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Herbicides and polythene mulching effects on yield of cassava

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ABSTRACT

A field experiment was conducted to study the effects of weed management practices on cassava under irrigated conditions in Bhubaneswar (Odisha), India for consecutive three years (2010-11 to 2012-13). The results revealed that four rounds of manual weeding at 1, 2, 3 and 4 months after planting (MAP) and black polythene mulching resulted in taller plants, more number of nodes and leaves per plant, maximum number of storage roots per plant, maximum length and girth of storage roots as well as fresh storage roots yield per plant with lower weed biomass. Mean fresh root yield due to black polythene mulching was at par with four rounds of manual weeding (at 1, 2, 3 and 4 MAP). Black polythene mulching resulted in higher dry matter partitioning efficiency and soil microbial population. The root yield decreased by 9.6%, due to pre-emergence application of oxyfluorfen + two rounds of manual weeding (at 2 and 3 MAP) treatment and 10.1% in two rounds of manual weeding (at 1 and 2 MAP) + post-emergence application of glyphosate (at 3 MAP) compared to four rounds of manual weeding (at 1, 2, 3 and 4 MAP).

Key words: Cassava, Chemical control, Mulching, Polyethene, Root yield, Weed control efficiency

The carbohydrate rich cassava (*Manihot esculenta* Crantz) is grown for food, feed and raw material for industries. Cassava is grown throughout tropics. In India, it is largely grown in states like Tamil Nadu, Kerala, Andhra Pradesh, Maharashtra, Gujarat, Odisha and North-Eastern States in a total area of 0.24 million hactares with an annual production of 9.94 million tonnes of roots (NHB 2013). In Kerala, Odisha and North-Eastern states, cassava is grown for table purpose, whereas in Tamil Nadu, Andhra Pradesh and Maharashtra states it is mainly grown for industries.

Weeds are the major crop pests in humid and sub humid tropics where adequate rainfall, temperature, high sunshine and humidity favour cassava growth (Nedunchezhiyan *et al.* 2013). Cassava plants cover the ground after three months due to initial slow growth and wide plant spacing (Srinivasan and Maheswarappa 1993). Weed infestation at early stage causes severe yield losses and it may go up to 100% (Ambe *et al.* 1992). It is one of the major constraints for cassava production. Weeding consumes about 30% of total labour input and about 150-200 man days/ha. Under irrigated conditions in India, farmers do up to 5 rounds of manual weeding for cassava (Ravindran and Ravi 2009). Chemical method of weed control can reduce the dependency on manual weeding. Herbicides are likely to become inevitable method of weed control in cassava especially where labour is scarce or expensive or farm size is large (Agahiu *et al.* 2011). Mulching suppresses the weed growth and development. Black polythene mulching even prevents germination of weed seeds by arresting sun light and solarizing the soil, while the soil remains undisturbed. Beneficial effects of black polythene mulching for weed control in widely spaced crops were reported (Halemani *et al.* 2009, Mamkagh 2009). However, information on herbicides and polythene mulching on irrigated cassava is not available. Therefore, the present study was conducted to ascertain whether high level of weed control could be obtained by combining hand weeding with the use of a pre-emergence or post-emergence herbicide, and also to compare such combined treatment with the use of black polythene ground cover as a mulch cover in cassava.

