Indian Journal of Agronomy **62** (3): 354–358 (September 2017)

Research Paper

Integrated weed management practices in turmeric (*Curcuma longa*)

SHATRUGHNA KUMAR SINGH[1], UMESH SINGH[2], DILEEP KUMAR MAURYA[3], ADITYA PRAKASH DWIVEDI[4] AND JAI DEV[5]

Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad, Uttar Pradesh 224 229

Received : October 2016; Revised accepted : April 2017

ABSTRACT

A field experiment was conducted during rainy (*kharif*) season of 2012–13 and 2013–14 at Faizabad, Uttar Pradesh, to study the effect of conventional and integrated weed management [rice (*Oryza sativa* L.) straw mulch and mechanical weeding along with herbicides] practices on the control of weeds and yield of turmeric (*Curcuma longa* L.). The application of metribuzin 700 g/ha as pre-emergence followed by (fb) straw mulch 10 t/ha fb 1 hand-weeding (HW) 75 days after planting (DAP), being at par with pendimethalin 1 kg/ha as pre-emergence fb straw mulch 10 t/ha fb 1 HW 75 DAP and atrazine 750 g/ha as pre-emergence fb straw mulch 10 t/ha fb 1 HW 75 DAP, was found significantly more effective in controlling weeds and improving yield attributes and yield (6.7 t/ha dry rhizome; 272% and 26% increase over weedy check and farmers' practice respectively). The application of metribuzin 700 g/ha as pre-emergence fb straw mulch 10 t/ha fb 1 HW 75 DAP also recorded the maximum net returns (₹392,493/ha) and benefit: cost ratio (3.2). Results showed that integration of mulches and hand weeding with pre-emergence herbicides achieved the maximum yield and returns. However, pre-emergence application of metribuzin 700 g followed by rice straw mulch 10 tonnes/ha along with 1 hand-weeding at 75 days after planting proved most remunerative and economical for growing turmeric crop.

***Key words* :** Economics, Herbicide, Mulching, Productivity, Turmeric, Weeding

Turmeric, an ancient and sacred spice of India, is a major rhizomatous spice produced in and exported from India. In India, it is grown over an area of 0.18 million ha, with a production of 0.83 million tonnes and productivity of 4.6 t/ha respectively (Indiastat, 2014). Since turmeric is being grown during the rainy season and is a long-duration crop, a large number of weeds compete with the crop for nutrients, moisture and space causing yield reduction of 35–75% (Krishnamurty and Ayyaswamy, 2000). Being a long-duration crop (more than 280 days), pre-emergence application of herbicides alone does not control weeds throughout the critical crop-weed competition period and hence needs an integration of post-emergence application of herbicide or intercultural operation in combination with pre-emergence herbicide application. Straw mulch is another approach adopted by the farmers that conserves soil moisture and modifies soil temperature for benefit of crop, besides controlling weeds (Mahey *et al*., 1986). Management of the weeds at proper time is one of the major activities related to the crop returns by increasing the crop productivity. Generally, for the control of weeds, farmers do manual weeding, but with increase in wages and scarcity of labourers, manual weed control has become a difficult task. Under such a situation, an alternative method of weed management through integrated system has to be explored. Hence an investigation was carried out to study the effect of conventional and improved integrated weed-management practices on productivity and economics of turmeric crop.

[1]**Corresponding author's Email:** singhshatruag@gmail.com
[1]Technical Assistant, O/o Deputy Director (Agriculture), Rampur Farm, Near Harka Chauraha, Kubersthan Road, P.O. Padrauna, District Kushinagar, Uttar Pradesh 274 304; [2]Scientist, Defence Institute of Bio-Energy Research (DRDO) Field Station, Pithoragarh, Uttarakhand 262 501; [3]Assistant Manager, Rural Development, Syndicate Bank, Allur, Andhra Pradesh 524 315; [4]Senior Scientist (Agronomy), IISR (ICAR), Lucknow, Uttar Pradesh; [5]Professor of Agronomy, Narendra Deva University of Agriculture and Technology, Kumarganj, Distt. Faizabad, Uttar Pradesh 224 229

