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Pre- and post-emergent herbicides for control of castor weeds

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ABSTRACT

A field experiment was conducted during 2012 to 2014 to find out most suitable and cost effective weed management practice for rain fed castor on the medium black soils of central dry zone of Karnataka. The experiment consisted of ten treatments involving two pre-emergence herbicides (trifluralin and pendimethalin) alone and in combination with hand weeding / intercultivation, inter-cropping of castor + groundnut (1:3 ratio), three weedings (20, 40 and 60 DAS), farmers' practice (one weeding at 20 DAS *fb* two inter-cultures at 45 and 60 DAS), two post–emergence herbicides (quizalofop-ethyl and fenoxaprop-p-ethyl, both at 0.05 kg/ha at 25 DAS) and weedy check. The pooled results of three seasons revealed that pre-emergence application of pendimethalin at 1.0 kg/ha *fb* one inter-cultivation at 40 DAS resulted in better weed control efficiency and seed yield (1.61 t/ha) and B:C ratio (4.3) comparable to farmers' practice (1.33 t/ha) and three weeding (1.99 t/ha). Herbicides controlled grasses gave moderate yield comparable to farmers' fields. Weedy check reduced the yield by 76% due to severe competition offered by grasses and broad-leaf weeds. The large scale demonstration on five farmers' fields in Chitradurga district also revealed that pendimethalin at 1.0 kg/ha *fb* one inter-cultivation at 40 DAS (1.48 t/ha and 3.90) gave seed yield and B:C ratio comparable to farmers' practice of weed control (1.49 t/ha and 3.70).

Key words: Castor, Economics, Pendimethalin, Trifluralin, Weed control

Castor (*Ricinus communis* L.) is indigenous to the south-eastern Mediterranean Basin, Eastern Africa and India, but is wide spread throughout tropical regions and is widely grown elsewhere as an ornamental plant (Phillips and Rix 1999). Castor is a member of the Euphorbiaceae (spurge) family. Castor has been cultivated for centuries for oil stored in its seeds. Since ancient times, it has been exploited for its oils and fats to serve as important raw material for the manufacture of soaps, paints and varnishes, hair oils, lubricants, textiles, auxiliaries, pharmaceuticals etc. (Copley *et al.* 2005, Morris *et al.* 2011).

Oilseeds in India constitute the principal commercial crop. (Kumar Naik *et al.* 2015). Castor is preferred by the farmers in traditional castor growing states due to increasing demand and remunerative market price. In India during 2012-13, castor occupied an area of 13.17 lakh ha with a production of 21.77 lakh tones and productivity of 1.65 t/ha (Anonymous 2014) and meets about 90% of the world's requirement of castor oil. India is earning about ` 2253 crores of foreign exchange through export of castor oil and its derivatives with high level of demand rising annually at 3-5% annum (Hegde 2010). Weed infestation is one of the constraints limiting the production of castor (Yadav and Singh 2007). Prevalence of high temperature coupled with relative humidity and frequent rainfall favors luxuriant weed growth which smother crop by restricting its growth particularly during early stages by offering severe weed competition for essential resources (Prasad *et al.* 1991). Castor is a species of C_3 photosynthetic metabolism and being a wider spaced crop with slow initial growth and a low ability to compete for resources with other species makes it vulnerable to weed competition (Azevedo *et al.* 2006) and first 40 days appeared to be critical.The conventional method of weed control is very effective, expensive, labour intensive and time consuming and do not allow weeding at rains during the critical period (Singh *et al.* 2013) resulting in poor weed control. According to a study by Azevedo *et al.* (2006), weeds decreased castor yield by 86%.

Option to control grass species are the ACCase (Acetyl-CoA carboxylase (ACC)) inhibitor herbicides applied post-emergence, such as quizalofop-p-ethyl, clethodim, fenoxaprop-p-ethyl, propaquizafop and butroxydim (Macielet *et al.* 2007, 2008, 2012, Silva

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et al. 2012). The possibility of applying post-emergence herbicides can be a strategy to enhance the control of eudicotyledons plants (Sofiatti *et al*. 2012). Information regarding use of herbicides in castor under rain fed conditions is meager and hence, an attempt has been made to work out an effective weed management strategy using herbicides alone or in combination with inter-culture/hand weeding in central dry zone of Karnataka.

