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Research Paper

Integrated weed management in poplar (*Populus deltoides*)–turmeric (*Curcuma longa*) based agroforestry system in Punjab

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ABSTRACT

A field study was conducted during 2013–14 and 2014–15 to find out the effective and economical approach for weed control in turmeric (*Curcuma longa* L.) grown under poplar (*Populus deltoides* Bartr.) block plantation which was established at 4 m × 3 m spacing in January 2012. Three pre-emergence herbicides (pendimethalin 0.75 and 1.0 kg/ha, oxyfluorfen 0.176 and 0.235 kg/ha, atrazine 0.563 and 0.75 kg/ha) were integrated with 9 t/ha paddy straw mulching during both the years except with atrazine during 2014–15. Integrated use of oxyfluorfen 0.235 kg/ha or pendimethalin 1.0 kg/ha with straw mulch provided similar level of weed control to that of 3 hand-weedings and increased rhizome yield of turmeric by 36–42% over weedy check. Pendimethalin 1.0 kg/ha + straw mulch recorded higher benefit: cost ratio than hand-weedings. Atrazine + straw mulch recorded effective control of weeds, however it killed the poplar trees at both the levels; hence not safe for use in turmeric grown in poplar plantations. Treatment combinations of pendimethalin and oxyfluorfen with straw mulch were found to be safe for weed management in poplar-turmeric based agroforestry system.

Key words **:** Agroforestry, Herbicides, Poplar, Straw mulch, Turmeric, Weeds

Agroforestry offers an economical and ecologically viable option for large-scale diversification in agriculture on one hand and environment amelioration on the other. It involves intercropping of trees and crops on same piece of land. Characteristics of particular tree species, e.g. root-system, canopy, alleopathic effect of litter, agro-climatic and edaphic factors, decide the type of intercrop suitable for a particular agroforestry system (Batish *et al.*, 2007). In Punjab, farmers have widely adopted poplar-based agroforestry system owing to its fast growth and good compatibility with crops. Poplar is usually grown on field boundaries or in compact blocks along with agricultural crops like turmeric, sugarcane, fodders, wheat, mentha and vegetables. Amongst these crops, turmeric is a partial shade-tolerant crop, and is capable of giving higher rhizome yield with good curcumin content even at 59–73% relative light intensity (Hossain *et al.,* 2009). Turmeric is increasingly being used in many countries as a spice, cosmetic and natural medicine (Ishimine *et al*., 2004; Hossain *et al*., 2005). Curcumin and oleoresin are extracted from turmeric. India accounts for 78% in world production and 60% in world export share of turmeric (Angles *et al.,* 2011). Though India leads in production of turmeric, its average productivity is quite low, mainly due to heavy infestation of weeds, which can reduce the crop yield by 30–75% (Krishnamurthy and Ayyaswamy, 2000). The critical period of weed competition is an important consideration in the development of alternative weed-management strategies (Swanton and Weise, 1991). According to Hossian *et al*. (2008) the weeds need to be removed during 70 to 160 days after planting for higher yield of turmeric, indicating that it needs a longer period of weed-free condition than other crops.

In sole turmeric, hand-weedings is the most common method for weed management, however it has become uneconomical due to reduced availability of labour and rising wages. Kaur *et al.* (2008) have recorded effective weed control in turmeric with integrated use of herbicides and paddy straw mulch. However, in an intercropping system, it may not be possible to use herbicides recommended for weed control in sole cropping. Several herbicides such as atrazine, metribuzin (Gill *et al*., 2000; Kaur *et al*., 2008), oxyfluorfen (Ratnam *et al*., 2012) and pendimethalin (Kumar and Reddy, 2000) have been found to be effective and safe in sole turmeric. However, herbi-

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cides such as atrazine and metribuzin might not be safe to poplar trees whereas some other herbicides can be used safely. Pendimethalin (James *et al.,* 2003), imazaquin, and oxyfluorfen have been shown to be safe for poplars (Miller and Bloese, 2002). Straw mulch suppressed weed growth and improved crop yield (Hossain *et al*., 2005) and can be used in almost all widely spaced crops. Since information on selectivity and efficacy of herbicides, their tolerance by poplar trees in poplar-turmeric based intercropping system is scarce, this study was undertaken to determine the selectivity and effectiveness of different integrated weed-control approaches for higher productivity of turmeric grown under poplar trees.