MATERIALS AND METHODS

A field experiment was conducted at Agronomy Research Farm of the Narendra Deva University of Agriculture and Technology, Faizabad (26.32°N and 82.12°E) during the rainy (*kharif*) season of 2012–13 and 2013–14. The soil (reclaimed *usar*) of the experimental field was silt loam in texture with slightly alkaline in reaction (8.3), low in organic carbon (0.31%) and available nitrogen (187 kg/ha), medium in phosphorus (16.1 kg/ha) and high in potassium (283 kg/ha). The experimental site falls under sub-tropical zone in the Indo-Gangatic plains. The region enjoys sub-humid climate, receiving a mean annual rainfall of about 1,200 mm; out of which about 80% is received from mid-June to end of September. In the area of experiment normally monsoon begins in the third week of June and lasts up to end of September or the first week of October. The winter months are cold with occasional frost. Period from March to May remains generally hot and dry. Western hot winds start from April and continue up to mid of June. Weekly average minimum and maximum temperatures during the crop season ranged 2.9–29.2 and 14.2–44.3°C during 2012–13 and 5.9–27.1 and 15.7–35.7°C during 2013–14, whereas total rainfall received was 878 and 1,064 mm during 2012–13 and 2013–14 respectively. The relative humidity, evaporation rate and sunshine hours were found to vary from 34.6 to 78.6 and 53.9 to 87.9%, 9.1 to 58.4 and 9.6 to 44.4 mm/day and 1.6 to 8.4 and 0.4 to 8.7 hours during 2012–13 and 2013–14 respectively. Ten treatments [T_1, metribuzin 700 g/ha as pre-em fb 2 hoeings 45 and 75 days after planting (DAP); T_2, Metribuzin 700 g/ha as pre-emergence (pre-em) fb fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha as tank mixed and post-emergence (post-em) 45 DAP; T_3, metribuzin 700 g/ha as pre-em, fb straw mulch 10 t/ha fb 1 hand-weeding (HW) 75 DAP; T_4, pendimethalin 1 kg/ha as pre-em, fb 2 hoeings 45 and 75 DAP; T_5, pendimethalin 1 kg/ha as pre-em, fb fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha as tank mixed and post-em, 45 DAP; T_6, pendimethalin 1 kg/ha as pre-em fb straw mulch 10 t/ha, fb 1 HW 75 DAP; T_7, atrazine 750 g/ha as pre-em fb fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha as tank mixed and post-em 45 DAP; T_8, atrazine 750 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP; T_9, farmers' practice (HW 25, 45 and 75 DAP); T_{10}, weedy check] were replicated thrice in a randomized block design with plot size of 5 m × 6 m. All the herbicides were applied as pre-em (3 DAP) with the help of manually operated knapsack sprayer fitted with flat fan nozzle using 500 liters of water/ha. However, a treatment of fenoxaprop and metsulfuron-methyl as tank mixed was executed as superimposed in the treatments of the pendimethalin, metribuzin and atrazine at 45 DAP. Species-wise number of weeds was recorded from 3 places, selected randomly in each plot using a quadrate of 50 cm × 50 cm size. Weeds within the quadrate were identified and counted and weed count expressed as number/m^2. The dry weight of total weed species was recorded from three places in each plot selected randomly. After sun drying, weeds were dried in hot air oven at 70 ± 1°C for 48 hours to obtain a constant weight. Five plants were randomly selected from each plot and the total area of leaves of 5 plants was estimated with the help of electronic leaf area meter, and finally total leaf-area was divided by the number of plants to get the leaf area/plant. Leaf area index was calculated as:

$$\text{Leaf area index (LAI)} = \frac{\text{Total leaf area}}{\text{Unit land area}}$$