MATERIALS AND METHODS

This study was conducted at the Zonal Agricultural and Horticultural Research Station, Hiriyur (13^0 57' 32" N, 70^0 37' 38" E, 606 MSL), University of Agricultural and Horticultural Sciences, Shivamogga, India. The soil of the experimental sites belonged to medium black soil having pH of 7.7, low available nitrogen (162 kg/ha), medium available phosphorus (16.2 kg/ha) and potassium (270 kg/ha). The total rainfall received during 2009, 2010 and 2011 was 745.2, 937.6 and 347.8 mm with 50, 51 and 28 rainy days respectively, during the crop growth period (June - December). The meteorological data during the course of crop growth were obtained from Agro Met Observatory (Gramina Krushi Mausam Sewa), Department of Agronomy, Hiriyur.

Field experiments were conducted for three consecutive years (2009, 2010 and 2011) during the *Kharif* seasons at Zonal Agricultural and Horticultural Research Station, Hiriyur, Karnataka to identify the most suitable integrated weed management option in castor. The experiment consisted of 10 treatments (Table 1) namely two pre-emergence herbicides (trifluralin and pendimethalin) alone and in conjunction with hand weeding/inter-cultivation, inter-cropping of castor + groundnut, weed free plots also maintained for comparison (3 times weeding), two post-emergence herbicides (quizalofop-ethyl and fenoxaprop-p-ethyl) and season-long weed competition (weedy check). The experiment was laid out in a randomized block design with three replications. The previous crop was chickpea in experimental field. The '*DCH- 177'* variety of castor was sown using two castor seeds per hill on ridges by hand dibbling at recommended spacing of 90 cm (between rows) x 60 cm (plant to plant) with a depth of 8-10 cm. Seeds were treated with bavistin 3 g/kg to protect plants from seed borne diseases. Compound fertilizer [NPK (12:32:16)] at a rate of 20 kg nitrogen, 40 kg of phosphorus and 20 kg potassium as basal dose followed by top dressing with an additional 20 kg N/ha each at 35-40 and 65-70 days after sowing applied. Pre-emergence (one day after sowing) and post-emergence herbicides (25 DAS) were applied using spray volume of 600 and 500 l/ha respectively, using knap sack sprayer with flat fan nozzle. At two weeks after sowing, the seedlings of castor crop were thinned to 1 plant per hill. Acephate at the rate of 1.25 kg/ha was applied with a hand operated knapsack sprayer to semi-looper (*Achoea janata* L.) control.

Data on weed density and weed biomass were recorded with the help of a quadrant (0.25 m^2 area) placed randomly at two spots in the plots at 30 DAS and harvest. Weed control efficacy was calculated based on weed density by using the formula suggested by Mani *et al*. (1973). The data on weed density and weed biomass were subject to square root transformation prior to statistical analysis to improve variance homogeneity.

RESULTS AND DISCUSSION

The major weed flora in the experimental fields and on farm validation sites consisted of *Digitaria ciliaris*, *Dactyloctenium aegyptium*, *Echinochloa colona* and *Chloris barbata* (among grasses); *Cyperus rotundus* (sedge), *Ageratum conyzoides*, *Acanthospermum hispidum* and *Commelina benghalensis* (among broad-leaved weeds).

During all the years, different weed control treatments including herbicidal weed control practices applied either alone or in combination with hand weeding and farmer's practice proved effective in reducing the total weed count and weed dry weight compared to weedy check (Table 1). In weed free treatment, plots were hand weeded thrice at 20 days interval (20, 40 and 60 DAS) and farmers practice (one hand weeding (HW) 25 DAS *fb* two intercultural at 45 and 60 DAS) plot was also an effective means of weeding where weed density and weed biomass was significantly lower than weedy check. However, herbicides sole application of trifluralin or pendimethalin (PE) at 1.0 kg/ha without supplemening of HW and interculture were found less effective in season-long control of weeds compared to integrated treatments and proved to be superior to weedy check. In different weed control treatments, integration of one hand weeding over the application pendimethalin herbicides and farmer's practice at 40 DAS caused significant reductions in the density and fresh biomass of weeds when compared to respective sole application of pre- and post-emergent herbicides.

