Indian Journal of Weed Science **49**(3): 300–302, 2017
DOI: 10.5958/0974-8164.2017.00080.6

Short communication

Effect of IWM on weed dynamics, dry matter accumulation, yield and economics of turmeric

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Received: 2 August 2017; Revised: 7 September 2017

Key words: Plant dry matter accumulation, Productivity, Profitability

Turmeric (*Curcuma longa* L.) is one of the important spice crops grown in India in an area of 1.94 Mha with an average production of 9.71 ton and productivity 5 ton/ha (Anonymous 2013). Weed competition is one of the limiting factors for low yield of turmeric. Due to improper weed management, 30-70% yield losses have been reported in the crop (Krishnamurty and Ayyaswamy 2000). Turmeric is a long durational crop takes 8-9 months, therefore, pre-emergence application of herbicides alone can not control weeds throughout critical crop-weed competition period of the crop and needs an integration of pre- and post-emergence application of herbicide or inter-culture operation in combination with pre-emergence herbicide application. Hence, a field experiment was carried out to suggest a suitable integrated weed management for better production of turmeric.

The experiment was carried out during rainy season, 2014 at Birsa Agricultural University, Ranchi, Jharkhand in randomized block design with three replications. The soil of experimental field was sandy loam slightly acidic in reaction (pH 5.9), low in organic carbon (4.2 g/kg) and N (243 kg/ha) while medium in P 19.15 kg/ha and K (188 kg/ha). The turmeric variety '*Rajendra sonia*' was planted at 40 x 25 cm spacing on 3rd July 2014. The recommended dose of FYM at 10 t/ha and 120:60:100 kg/ha NPK was applied. The experiment comprised of 15 treatments (**Table 1**). Un-weeded check as hand weeding at 25, 45 and 75 DAP and un-weeded check respectively. All the herbicides alone or in mixture were applied with knapsack sprayer fitted with flat-fan nozzle using 600 litres water/ha. Crop growth rate ($g/m^2/day$) was calculated by using the following standard formulae suggested by Leopold and Kridemann (1975) between 30-90 and 90-150 DAP –

$$\text{Crop growth rate } (g/m^2/day) = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_2 and W_1 are plant dry weight at time t_2 and t_1.

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Weed flora

The major weeds found in experimental plot, *viz. Ageratum conyzoides* (L.), *Celosia argentea* (L.), *Acalypha indica* (L.) among broad-leaved weeds; *Digitaria sanguinalis* (L.), *Panicum dichotomiflorum* among grassy and *Cyperus rotundus* (L.) among sedges were predominant. Among all the categories broad-leaved dominated (60.4%) followed by grassy (28%) and sedges (11.6%).

Effect of weed density and dry matter

Among chemical weed control methods application of metribuzin 0.7 kg/ha PE *fb* fenoxaprop-p-ethyl 67 g/ha + metsulfuron 4 g/ha at 45 DAP recorded reduced total weed density at 90 and 150 DAP to the tune of 66.96 and 54.67% compared to hand weeding at 25, 45 and 75 DAP respectively. Similarly, total weed dry matter accumulation was reduced in metribuzin 0.7 kg/ha PE *fb* fenoxaprop-p-ethyl 67 g/ha + metsulfuron 4 g/ha at 45 DAP at 90 and 150 DAP to the tune of 44.24 and 52.27% respectively compared to hand weeding at 25, 45 and 75 DAP.