The planting of crop was done on 17 June 2012 and 13 June 2013 in rows, 45 cm apart having plant-to-plant distance of 20 cm. The rhizomes were planted 5–7 cm deep. Four irrigations were provided to maintain adequate soil moisture at all the stages of crop growth during both seasons. Urea, diammonium phosphate and muriate of potash were used to supply 125 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha respectively. The crop was harvested on 18 February 2013 and 24 February 2014 during the first and second seasons respectively. The moisture content in rhizomes at harvesting was around 85%. The data collected on weeds and turmeric crop were statistically analyzed as per analysis of variance procedure (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Weed and weed control efficiency

The dominant weed species in weedy plots at 120 DAP were grassy weeds like jungle rice–*Echinochloa colona* L. (3.3/m^2) and crowsfoot grass, *Eleusine indica* (3.1/m^2), broad-leaved weeds like monarch redstem, *Ammannia baccifera* L. (3.8/m^2), tropical whiteweed, *Ageratum conyzoides* L. (3.2/m^2), yellow sweet clover, *Melilotus indica* (3.1/m^2), tropical spiderwort–*Commelina benghalensis* L. (3.1/m^2) and black nightshade–*Solanum nigrum* (3.6/m^2) and sedges like nutgrass, *Cyperus rotundus* L. (3.7/m^2) and forked fringerush, *Fimbristylis dichotoma* (L.) Vahl. (3.2/m^2). The grassy weeds constituted 27.8, broad-leaf 49.8 and sedges 18.9% of the total weed population under weedy conditions. The application of metribuzin 700 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP, being at par with pendimethalin 1 kg/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP and atrazine 750 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP, was found significantly more effective in controlling weeds (Table 1). Significant reduction in weed dry-matter accumulation at 120 DAP was observed due to weed-control treatments, viz. metribuzin 700 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP, farmers' practice, pendimethalin 1 kg/ha as pre-em fb 2 hoeings 45 and 75 DAP, pendimethalin 1 kg/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP, metribuzin 700 g/ha as pre-em fb 2 hoeings 45 and 75 DAP, atrazine 750 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP which were equally effective in reducing weed dry matter and achieving higher weed-control efficiency. Jadhav and Pawar (2014) also reported that application of metrbuzin 700 g/ha fb straw mulch 10 t/ha fb 1 HW proved most effective recording lowest weed dry matter and highest weed control efficiency.

Growth attributes of turmeric

Herbicides superimposed with straw mulch recorded higher rhizome emergence (95.5–96.5%) at 30 DAP (Table 1). It might be owing to the fact that favourable conditions provided by rice straw mulch helped conserve the moisture in the soil and encouraged the better and fast sprouting of rhizomes, as also reported by Hossain (2005). Metribuzin 700 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP, being at par with pendimethalin 1 kg/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP, atrazine 750 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP and farmers' practice (HW 25, 45 and 75 DAP) [only for plant height], exhibited significantly higher plant height (95.4–102.2 cm) at 180 DAP, LAI (5.1–5.3) at 120 DAP and dry-matter accumulation (289.5–295.0 g/plant) at 180 DAP in turmeric crop. Verma and Sarnaik (2006) observed maximum plant height in turmeric with paddy straw as mulch in combination with herbicides. Higher LAI in turmeric was recorded in weed-free check followed by pendimethalin at 1.5 kg/ha as reported by Channappagoudar *et al*. (2013).