Improvement in the weed control efficiency to the tune of 18 to 20% was recorded when one hand weeding was super imposed with sole application of

pre-emergence herbicides, trifluralin or pendimethalin. The lowest weed density (1.67 g/m^2), minimum weed dry weight (11.67 g/m^2) and the highest weed control efficiency (95.5%) was recorded with pre-emergence application of pendimethalin 1.0 kg/ha *fb* hand weeding at 40 DAS (Table 1). The present results were in agreement with the findings of earlier study which indicated that integrating one hand weeding at 40 DAS along with pre-emergence application of metolachlor 1.0 kg/ha (Manickam *et al*. 2009) or alachlor at 2.0 kg/ha (Dungarwal *et al*. 2002) significantly increased the yield of *Kharif* castor through better weed control. Further, as observed in the present study Iswar Singh *et al*. (2013) has also reported improvement in the weed control efficiency to the tune of 22 to 23% due to combination of one hand weeding along with fluchloralin (PPI) and pendimethalin (PE). Inter-cropping of castor with groundnut in 1:3 ratio lowered the weed density (by 48%) and weed dry matter (by 80%) as compared to weedy check due to more ground coverage by the crops (18.6 g/m^2 and 53.3 g/m^2 as against 36 g/m^2 and 263 g/m^2 in weedy check). The present findings confirmed the earlier studies made by Iswar Singh *et al*. (2013) with inter cropping of castor and groundnut in 1:4 ratio due to coverage of more surface area and suppressing weed growth.

Application of either quizalofop-ethyl or fenoxaprop-p-ethyl 50 g/ha 25 DAS also lowered the weed density and weed dry matter as compared to weedy check and sole application of trifluralin or pendimethalin (PE) at 1.0 kg/ha. However, the extent of control was not at par with weed free plots in these graminicides, as these herbicides control only grasses, without affecting broad-leaf weeds and sedge.

The variations in weeds' growth resulted variations in growth of crop (plant height and number of branches/plant) which directly influenced yield components (100 - seed weight, number of spikes/ plant, primary spike length and number of capsules/ spike) and ultimately castor yield. Major physiological growth parameters and yield attributing characters for three seasons were studied and pooled analyzed (Table 2). There was significant improvement in yield components like primary spike length, 100 seed weight and number of capsules/spike by 39 cm, 30 g and 45.4 respectively due to pendimethalin application at 1.0 kg/ha *fb* inter culture at 40 DAS as compared to weedy check (24.3 cm, 24.7 g and 24.6 respectively). Pendimethalin at 1.0 kg/ha as pre-emergence *fb* weeding at 40 DAS produced significantly higher seed yield (1.61 t/ha) as compared to weedy check (0.48 t/ha), but comparable to three hand weeding (20, 40 and 60 DAS, 1.99 t/ha). These findings were in line with the reports of Dungarwal *et al*. (2002) who obtained effective weed control with the combination of pre-emergence application of pendimethalin (1.0 kg/ha) *fb* hoeing at 40 DAS in castor.

The treatment receiving weeding thrice (` 43,989 /ha) and pendimethalin at 1.0 kg/ha as pre-emergence *fb* inter- culture at 40 DAS recorded

Table 1. Weed competition index (%), weed control efficiency (%), weed dry weight (g/m^2) and total weed count (no./m^2) at harvest in castor as influenced by integrated weed management practices under rain fed condition (pooled data of 2009, 2010 and 2011-12)

