growing period and favoured crop growth. The treatments having straw mulch had significantly higher fresh weight of rhizomes. Mulch application had positive effect for increasing above ground biomass which was responsible for increasing dry matter accumulation by rhizomes, because more photosynthates were transferred to rhizomes from above ground parts. Swain *et al.* (2007) also reported significantly higher fresh weight of rhizome per plant with application of paddy straw mulch as compared to no mulch. The lower dry matter accumulation and weight of rhizomes/plant was observed where fenoxaprop + metsulfuron-methyl was used indicating its phytotoxic effect.

All treatments were significantly superior to weedy check in increasing fresh rhizome yield. Mulching proved to be an extremely important

Table 4. Effect of treatments on cost of weed control, gross returns, gross returns due to weeds, net return due to weed control and MBCR (mean of two years)

Treatment	Dose (g/ha)	Cost of cultivation (x10^3 `/ha)	Cost of weed control (x10^3 `/ha)	Gross returns (x10^3 `/ha)	Gross return due to weed control (x10^3 `/ha)	Net return due to weed control (x10^3 `/ha)	MBCR
Metribuzin *fb* hoeing	700 g	82.43	6.02	162.50	86.25	80.23	13.33
Metribuzin *fb* fenoxaprop + metsulfuron-methyl	700 g *fb* 67+ 4g	81.07	4.66	96.25	20.00	15.34	3.29
Metribuzin *fb* straw mulch *fb* hoeing	700 g *fb* 10 t/ha	82.21	5.80	350.00	273.75	267.95	46.20
Pendimethalin *fb* hoeing	1000 g	80.76	4.35	188.75	112.50	108.15	24.86
Pendimethalin *fb* fenoxaprop + metsulfuron-methyl	1000 g *fb* 67+ 4 g	78.68	2.27	92.50	16.25	13.98	6.15
Pendimethalin *fb* straw mulch *fb* hoeing	1000 g *fb* 10 t/ha	81.26	4.85	346.25	270.00	265.15	54.67
Atrazine *fb* fenoxaprop + metsulfuron-methyl	750 g *fb* 67 + 4 g	78.59	2.18	81.25	5.00	2.82	1.29
Atrazine *fb* straw mulch *fb* hoeing	750 g *fb* 10 t/ha	81.17	4.76	322.50	246.25	241.49	50.73
Weed free (3 hand weeding)	-	95.91	19.50	208.75	132.50	113.00	5.79
Weedy check	-	76.41	-	76.25	-	-	

Metribuzin/pendimethalin/atrazine applied as pre-emergence, fenoxaprop + metsulfuron-methyl applied as post-emergence, straw mulch applied immediately after spray and hoeings at 25-35 DAP and 45-55 DAP, MBCR: Marginal benefit cost ratio

practice as the treatments constituting the straw mulch treatment *viz*. pendimethalin/metribuzin/ atrazine *fb* mulch *fb* hoeing resulted in significantly higher fresh rhizome yield over other treatments. The superiority of mulch in increasing rhizome yield of turmeric has been documented by Mahey *et al*. in 1986 and Hossain in 2005. Weeds in unweeded check reduced the rhizome yield by 78.2% over metribuzin *fb* mulch *fb* hoeing. Krishnamurthy and Ayyaswamy (2000) have reported 75% reduction in the yield of turmeric due to season long competition with weeds. Atrazine / pendimethalin/ Metribuzin *fb* mulch *fb* hoeing increased fresh rhizome yield by 1.54-1.68 times over weed free (hand weeding thrice).

Economics

Due to higher rhizome yield, gross returns were highest under metribuzin *fb* mulch *fb* hoeing followed by application of pendimethalin/atrazine *fb* mulch *fb* hoeing and weed free. Net returns followed the trend similar to total gross returns. Marginal benefit cost ratio (MBCR) was highest under pendimethalin *fb* mulch *fb* hoeing (54.67) followed by atrazine *fb* mulch *fb* hoeing (50.73), metribuzin *fb* mulch *fb* hoeing (46.2) and pendimethalin *fb* hoeing (24.86). Due to the higher cost of maintaining weed free environment, weed free (hand weeding 3 times) resulted in lower MCBR. Thus, use of herbicides in turmeric was the cheapest alternative to manual weed control.

The findings of present investigation conclusively inferred that weeds in turmeric can be effectively managed with satisfactory yield and profit gain by pre emergence application of metribuzin (700 g/ha), pendimethalin (1000 g/ha) or atrazine (750 g/ ha) *fb* mulch (paddy straw 10 t/ha) and one hoeing.

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