Yield attributes and yield

The yield attributes and yield of turmeric were significantly influenced by the weed-control treatments (Table 2). The application of metribuzin 700 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP, being at par with pendimethalin 1 kg/ha as pre-em fb straw mulch 10

Table 1. Effect of weed control on weed density, weed dry weight, weed-control efficiency and growth attributes of turmeric (pooled data of 2 years)

Treatment	Weed density (Nos./m^2) 120 DAP: Grasses	Sedges	Broad-leaf weeds	Other weeds	Total	Weed dry weight (g/m^2) 120 DAP	Weed-control efficiency (%)	Rhizome emergence (%) 30 DAP	Height (cm) 180 DAP	LAI 120 DAP	Plant dry weight (g) 180 DAP
T_1, Metribuzin 700 g/ha as pre-em fb 2 hoeings 45 and 75 DAP	3.7 (13.2)	3.1 (9.2)	3.9 (14.4)	1.5 (2.1)	6.3 (38.9)	5.9 (33.7)	89.2	90.0	82.0	3.2	206.8
T_2, Metribuzin 700 g/ha as pre-em fb fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha as tank mixed and post-em 45 DAP	4.6 (21.1)	3.8 (14.0)	6.0 (35.4)	2.1 (4.0)	8.7 (74.5)	21.4 (456.2)	8.7	87.5	50.7	2.3	125.2
T_3, Metribuzin 700 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP	2.5 (6.0)	2.2 (4.5)	3.3 (10.6)	1.2 (1.3)	4.8 (22.4)	5.2 (26.2)	93.5	95.5	102.2	5.3	295.0
T_4, Pendimethalin 1 kg/ha as pre-em fb 2 hoeings 45 and 75 DAP	3.6 (12.5)	2.9 (8.3)	3.5 (11.8)	1.5 (2.0)	5.9 (34.6)	5.5 (30.1)	90.6	93.5	85.4	3.4	213.6
T_5, Pendimethalin 1 kg/ha as pre-em fb fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha as tank mixed and post-em 45 DAP	4.4 (18.7)	3.5 (11.9)	5.7 (31.7)	2.0 (3.6)	8.2 (65.9)	21.0 (437.1)	13.1	91.0	59.8	2.6	129.0
T_6, Pendimethalin 1 kg/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP	2.6 (6.7)	2.4 (5.4)	3.5 (12.2)	1.3 (1.5)	5.1 (25.8)	5.8 (32.6)	92.2	96.5	97.8	5.1	292.2
T_7, Atrazine 750 g/ha as pre-em fb fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha as tank mixed and post-em 45 DAP	4.5 (19.6)	3.7 (13.3)	5.8 (33.3)	2.0 (3.8)	8.4 (70.0)	21.2 (448.1)	15.4	89.5	55.5	2.5	124.3
T_8, Atrazine 750 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP	2.8 (7.5)	2.5 (6.0)	3.7 (13.6)	1.4 (1.8)	5.4 (28.9)	6.3 (39.2)	90.3	96.0	95.4	5.1	289.5
T_9, Farmers' practice (HW 25, 45 and 75 DAP)	3.9 (14.5)	3.3 (10.3)	5.0 (24.8)	1.8 (3.2)	7.3 (52.3)	5.3 (27.0)	92.9	89.5	99.9	3.9	216.0
T_{10}, Weedy check	5.9 (33.9)	4.8 (23.0)	7.8 (60.6)	3.1 (9.3)	11.3 (126.8)	22.4 (497.8)	-	89.0	46.9	2.2	119.3
SEm±	0.1	0.1	0.2	0.1	0.3	0.5	-	-	3.2	0.1	8.7
CD (P=0.05)	0.4	0.3	0.5	0.2	0.8	1.6	-	-	9.9	0.4	25.7