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MATERIALS AND METHODS

A field experiment was carried out for consecutive three years (2010-11 to 2012-13) at the ICAR-Central Tuber Crops Research Institute, Regional Centre, Dumuduma, Bhubaneswar, Odisha under irrigated conditions on Alfisols (Typic Rhedustalfs). The experiment was laid out in a randomized block design (RBD) with three replications. The treatments consisted of weedy check, two rounds of manual weeding at 1 and 2 months after planting (MAP), four rounds of manual weeding (at 1, 2, 3 and 4 MAP), oxyfluorfen 0.06 kg/ha as pre-emergence application at 1 day after planting (DAP), oxyfluorfen 0.06 kg/ha (pre-emergence application at 1 DAP) + 1 round of manual weeding (at 3 MAP), oxyfluorfen 0.06 kg/ha (pre-emergence application at 1 DAP) + 2 rounds of manual weeding (at 2 and 3 MAP), glyphosate 2.0 kg/ha (post-emergence application at 1 MAP), one round of manual weeding (at 1 MAP) + glyphosate 2.0 kg/ha (post-emergence application at 2 MAP), two rounds of manual weeding (at 1 and 2 MAP) + glyphosate 2.0 kg/ha (post-emergence application at 3 MAP) and black polythene mulching. The pre-emergence herbicide oxyfluorfen 0.06 kg/ha was applied at 1 DAP cassava on the ground directly leaving the setts. Post-emergence herbicide glyphosate 2.0 kg/ha was applied directly on weeds with protection hood. Black polythene (100 µ thickness) was spread on ground to cover the ridge and furrows before planting and the ends were covered with soils. The variety '*H-226*' was planted at 75 x 75 cm spacing. In black polythene mulching treatment, cassava setts were planted after making 5 cm diameter holes with GI pipe. The crop was irrigated through drips as and when required. Irrigation was withheld 15 days before harvest. Farmyard manure (FYM) 12.5 t/ha and N-P_2O_5-K_2O 100-75-100 kg/ha was applied. FYM was incorporated in the last plough. Full dose of phosphorus (single super phosphate) and half doses of nitrogen (urea) and potassium (white potash) were applied as basal at the time of planting and the remaining half doses of nitrogen and potassium were applied three months after planting (MAP) through drip irrigation after dissolving in water with ventury system. The crop was harvested at 10 MAP. Data on weed dry biomass, yield and economics were recorded.

Data on weeds (x) were subjected to square root transformation $(\sqrt{x+1})$ before statistical analysis. Data were analyzed using SAS 11.0 version. Analysis of variance (ANOVA) was carried out appropriate to the design of experiment. Treatment means were compared using least significant difference (LSD) at 5% probabilities.

RESULTS AND DISCUSSION

Weed flora and weed control efficiency

The major weed species observed in the cassava fields were one sedge - *Cyperus rotundus* L.; four grasses - *Dactyloctenium aegyptium* (L.) Beauv., *Digitaria sanguinalis* L., *Cynodon dactylon* L., *Echinochloa crusgalli* (L.) Beauv. and seven broad-leaved species - *Borreria hispida* L., *Celosia argentia* L., *Ageratum conyzoides* L., *Commelina benghalensis* L., *Cleome viscosa* L., *Mimosa pudica* L., *Phyllanthus niruri* Hook. f. In the present study on alfisols (Typic Rhedustalfs), continuous favourable moisture regimes due to drip irrigation and high rainfall resulted in sedge, grasses and broad-leaved weed species grew in flushes as soon as cassava was planted. Among weed species, *Celosia argentia* L., *Digitaria sanguinalis* L. and *Cleome viscosa* L. grew robustly and quickly, and dominated the other weed flora. Similar findings were reported in sweet potato (*Ipomoea batatas* L.) and taro (*Colocasia esculenta* Schott.) under Typic Rhedustalfs soils of Bhubaneswar, India by Nedunzhiyan *et al*. (1996) and Nedunzhiyan *et al*. (1998). *Cynodon dactylon* L. creeping on the ground remained throughout the crop growth period. After manual weeding at 3 MAP, *Synedrella nudiflora* L., *Oldenlandia corymbosa* L., *Oldenlandia biflora* L. and *Triumfetta rhomboidea* L. appeared under partial shade.

At harvest, four rounds of manual weeding (at 1, 2, 3 and 4 MAP) resulted in significantly lower weed dry biomass, due to regular and frequent removal of weeds (**Table 1**). Manual weeding either one (at 1 MAP) or two (at 1 and 2 MAP) rounds + post-emergence application of glyphosate (at 2 or 3 MAP) resulted in lower level of weed dry biomass at harvest. Black polythene mulching significantly reduced total weed dry biomass, owing to complete cover of the ground did not allow weeds to germinate and emerge. Pre-emergence application of oxyfluorfen and two rounds of manual weeding (at 2 and 3 MAP) treatments were resulted in relatively higher total weed dry weight.

Under rainfed conditions, pre-emergence herbicide with one round of manual weeding resulted in maximum yield (Tan 1988). Pre- and post-emergence herbicides were effective up to 20-30 days only (Balusamy and Pothiraj 1989).