Treatment	Total weed density(no./m^2)		Weed dry weight (g/m^2)*		Weed control efficiency (%)	Weed index
	30 DAS	At harvest	30 DAS	at harvest	at harvest	(%)
Trifluralin at 1.0 kg/ha (PE)	4.3 (18.0)	3.7 (13.3)	4.2 (16.6)	8.3 (68.7)	73.9	50.7
Trifluralin at 1.0 kg/ha (PE) *fb* 1 hand weeding 40 DAS	4.3 (18.0)	3.5 (11.0)	3.7 (12.6)	4.5 (19.3)	92.7	39.0
Pendimethalin 30 EC at 1.0 kg/ha (PE)	3.1 (8.5)	3.7 (12.7)	3.5 (12.0)	8.1 (64.7)	75.4	39.2
Pendimethalin 30 EC (1.0 kg/ha (PE) *fb* inter-cultivation at 40 DAS	2.9 (8.0)	1.6 (1.7)	2.7 (6.6)	3.5 (11.7)	95.6	19.2
Intercropping castor + groundnut (1:3)	5.8 (32.6)	4.4 (18.7)	4.6 (21.0)	7.3 (53.3)	67.3	39.5
Farmers practice (1 hand weeding 25 DAS *fb* 2 intercultures at 45 and 60 DAS)	1.0 (0.0)	1.8 (2.3)	1.0 (0.0)	3.2 (10.0)	96.2	33.2
Quizalofop-ethyl at 0.05 kg/ha at 25 DAS	3.9 (14.6)	4.7 (21.0)	5.2 (27.0)	14.2 (201)	23.4	34.9
Fenoxaprop -p-ethyl at 0.05 kg/ha at 25 DAS	4.0 (15.3)	4.9 (23.0)	5.6 (31.0)	13.7 (186)	29.0	27.5
Three weeding (20, 40 and 60 DAS)	1.0 (0.8)	1.0 (0.0)	2.3 (8.0)	1.0 (0.0)	100	0
Weedy check	7.2 (51.3)	6.1 (36.3)	6.3 (38.6)	16.2 (263)	0	76.0
LSD (P=0.05)	0.51	0.61	0.6	0.98		

DAS= Days after sowing, PE= Pre-emergence, *fb* = Followed by, NA= Not analysed, averaged over replications. Figures in parentheses are the means of original values. Data were subjected to square root transformation.

Table 2. Growth, yield attributes and seed yield of castor as influenced by integrated weed management practices under rain fed condition (pooled data of 2009, 2010 and 2011-12)

Treatment	Plant height up to primary raceme (cm)	Number of branches /plant	Number of spikes / plant	Primary spike length (cm)	Number of capsules/ spike	100 seed weight (g)	Seed yield (t/ha)	Gross returns (x10^3 `/ha)	Net returns (x10^3 `/ha)	Benefit : cost ratio
Trifluralin at 1.0 kg/ha (PE)	75.6	4.9	3.7	31.1	34.2	25.0	0.98	30.50	17.42	2.3
Trifluralin at 1.0 kg/ha (PE) *fb* 1 hand weeding 40 DAS	71.7	5.6	3.5	29.7	30.8	28.7	1.22	37.73	24.65	2.9
Pendimethalin 30 EC at 1.0 kg/ha (PE)	72.7	5.6	4.3	28.1	35.7	29.3	1.21	37.57	23.70	2.7
Pendimethalin 30 EC (1.0 kg/ha (PE) *fb* inter-cultivation at 40 DAS	80.1	6.4	4.9	39.0	45.4	30.0	1.61	49.97	36.10	3.6
Intercropping castor + groundnut (1:3)	80.9	4.3	3.2	28.73	35.1	28.0	1.21	37.39	22.53	2.5
Farmers practice (1 hand weeding 25 DAS *fb* 2 intercultures at 45 and 60 DAS)	86.4	5.9	4.6	35.9	42.4	29.3	1.33	41.29	24.94	2.5
Quizalofop-ethyl at 0.05 kg/ha at 25 DAS	74.5	5.5	4.1	32.9	35.5	28.7	1.30	40.27	26.81	3.0
Fenoxaprop -p-ethyl at 0.05 kg/ha at 25 DAS	78.7	6.3	5.1	35.3	36.4	30.0	1.45	44.83	31.81	3.4
Three weeding (20, 40 and 60 DAS)	74.7	7.0	4.7	37.1	42.4	30.0	1.99	61.84	43.99	3.5
Weedy check	67.9	3.8	2.8	24.3	24.6	24.7	0.48	14.82	2.96	1.2
LSD (P=0.05)	NS	NS	NS	8.73	9.5	3.6	0.75			