t/ha fb 1 HW 75 DAP and atrazine 750 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP, recorded significantly higher number (27.3–29.1) and volume (317.2–344.3 cm^3) of rhizomes/plant, fresh (452.8–474.5 g) and dry weight (93.5–95.6 g) of rhizomes/plant and fresh (31.1–33.9 t/ha) and dry (6.2–6.7 t/ha) yield of rhizomes. Barooah *et al*. (2011) observed that integration of mulching (just after planting of rhizomes and 90 days after planting of rhizomes) with manual (hoeing 40 days after planting and hand-weeding 90 days after planting) and mechanical measures (grubber at 60 days after planting) recorded significantly higher yield in ginger. Metribuzin 700 g/ha fb straw mulch 10 t/ha fb 1 HW, pendimethalin 700 g/ha fb straw mulch 10 t/ha fb 1 HW and atrazine 750 g/ha fb straw mulch 10 t/ha fb 1 HW were the most effective weed-control treatments in turmeric as reported by Kumar *et al*. (2014). The weed-control treatments, metribuzin 700 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP and pendimethalin 1 kg/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP recorded the highest dry rhizome yield and lowest weed index followed by the treatment, atrazine 750 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP which might be due to higher number and weight of rhizomes/plant and better weed-control efficiency. Pre-emergence application of pendimethalin + straw mulch 9 t/ha resulted in higher fresh rhizome yield (29.6 t/ha) and was on par with metribuzin and atrazine both integrated with straw mulch 9 t/ha in turmeric, as also reported by Kaur *et al*. (2008). Sathiyavani and Prabhakaran (2014) also reported that pre-emergence application of metribuzin 700 g/ha *fb* straw mulch 10 t/ha *fb* 1 HW 75 DAP was the most effective for controlling the weeds and enhancing the productivity of turmeric. Ratnam *et al*. (2012) also reported that, integration of pre + post-emergence herbicides supplemented with hand-weeding at 60 and 90 DAP recorded higher fresh rhizome yield in turmeric. However, quality content of turmeric (curcumin and essential oil) was not affected either due to

Table 2. Effect of weed control on yield attributes, rhizome yield, weed index, quality and economics of turmeric (pooled data of 2 years)

Treatment	Rhizomes/ plant	Volume of rhizomes (cm^3/plant)	Fresh weight of rhizomes/ plant (g)	Dry weight of rhizomes/ plant (g)	Fresh yield of rhizomes (t/ha)	Dry yield of rhizomes (t/ha)	Weed index (%)	Curcumin (%)	Essential oil (%)	Gross returns (× 10^3 ₹/ha)	Net returns (×10^3 ₹/ha)	Benefit: cost ratio
T_1, Metribuzin 700 g/ha as pre-em fb 2 hoeings 45 and 75 DAP	20.4	258.1	365.0	77.7	23.6	4.8	9.4	7.2	2.2	359.6	245.1	2.17
T_2, Metribuzin 700 g/ha as pre-em fb fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha as tank mixed and post-em 45 DAP	11.7	189.3	227.9	47.3	9.9	2.2	58.5	7.0	2.3	150.9	38.5	0.35
T_3, Metribuzin 700 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP	29.1	344.3	474.5	95.6	33.9	6.7	–26.4	7.3	2.1	516.6	392.5	3.20
T_4, Pendimethalin 1 kg/ha as pre-em fb 2 hoeings 45 and 75 DAP	21.7	273.9	385.3	79.2	24.8	5.1	3.8	7.1	2.1	377.4	263.2	2.32
T_5, Pendimethalin 1 kg/ha as pre-em fb fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha as tank mixed and post-em 45 DAP	13.4	207.7	252.7	52.0	12.7	2.6	50.9	7.0	2.2	192.8	80.6	0.73
T_6, Pendimethalin 1 kg/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP	28.1	319.9	463.3	93.5	32.2	6.7	–26.4	7.2	2.2	489.9	366.1	2.99
T_7, Atrazine 750 g/ha as pre-em fb fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha as tank mixed and post-em 45 DAP	12.2	195.6	236.4	50.6	11.9	2.4	54.7	6.9	2.2	181.4	69.8	0.64
T_8, Atrazine 750 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP	27.3	317.2	452.8	95.0	31.1	6.2	–17.0	7.2	2.2	472.4	349.3	2.88
T_9, Farmers' practice (HW 25, 45 and 75 DAP)	22.4	282.5	408.4	83.1	25.8	5.3	-	7.1	2.1	397.1	279.7	2.41
T_{10}, Weedy check	11.4	185.3	223.7	44.1	9.8	1.8	66.0	7.0	2.2	146.2	37.4	0.27
SEm±	0.8	11.0	16.5	2.8	1.0	0.2	-	-	-	-	-	-
CD (P=0.05)	2.4	32.7	49.1	8.2	3.0	0.6	-	-	-	-	-	-

Figures in parentheses are original values; DAP, days after planting; *fb*, followed by; HW, hand weeding; LAI, leaf area index conventional or improved weed management practices.