MATERIALS AND METHODS

A study was conducted in poplar plantation established at a spacing of 4 m × 3 m (825 trees/ha) during January 2012 at the Research Area of the Department of Forestry and NR, Punjab Agricultural University, Ludhiana. The area between the tree rows (4 m wide strip) was used to plant turmeric crop with a net plot size of 10 m^2 during its second and third year of tree growth, i.e. 2013–14 and 2014–15. The soil was loamy sand with *p*H 7.9, electrical conductivity 0.25 dS/m, organic carbon 3.2 g/kg, available N 137 kg/ha, available P 10.6 kg/ha and available K 12 kg/ha. The experiment was laid out in randomized complete block with 4 replications. There were 8 weed-control treatments, viz. pre-emergence pendimethalin @ 0.75 and 1.0 kg/ha, oxyfluorfen @ 0.176 and 0.235 kg/ha, atrazine @ 0.563 and 0.75 kg/ha, hand-weeding (30, 60, and 90 days after sowing) and unweeded check, during the first year. In the subsequent year, herbicide treatments of atrazine application were not repeated, as it has caused phytotoxicity to the poplar trees. Available literature on weed control in turmeric indicated that either of herbicides or straw mulch alone did not provide efficient and long-term control of weeds, hence only combination of herbicides and straw mulch were used in the study. Turmeric rhizomes @ 1.5 t/ha (cv. 'PH 1') were planted on flat beds at 30 cm × 20 cm spacing, between tree rows, in the last week of April during both the years. The herbicides were sprayed within 2 days after planting and paddy straw mulch @ 9 t/ha was spread uniformly immediately after the application of herbicides. The crop was raised by using recommended package of practices. The crop was harvested in the end of January during both the years. Economics of turmeric was calculated by using prevailing market prices of inputs and outputs under different weed-control treatments. Main inputs for calculating the cost of cultivation included the cost of seed (₹12,500/ha), human labour (₹370/day), fertilizers and manures (₹6,100/ha), paddy straw mulch (₹1,000/t), Stomp 30 EC (pendimethalin) @ ₹450/litre, Goal 23.5 EC (oxyfluorfen) @ ₹ 210/100 ml, Atrataf 50 WP (Atrazine) @ 185/500 g etc. The market price of fresh rhizomes was ₹ 25,000/t.

All the trees in the experiment were taken for measurement of growth parameters. Height of trees (m) was recorded from base of the tree to growing tip with the help of Ravi's multimeter. The clear bole height was also measured with Ravi's multimeter from ground level to the point where crown branches started. Girth at breast height (GBH) was measured by measuring tape at 1.37 m from ground level and converted to diameter at breast height (DBH, cm). The weed data and various growth and yield attributes of the crop were recorded.

As there was reduction in quantum of turmeric yield grown under poplar plantation with increase in age of trees, data of both the years are presented separately. Analyses of variance (ANOVA) were performed and means were separated at $P \leq 0.05$ with critical difference (CD) test when the treatment effects were significant. Data on weed density and dry-matter accumulation were recorded at 30-day intervals till 120 days and were subjected to square-root transformation before analysis.

RESULTS AND DISCUSSION

Tree growth

Atrazine at both the doses caused the mortality of 2 year-old poplar plants during the first year (data not shown), hence is not safe for use in poplar plantations. Pendimethalin and oxyfluorfen were found to be safe for poplar trees at their respective doses during both the years. In general, height of poplar trees increased from 9.77 m to 13.40 m in a span of 1 year (Table 1). There was 27% increase in diameter at breast height (DBH). The clear bole and crown length increased 2.6 m and 1.06 m from second to third year respectively. The crown spread also increased from 8.4 m^2 to 11.3 m^2.