The mean dry matter accumulation (g/m^2) by total plant parts increased gradually from 30 DAP to 150 DAP and then slightly decreased at 210 DAP. The mean dry matter accumulation at 30, 90, 150 and 210 DAP were 42.8, 345, 570 and 554 g/m^2. The respective increase over preceding values were to the tune of 705.2 percent up to 90 DAP and 65.3% up to 150 DAP while at 210 DAP it was decreased to the extent of 2.8%. Maximum mean dry matter accumulation by stem was (41.6 g/m^2) at 90 DAP which was 92.5% higher than at 30 DAP and further it reduced marginally by 5.17% (39.4 g/m^2) at 150 DAP. The mean dry matter accumulation by rhizomes of turmeric at 90, 150 and 210 DAP was 238, 483 and 386 g/m^2 respectively. The dry matter accumulation by rhizomes started decreasing after 150 DAP as majority of leaves dried and stopped photosynthesis. Moreover, dehaulming performed at 167 DAP as a normal practice in order to harden the underground

rhizome. This reduced dry matter accumulation by rhizome compared to 150 DAP was marginal (**Table 1**).

Among weed control methods, application of atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP recorded maximum dry matter accumulation to the extent of 7.27, 42.2 and 80.5% higher at 30, 90 and 150 DAP respectively compared to hand weeding at 25, 45 and 75 DAP by turmeric leaves. Similarly, application of atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP also recorded significantly higher stem dry matter accumulation which were 63.5 and 70.6 % higher compared to hand weeding at 25, 45 and 75 DAP, at 90 and 150 DAP respectively (**Table 1**). Moreover, similar result was also observed in case of dry matter accumulation by rhizomes as atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP recorded significantly higher dry matter accumulation by rhizomes to the tune of 180, 152 and 154% compared to hand weeding at 25, 45 and 75 DAP, at 90, 150 and 210 DAP respectively. Application of atrazine 0.75 kg/ha pre-emergence *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP also recorded maximum total dry matter accumulation by plants which were 8.95, 136, 140 and 154% higher than hand weeding at 25, 45 and 75 DAP, at 30, 90, 150 and 210 DAP respectively. Sathiyavani and Prabhakaran (2015) have also reported that either use of mulch or its integration with herbicides and hand weeding has resulted in better dry matter accumulation by plants.

Plant injury of turmeric as a result of phyto-toxicity recorded at 60 DAP was maximum under treatments of integration of chemicals like metribuzin 0.7 kg/ha *fb* fenoxaprop-p-ethyl 67 g/ha + metsulfuron 4 g/ha at 45 DAP *i.e.,* 7.67, at a scale of 0-10. Among all the treatments, integration of chemical along with straw mulch and hand weeding recorded reduced phyto-toxicity on turmeric plant *i.e.* atrazine 0.75 kg/ha pre-emergence each *fb* straw mulch at 10 DAP followed by hand weeding at 75 DAP. The phyto-toxic effect of herbicide on turmeric plants have also been observed by Bharty *et al*. (2016a), Barla *et al.* (2015) and Jadhav and Pawar (2014).

Yield and net returns

Application of atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP recorded 50.5% higher fresh yield than hand weeding (**Table 1**). The higher yield owing to treatments integrated with metribuzin 0.7 kg/ha or pendimethalin 1.0 kg/ha or atrazine 0.75 kg/ha PE each *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP can be justified as combined effect of better weed control and reduced phyto-toxicity. Bharty *et al.* (2016a, b), Barla *et al*. (2015), Manhas *et al*. (2011) and Kaur *et al*. (2008) have also observed higher yield of turmeric under the treatments having straw mulch along with heribicides each *fb* hand weeding at 75 DAP. Similarly, maximum net return (` 621216/ha) and B:C ratio (4.45) was under atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP.

Table 1. Effect of weed control methods on total weed density, total dry matter accumulation by weeds, yield, net return and B:C ratio of turmeric