DAS = Days after sowing, PE= Pre-emergence, Average sale rate of castor bean - Rs 31.0/kg, NA= Not analysed, averaged over replications

Table 3. Marginal returns and marginal cost of castor as influenced by integrated weed management practices under rain fed condition

Treatment	Marginal cost (MC)	Marginal returns (MR)	MR/MC
Trifluralin at 1.0 kg/ha (PE)	1225	15686	12.8
Trifluralin at 1.0 kg/ha (PE) *fb* 1 hand weeding 40 DAS	1225	22909	18.7
Pendimethalin 30 EC at 1.0 kg/ha (PE)	2017	22754	11.3
Pendimethalin 30 EC at1.0 kg/ha (PE) *fb* inter-cultivation at 40 DAS	2017	35154	17.4
Intercropping Castor + groundnut (1:3)	3000	22568	7.5
Farmers practice (1 hand weeding 25 DAS *fb* 2 inter-cultures at 45 and 60 DAS)	4500	26474	5.9
Quizalofop-ethyl at 0.05 g/ha at 25 DAS	1600	25451	15.9
Fenoxaprop -p-ethyl at 0.05 kg/ha 25 DAS	1160	30008	25.9
Three weeding (20, 40 and 60 DAS)	6000	47027	7.8
Weedy check	-	-	-

higher net returns (` 36,099/ha) and with respect to B:C ratio pendimethalin at 1.0 kg/ha as pre-emergence *fb* inter- culture at 40 DAS recorded higher (3.6) than other treatments. As observed in the present study, Iswar Singh *et al*. (2013) also observed similar net returns (` 74,464/ha) and B:C ratio (1.3:1) by use of pendimethalin (1.0 kg/ha) *fb* inter-culture over weedy check.

The marginal returns (MR) and marginal cost (MC) of castor were also worked-out to assess the increase in net returns due to different weed management practices. Marginal cost in herbicide treated plots was considerably less (` 1160/ha in fenoxaprop-p-ethyl treatment ` 2017 /ha in pendimethalin) as compared to three hand-weeding costing ` 6000/ha and farmer's practice ` 4500/ha. The higher marginal returns /marginal-cost ratio was obtained in the plot treated with fenoxaprop-p-ethyl, followed by trifluralin and pendimethalin; while it was quite low with farmer's practice and three handweeding owing to herbicides management being cheaper than hand weeding and farmer's practice (Table 3).

Validation through large scale demonstration

The best treatment of pre-emergence pendimethalin at 1.0 kg/ha *fb* inter-culture at 40 DAS was compared with farmers' practice (one hand weeding at 20 DAS *fb* two intercultures at 40 and 60 DAS) on five farmers fields of village Kasturi Rangavanahalli (plot size of one ha) in Chitradurga district during 2013-14 as farm trials through

Table 4. Seed yield and B:C ratio of castor as influenced by integrated weed management practices at farmer's fields in Hiriyur taluk, Chitradurga district (mean of five sites, season: 2012-13)

Treatment	Seed yield (t/ha)	Benefit :cost ratio
Pendimethalin 30 EC (1.0 kg/ha) *fb* inter-cultivation at 40 DAS	1.48	3.9
Farmer's practice (one hand weeding 25 DAS + two inter-culture at 45 and 60 DAS)	1.49	3.7

Note: Averaged over 5 locations; Village: Kasturi Rangavanahalli

farmers' participatory approach. The large scale demonstration revealed that farmers practice (one hand weeding 25 DAS + 2 interculture at 45 and 60 DAS) gave seed yield (1493 kg/ha) comparable to that of pre-emergence pendimethalin at 1.0 kg/ha *fb* one inter cultivation at 40 DAS (1477 kg/ha), besides similar benefit: cost ratio (3.70 and 3.90, respectively).

It was concluded from the study that pre emergence application of pendimethalin (1.0 kg/ha) followed by inter -cultivation at 40 DAS resulted in better weed control to realize higher seed yield and economic returns under rain fed conditions of Hiriyur.

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