Production economics

The application of metribuzin 700 g/ha as pre-em fb straw mulch 10 t/ha fb 1 HW 75 DAP resulted in higher net returns of ₹392,493/ha and benefit: cost ratio of 3.2 (Table 2). However, moderate net returns ₹279,691/ha) and benefit: cost ratio (2.4) was registered with farmers' practice. Higher economic returns from turmeric with the application of metribuzin 700 g/ha fb straw mulch 10 t/ha fb 1 HW 75 DAP was also reported by Sathiyavani and Prabhakaran (2014).

It was concluded that integration of mulches and hand-weeding with pre-emergence herbicides achieved the maximum yield and returns. However, pre-emergence application of metribuzin 700 g followed by rice straw mulch 10 tonnes/ha along with 1 hand-weeding 75 days after planting in turmeric crop proved superior with respect to productivity and economics.

REFERENCES

Barooah, L., Saikia, S. and Rajkhowa, D.J. 2010. Production potential and economics of integrated weed control measures in ginger (*Zingiber officinale* Rosc.) cv. Nadia. *Indian Journal of Weed Science* **42**(1 and 2): 107–110.

Channappagoudar, B.B., Babu, V., Naganagoudar, Y.B. and Rathod, S. 2013. Influence of herbicides on morpho-physiological growth parameters in turmeric (*Curcuma longa* L.). *The Bioscan* **8**(3): 1,019–1,023.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research,* 25–28 pp. Wiley India Pvt. Ltd, New Delhi.

Hossain, M.A. 2005. Agronomic practices for weed control in turmeric (*Curcuma longa* L.). *Weed Biology and Management* **5**(4): 166–175.

Indiastat. 2014. *http://www.indiastat.com/agriculture/2/spices/262/turmeric/19562/stats.aspx*

Jadhav, A. and Pawar, S. 2014. Integrated weed management in turmeric. *Indian Journal of Weed Science* **46**(3): 293–295.

Kaur, K., Bhullar, M.S., Kaur, J. and Walia, U.S. 2008. Weed management in turmeric (*Curcuma longa*) through integrated approaches. *Indian Journal of Agronomy* **53**(3): 224–229.

Krishnamurthy, V.V. and Ayyaswamy, M. 2000. Effect of herbicides on yield of turmeric. *Spice India* **13**: 9–11.

Kumar, S., Rana, S.S. and Sharma, N. 2014. Weed-management in turmeric. (In) *Extended Summaries*, Biennial Conference of Indian Society of Weed Science, 15–17 February 2014, Jabalpur, pp. 153.

Mahey, R.K., Randhawa, G.S. and Gill, S.R.S. 1986. Effect of irrigation and mulching on water conservation, growth and yield of turmeric. *Indian Journal of Agronomy* **31**(1): 79–82.

Ratnam, M., Rao, A.S. and Reddy, T.Y. 2012. Integrated weed management in turmeric (*Curcuma longa*). *Indian Journal of Agronomy* **57**(1): 82–84.

Sathiyavani, E. and Prabhakaran, N.K. 2014. Performance of pre and post-emergence herbicides on weed flora and yield of turmeric. *Trends in Biosciences* **7**(12): 1,350–1,353.

Verma, A. and Sarnaik, D.A. 2006. Effect of different types of mulches on growth and yield of turmeric (*Curcuma longa*). *International Journal of Agricultural Sciences* **2**(2): 425–426.