Treatment	Total weed density (no./m^2)			Total dry matter accumulation by weeds (g/m^2)			Phyto-toxicity (0-10 scale)	Yield (t/ha)	Net return (x10^3 `/ha)	B:C ratio
	30 DAP	90 DAP	60 DAP	30 DAP	90 DAP	150 DAP	60 DAP			
Metribuzin *fb* 2 HW	24.6(609)	32.7(1072)	25.8(667)	8.7(76)	22.6(513)	20.9(435)	3.33	20.95	415.93	3.86
Pendimethalin *fb* 2 HW	31.3(983)	36.2(1312)	32.7(1075)	11.7(138)	29.8(888)	22.2(493)	3.00	18.90	364.98	3.39
Atrazine *fb* 2 HW	21.2(451)	32.2(1040)	22.9(534)	7.9(61)	21.3(453)	19.6(386)	2.33	20.58	408.16	3.84
Oxyfluorfen *fb* 2 HW	18.3(340)	27.8(779)	20.5(422)	6.9(47)	18.6(344)	19.3(371)	3.33	16.07	293.11	2.70
Oxadiargyl *fb* 2 HW	17.7(319)	26.9(725)	21.3(454)	6.7(44)	18.2(330)	18.3(336)	3.67	15.26	273.74	2.54
Glyphosate 1.25 l/ha *fb* 2 HW	14.7(223)	24.2(591)	18.7(350)	6.8(46)	17.3(300)	17.8(316)	5.00	18.51	355.96	3.33
Glyphosate1.85 l/ha *fb* 2 HW	14.6(217)	22.3(496)	18.6(348)	6.5(42)	17.0(289)	17.6(309)	5.00	18.16	346.68	3.23
Metribuzin *fb* fenoxaprop-p-ethyl + metsulfuron	21.9(484)	15.0(224)	12.7(160)	8.0(63)	13.5(181)	12.2(148)	7.67	7.44	86.16	0.86
Pendimethalin *fb* fenoxaprop-p-ethyl + metsulfuron	26.3(692)	17.1(292)	15.7(248)	10.8(115)	15.9(254)	15.0(226)	8.00	5.55	39.15	0.39
Atrazine *fb* fenoxaprop-p-ethyl + metsulfuron	18.7(357)	21.0(443)	17.6(311)	7.4(53)	16.6(275)	17.1(292)	8.33	3.25	-17.26	-0.18
Metribuzin *fb* straw mulch *fb* HW	23.2(540)	32.3(1056)	25.2(640)	8.2(68)	21.5(464)	19.3(371)	1.33	28.06	595.38	5.61
Pendimethalin *fb* straw mulch *fb* HW	30.2(917)	34.3(1179)	29.3(862)	11.2(125)	26.8(721)	21.0(441)	1.67	26.05	545.40	5.18
Atrazine *fb* straw mulch *fb* HW	19.5(384)	31.2(976)	21.2(448)	7.6(58)	20.6(422)	18.4(339)	0.67	29.04	621.22	5.93
Three hand weeding	15.9(253)	26.0(678)	18.8(353)	6.6(43)	18.0(325)	17.7(312)	0.00	19.29	371.75	3.36
Un-weeded check	32.9(1086)	45.8(2096)	34.4(1182)	12.1(146)	33.0(1089)	25.1(630)	0.00	2.81	-24.23	-0.26
LSD (p=0.05)	3.92	3.16	2.60	0.82	1.12	0.81	1.48	3.19	798.8	0.75

Data in parentheses are original values.

Table 2. Effect of weed control methods on dry matter accumulation and crop growth rate of turmeric plants