Weed density

The major weed flora observed in turmeric grown under poplar trees consisted of *Cyperus rotundus, C. compressus, Acrachne racemosa, Commelina*

Table 1. Tree growth parameters during second and third year of poplar plantation

Tree growth parameters	Tree age	
	2 years	3 years
Tree height (m)	9.77	13.40
DBH (cm)	9.63	12.26
Clear bole length (m)	4.34	6.91
Crown length (m)	5.43	6.49
Crown spread (m^2)	8.4	11.3

benghalensis, Oenothera drummondii, Cannabis sativa, Amaranthus viridis, Chenopodium album and *Lepidium sativum.* Pendimethalin effectively controlled *A. racemosa* and *L. sativum,* while atrazine gave poor control of these weeds. Oxyfluorfen was effective against *C. benghalensis* and *C. album. Cyperus rotundus* was not controlled by any of the 3 herbicides. All the weed-control treatments recorded significantly lower weed density compared to weedy check at all the stages of observation (Table 2). The pre-emergence application of oxyfluorfen and pendimethalin integrated with straw mulch were at par with each other and significantly better than unweeded check; their higher dose were more effective than respective lower doses especially during the initial critical period of 2 months. Overall, the pendimethalin 1.0 kg and oxyfluorfen 0.235 kg/ha resulted in effective control of weeds and provided weed-free environment during initial phase of crop growth. And later on as the crop canopy developed, the crop plants smothered the weeds and reduced the crop-weed competition. Application of paddy straw mulch complimented the herbicides in preventing the germination and emergence of annual weeds which escaped with the application of herbicides or started germinating at later stages.

Weed dry matter

The weed-control treatments significantly influenced the total weed dry matter during both the years (Table 3). Three hand-weedings resulted in the lowest weed dry matter at all the stages of observation. The integrated use of pendimethalin 1.0, oxyfluorfen 0.235 and atrazine 0.75 kg/ha with straw mulch showed effective control of weeds up to 60 DAS during both the years and significantly reduced the weed dry matter compared to their respective lower doses and weedy check. Oxyfluorfen 0.235 recorded 70 and 67% lower weed dry matter followed by pendimethalin (56 and 62%) at 30 and 60 DAS, respectively, in turmeric grown under 2-year-old poplar plantation. The corresponding values for these herbicides were 46 and 58% and 40 and 47.5%, respectively in turmeric crop grown under 3 year old poplars. At 120 DAS, weed-control efficiency with pendimethalin 1.0 and oxyfluorfen 0.235 kg/ha plus straw mulch was 63.2 and 64.1% respectively. Hand-weeding, due to repeated weed removal, caused the lowest weed growth and highest weed-control efficiency amongst all the treatments. Kaur *et al*. (2008) also reported effective and long-term control of weeds with integration of herbicide and straw mulch.

Turmeric yield

All the herbicides were found safe to the turmeric crop. The pre-emergence application of pendimethalin 1.0 and

Table 2. Effect of weed-control treatments on weed density (Nos./m^2) in turmeric grown under poplar plantation during its second and third year of age

Treatment	30 DAS		60 DAS		90 DAS		120 DAS	
	Second year	Third year	Second year	Third year	Second year	Third year	Second year	Third year
Pendimethalin @ 0.75 kg/ha + paddy straw mulch	5.56 (30.0)	6.43 (40.7)	6.96 (47.7)	7.43 (54.3)	5.16 (26.0)	4.49 (19.3)	4.69 (21.7)	5.11 (26.7)
Pendimethalin @ 1.0 kg/ha + paddy straw mulch	4.26 (18.0)	4.18 (16.7)	4.84 (23.0)	5.93 (34.3)	4.30 (18.0)	14.7 (3.93)	4.68 (21.3)	5.12 (26.3)
Oxyfluorfen @ 0.176 kg/ha + paddy straw mulch	5.92 (34.3)	5.19 (26.3)	7.21 (51.0)	5.89 (33.7)	4.95 (24.3)	4.28 (17.7)	5.28 (27.7)	5.28 (27.7)
Oxyfluorfen @ 0.235 kg/ha + paddy straw mulch	3.97 (15.3)	3.41 (10.7)	4.97 (24.0)	4.64 (20.7)	4.38 (18.7)	5.12 (25.3)	4.06 (16.0)	4.06 (16.0)
Atrazine @ 0.563 kg/ha + paddy straw mulch	6.17 (37.3)	-	6.31 (39.3)	-	4.63 (20.7)	-	4.63 (20.7)	-
Atrazine @ 0.75 kg/ha + paddy straw mulch	4.38 (18.3)	-	5.39 (28.3)	-	4.80 (22.3)	-	3.99 (15.0)	-
Hand-weedings	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	5.59 (31.0)	6.32 (39.3)
Weedy check	8.59 (74.0)	9.37 (87.3)	8.11 (66.0)	8.98 (80.0)	8.24 (67.3)	7.92 (63.7)	7.89 (61.3)	7.09 (49.7)
SEm±	0.34	0.24	0.39	0.21	0.37	0.35	0.40	0.55
CD (P=0.05)	1.01	0.75	0.99	0.63	1.10	1.06	1.15	1.66