Treatment	Leaves (g/m^2)			Stems (g/m^2)			Rhizomes (g/m^2)			Total dry matter accumulation (g/m^2)				Crop growth rate (g/m^2/day)	
	30 DAP	90 DAP	150 DAP	30 DAP	90 DAP	150 DAP	90 DAP	150 DAP	210 DAP	30 DAP (L+S)	90 DAP (L+S+R)	150 DAP (L+S+R)	210 DAP (R)	30-90 DAP	90-150 DAP
Metribuzin *fb* 2 HW	22.3	81.4	58.7	22.5	49.2	49.5	285	580	462	44.8	416	688	462	6.19	4.53
Pendimethalin *fb* 2 HW	21.8	75.3	49.1	21.4	42.9	41.5	221	480	389	43.3	339	570	389	4.93	3.85
Atrazine *fb* 2 HW	22.2	79.0	53.1	22.2	47.2	46.4	247	523	419	44.4	373	622	419	5.48	4.16
Oxyfluorfen *fb* 2 HW	21.1	52.7	45.0	21.1	33.5	33.4	129	327	262	42.1	215	405	262	2.89	3.16
Oxadiargyl *fb* 2 HW	20.9	52.1	37.4	20.8	29.5	32.1	144	317	253	41.7	226	386	253	3.07	2.67
Glyphosate 1.25 l/ha *fb* 2 HW	21.9	71.1	48.0	21.3	37.6	40.7	204	447	353	43.3	313	535	353	4.50	3.70
Glyphosate1.85 l/ha *fb* 2 HW	21.3	64.6	46.8	21.3	37.3	37.3	200	400	319	42.6	302	484	319	4.33	3.03
Metribuzin *fb* fenoxaprop-p-ethyl + metsulfuron	20.8	38.9	27.2	20.6	25.8	27.8	110	303	246	41.4	175	358	246	2.23	3.05
Pendimethalin *fb* fenoxaprop-p-ethyl + metsulfuron	20.5	37.1	23.2	20.5	27.9	26.1	136	270	217	41.0	201	319	217	2.68	1.96
Atrazine *fb* fenoxaprop-p-ethyl + metsulfuron	20.2	32.6	22.8	20.1	46.4	22.8	122	233	187	40.3	202	279	188	2.69	1.29
Metribuzin *fb* straw mulch *fb* HW	23.2	87.6	75.4	23.4	53.6	51.9	386	787	623	46.6	528	914	624	8.03	6.43
Pendimethalin *fb* straw mulch *fb* HW	22.4	85.9	70.3	23.3	53.0	50.5	354	650	518	45.7	494	770	518	7.47	4.62
Atrazine *fb* straw mulch *fb* HW	23.7	112.0	92.2	23.8	75.9	70.9	689	1246	1003	47.6	877	1409	1003	13.8	8.88
Three hand weeding	22.1	78.7	51.1	21.5	46.4	41.5	245	493	393	43.7	371	585	393	5.46	3.58
Un-weeded check	14.1	27.6	20.2	20.1	17.8	19.3	95.5	190	152	34.2	141	230	152	1.78	1.49
LSD (p=0.05)	3.94	38.8	21.3	NS	20.2	17.0	95.1	172	140	5.2	117	162	140	1.94	3.03

The higher net return was a result of 41.4 % higher yield and 28.8% reduced cost of cultivation compared to mean yield and cost of cultivation recorded by rest of the chemical methods of weed control. Similar trend of yield, net return and B:C ratio also found by Barla *et al*. (2015), Manhas *et al*. (2011) and Kaur *et al*. (2008).

Crop growth rate

Crop growth rate was also higher under atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP at 30-90 and 90-150 DAP to the tune of 153.3 and 148.0% compared to hand weeding at 25, 45 and 75 DAP, respectively (**Table 2**).

Thus, it was concluded that application of atrazine 0.75 kg/ha pre-emergence *fb* straw mulch and hand weeding at 75 DAP may be practiced for better crop growth, higher productivity and profitability of turmeric owing to better weed control.

SUMMARY

A field experiment was conducted at Birsa Agricultural University, Ranchi during rainy season of 2014 to study the efficacy of weed control methods as a suitable integrated weed management for better production of turmeric. Dry matter accumulation by total plant parts was maximum under atrazine 0.75 kg/ha pre-emergence (PE) followed by (*fb*) straw mulch at 10 DAP *fb* hand weeding at 75 DAP at all the stages. Application of atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP recorded higher rhizome yield consequently higher gross return (` 725917/ha). However, maximum net return (` 621216/ha) and B:C ratio (5.93) was recorded with application of atrazine 0.75 kg/ha PE *fb* straw mulch at 10 DAP *fb* hand weeding at 75 DAP.

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