Data subjected to $\sqrt{x+1}$ transformation; figures in parentheses are original values; DAS, days after sowing

Table 3. Effect of weed-control treatments on weed dry matter (g/m^2) in turmeric grown under poplar plantation during its second and third year of age

Treatment	30 DAS		60 DAS		90 DAS		120 DAS		WCE (%) at 120 DAS (Mean of 2 years)
	Second year	Third year	Second year	Third year	Second year	Third year	Second year	Third year	
Pendimethalin @ 0.75 kg/ha + paddy straw mulch	7.57*(56.7)	7.53 (56.7)	16.1 (258.7)	12.2 (148.7)	14.5 (215.0)	13.6 (184.3)	14.5 (210.3)	12.1 (147.3)	57.0
Pendimethalin @ 1.0 kg/ha + paddy straw mulch	6.37 (39.7)	6.45 (41.3)	13.9 (193.7)	10.8 (115.7)	12.7 (161.0)	12.3 (152.7)	12.6 (158.7)	12.4 (154.3)	63.2
Oxyfluorfen @ 0.176 kg/ha + paddy straw mulch	8.36 (69.3)	7.33 (53.0)	14.6 (212.7)	13.4 (180.0)	14.3 (204.7)	12.3 (150.7)	13.3 (175.7)	12.0 (143.0)	62.0
Oxyfluorfen @ 0.235 kg/ha + paddy straw mulch	5.21 (27.0)	5.90 (53.0)	13.1 (171.3)	11.5 (132.3)	13.8 (189.0)	11.4 (130.3)	12.2 (149.3)	12.6 (158.3)	64.1
Atrazine @ 0.563 kg/ha + paddy straw mulch	6.96 (47.7)	-	14.7 (216.7)	-	13.7 (190.0)	-	15.1 (225.7)	-	39.0
Atrazine @ 0.75 kg/ha + paddy straw mulch	4.31 (17.7)	-	13.1 (171.0)	-	11.9 (142.7)	-	11.4 (129.3)	-	65.0
Hand weeding	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	11.5 (132.0)	12.7 (162.7)	67.3
Weedy check	9.54 (90.0)	9.90 (97.3)	22.7 (518.0)	14.8 (220.3)	20.2 (406.3)	18.1 (330.0)	19.1 (370.0)	22.4 (502.3)	-
SEm±	0.27	0.43	0.59	0.31	0.72	0.64	0.68	0.41	
CD (P=0.05)	0.78	1.28	1.73	0.94	2.12	1.94	2.01	1.23	

*Data, Weed dry matter subjected to $\sqrt{x+1}$ transformation; figures in parentheses are original values; DAS, days after sowing; WCE, weed-control efficiency

Table 4. Effect of weed-control treatments on yield and yield attributes of turmeric grown in poplar plantation during its second year and third year of age

Treatments	Rhizome/plant (Nos.)		Fingers/rhizome (Nos.)		Rhizome weight/plant (g)		Rhizome yield (t/ha)		Weed index (%)	
	Second year	Third year	Second year	Third year	Second year	Third year	Second year	Third year	Second year	Third year
Pendimethalin @ 0.75 kg/ha + paddy straw mulch	3.23	3.07	15.7	10.7	162.7	150.0	5.73	5.33	12.9	24.9
Pendimethalin @ 1.0 kg/ha + paddy straw mulch	3.97	3.80	17.7	14.3	188.3	179.7	7.05	6.57	38.8	53.8
Oxyfluorfen @ 0.176 kg/ha + paddy straw mulch	2.93	2.77	17.0	14.7	157.3	150.7	5.63	5.03	10.8	17.9
Oxyfluorfen @ 0.235 kg/ha + paddy straw mulch	3.83	3.63	19.3	16.0	183.7	173.7	6.59	5.80	29.7	35.8
Atrazine @ 0.563 kg/ha + paddy straw mulch	3.40	-	14.0	-	170.0	-	6.42	-	26.4	-
Atrazine @ 0.75 kg/ha + paddy straw mulch	4.10	-	22.0	-	173.0	-	7.27	-	42.8	-
Hand-weeding	4.63	4.40	26.0	20.3	201.7	188.3	8.09	7.13	59.3	67.1
Weedy check	2.70	2.67	13.0	11.3	104.0	95.3	5.08	4.27	12.9	53.8
SEm±	0.30	0.17	2.0	1.36	10.1	11.4	0.22	0.20	-	-
CD (P=0.05)	0.88	0.50	5.88	4.10	29.7	34.4	0.65	0.60	-	-

Table 5. Economics of turmeric grown under poplar during its second and third year of age

Treatments	Cost of cultivation (× 10^3₹/ha) (Mean of 2 years)	Gross returns (× 10^3₹/ha)		Net returns (× 10^3₹/ha)		Benefit: cost ratio	
		Second year	Third year	Second year	Third year	Second year	Third year
Pendimethalin @ 0.75 kg/ha + paddy straw mulch	83.4	143.3	133.3	59.9	49.9	1.72	1.60
Pendimethalin @ 1.0 kg/ha + paddy straw mulch	83.7	176.2	164.1	92.4	80.4	2.10	1.96
Oxyfluorfen @ 0.176 kg/ha + paddy straw mulch	83.8	140.6	125.8	56.7	41.9	1.68	1.50
Oxyfluorfen @ 0.235 kg/ha + paddy straw mulch	84.4	164.7	145.0	80.3	60.5	1.96	1.72
Atrazine @ 0.563 kg/ha + paddy straw mulch	82.6	160.5	-	77.8	-	1.94	-
Atrazine @ 0.75 kg/ha + paddy straw mulch	82.8	181.4	-	98.5	-	2.19	-
Hand-weedings	97.4	202.2	178.3	104.8	80.9	2.07	1.83
Weedy check	82.3	126.9	106.6	44.6	24.3	1.54	1.30
SEm±	-	2.03	4.92	2.03	4.92	0.02	0.05
CD (P=0.05)	-	5.9	14.8	5.9	14.8	0.07	0.16

oxyfluorfen 0.235 kg/ha, both integrated with straw mulch, recorded the highest fresh rhizome yield at par with hand-weeding and significantly higher over weedy check during both the years (Table 4). The increased yield in these treatments can be attributed to seasonlong effective control of weeds in early stage by pre-emergence herbicides followed by the application of mulch at later stages. Crop-weed competition has been minimized by pre-emergence spray of herbicides, resulting in higher crop yield of turmeric (Berevadia *et al*., 1996). Decomposition of straw mulch provides soil organic matter which makes the soil conducive for rhizome development and contributes to higher rhizome yield (Nwokocha *et al*., 2006). Unweeded control recorded the lowest rhizome yield, with a yield loss of 37 and 40% compared to 3 hand-weedings during second and third year respectively. Higher turmeric yield with integrated use of pre- and post-emergence herbicides (oxyfluorfen 0.25 kg followed by quizalofop-ethyl 0.05 kg/ha) with hand-weedings (Ratnam *et al*., 2012) and pre-emergence pendimethalin with paddy straw mulch (Kaur *et al*., 2008) have been reported earlier.

Economics

Amongst the weed-control treatments, hand-weedings incurred the highest cost of production when compared with rest of the treatments (Table 5). All weed-control treatments had higher gross and net returns than the weedy check during both the years. Amongst the herbicides, atrazine 0.75 kg/ha + paddy straw mulch showed the highest net returns during the first year and pendimethalin @ 1.0 kg/ha + paddy straw mulch during the subsequent year. The benefit: cost ratio under different treatments varied from 1.68–2.19 as compared to 1.54 under weedy check in 2-year-old plantation. Pendimethalin @ 1.0 kg/ha + paddy straw mulch recorded higher benefit: cost ratio over all other treatments in 3year-old plantation.

It may be concluded from this study that atrazine should not be used for controlling weeds in turmeric grown under poplar plantations due to its deleterious effect on the poplar plants. Weeds from turmeric-poplar based agroforestry system can be controlled effectively by using oxyfluorfen 0.235 kg/ha or pendimethalin 1.0 kg/ha along with straw mulch.

REFERENCES

Angles, S., Sundar, A. and Chinnadurai, M. 2011. Impact of globalization on production and export of turmeric in India–An economic analysis. *Agriculture Ecosystem Research Review* **24**(7–12): 301–308.

Batish, D.R., Kohli, R.K., Jose, S. and Singh, H.P .2007. *Ecological Basis of Agroforestry*. CRC Press, New York.

Berevadia, T.N., Patel, D.B. and Patel, J.B. 1996. Integrated weed management in Indian mustard. *Pestology* **20**: 42–44.

Gill, B.S., Randhawa, G.S. and Saini. S.S. 2000. Integrated weed management studies in turmeric (*Curcuma longa* L.). *Indian Journal of Weed Science* **32**(1 and 2): 114–115.

Hossain, M.A., Ishimine, Y., Akamine, H. and Motomura, K. 2005. Effects of seed rhizome size on growth and yield of turmeric (*Curcuma longa* L.). *Plant Production Sciences* **8**(1): 86–94.

Hossain, M.A., Yamawaki, K., Akamine, H. and Ishimine, Y. 2008. Weed infestation in turmeric in Okinawa, Japan. *Weed Technology* **22**(1): 56–62.

Hossain, M.A., Akamine, H., Ishimine, Y., Teruya, R., Aniya, Y. and Yamawaki, K. 2009. Effect of relative light intensity on the growth, yield and curcumin content of turmeric (*Curcuma longa* L.) in Okinawa, Japan. *Plant Production Sciences* **12**(1): 20–36.

Ishimine, Y., Hossain, M.A., Motomura, K., Akamine, H. and Hirayama, T. 2004. Effects of planting date on emergence, growth and yield of turmeric (*Curcuma longa* L.) in Okinawa Prefecture, Southern Japan. *Japanese Journal of Tropical Agriculture* **48**(1): 10–16.

James, E.A., Charles, H.G. and Glenn, R. 2003. Weed control in field nurseries. *Horticultural Technology* **13**: 9–14.

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

Kumar, A.K. and Reddy, M.D. 2000. Integrated weed management

in maize + turmeric intercropping system. *Indian Journal of Weed Science* **32**(1 and 2): 59–62.

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.

Miller, R.O. and Bloese, P.D. 2002. Imazaquin and pendimethalin use for weed control in hybrid poplar plantations in Michigan: second-year results plantations in Michigan. (In) *Proceedings of the North Central Weed Science Society* pp. 55.

Nwokocha, C.C., Olojede, A.O., Ano, A.O. and Mbagwu, J.S.C. 2006. Mulching an Ultisol at Umudike: Effects on aggregate stability and rhizome yield of turmeric (*Curcuma longa* L). (In) *Proceedings of the 40th Annual Conference of the Agricultural Society of Nigeria (ASN).* Asumugha, G.N., Olojede, A.O., Ikeorgu, J.G., Ano, A.O., Herbert, U. (Eds), held at NRCRI, Umudike, Abia State, Nigeria, pp. 378–381.

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.

Swanton, C.J. and Weise, S.F. 1991. Integrated weed management in Ontario: the rationale and approach. *Weed Technology* **5**(4): 657–663.