The total dry biomass production of weeds is directly related to weed control efficiency (WCE). The WCE of different weed management methods ranged 60.9-98.5% (**Table 2**). Higher WCE of 98.5% was achieved with black polythene mulching and it was followed by 90.8% with four rounds of manual weeding (at 1, 2, 3 and 4 MAP) because of their lower weed dry biomass. Better WCE with polythene mulching was reported by Ramakrishna *et al*. (2006), Nalayini *et al*. (2009). One (at 1 MAP) or two (at 1 and 2 MAP) rounds of manual weeding + post-emergence application of glyphosate resulted in 84.3-86.9% WCE.

Cassava growth and yield

All the treatments resulted in significantly taller plants, more number of nodes and leaves per plant than weedy check (**Table 2**). Lesser weed infestation (weed dry biomass) in the above treatments reduced competition for water, nutrients and space. It was optly indicated by high WCE in the above treatments (**Table 1**).

All the weed management treatments resulted in greater number of roots/plant (**Table 2**). Two (at 1 and 2 MAP) and four rounds of manual weeding (at 1, 2, 3 and 4 MAP), black polythene mulching as well as two rounds of manual weeding (at 1 and 2 MAP) + post- emergence application of glyphosate (at 3 MAP) resulted in maximum number of roots/plant. Four rounds of manual weeding (at 1, 2, 3 and 4 MAP), black polythene mulching and pre-emergence application of oxyfluorfen + two rounds of manual weeding (at 2 and 3 MAP) resulted in longer roots with maximum girth. Significantly lower number of roots/plant, smaller and lesser girth roots was noticed with weedy check. All the weed management methods resulted in significantly higher fresh root weight than weedy check. Four rounds of manual weeding (at 1, 2, 3 and 4 MAP) and black polythene mulching resulted in maximum fresh root weight (**Table 2**).

Table 1. Weed control efficiency and nutrient uptake as influenced by weed management practices (3 years pooled analysis)

Treatment	Weed dry biomass beforehand weeding (g/m^2)	Weed dry biomass before herbicide application (g/m^2)	Weed dry biomass at harvest (g/m^2)	Total weed dry biomass (g/m^2)	Weed control efficiency (%)
Two rounds of manual weeding (at 1 and 2 MAP)	3.9 (14.2)*	-	7.1 (49.7)	8.1 (63.9)	69.9
Four rounds of manual weeding (at 1, 2, 3 and 4 MAP)	4.3 (17.8)	-	1.6 (1.7)	4.4 (18.6)	90.8
Oxyfluorfen 0.06 kg/ha (pre-emergence application at 1 DAP)	-	-	9.2 (83.0)	9.2 (83.0)	60.9
Oxyfluorfen 0.06 kg/ha (pre-emergence application at 1 DAP) + one rounds of manual weeding (at 3 MAP)	4.8 (22.1)	-	4.7 (21.2)	6.7 (43.3)	79.6
Oxyfluorfen 0.06 kg/ha (pre-emergence application at 1 DAP) + two rounds of manual weeding (at 2 and 3 MAP)	4.6 (20.2)	-	4.4 (18.0)	6.3 (38.2)	82.0
Glyphosate 2.0 kg/ha (post-emergence application at 1 MAP)	-	3.1 (8.8)	7.0 (48.3)	7.6 (57.1)	73.1
One rounds of manual weeding (at 1 MAP) + glyphosate 2.0 kg/ha (post-emergence application at 2 MAP)	3.2 (9.1)	2.5 (5.4)	4.4 (18.8)	5.9 (33.3)	84.3
Two rounds of manual weeding (at 1 and 2 MAP) + glyphosate 2.0 kg/ha (post-emergence application at 3 MAP)	3.8 (13.6)	2.5 (5.2)	3.2 (9.0)	5.4 (27.8)	86.9
Black polythene mulching	-	-	2.0 (3.2)	2.0 (3.2)	98.5
Weedy check	-	-	14.6 (212.4)	14.6 (212.4)	-
LSD (p=0.05)	-	-	0.4	0.5	-

*Figures in parentheses indicate original values. Data transformed to square root transformation $(\sqrt{x+1})$; MAP: Months after planting; DAP: Day after planting

Table 2. Cassava growth and yield attributes as influenced by weed management practices (3 years pooled analysis)

Treatment	Plant height (cm)	No. of nodes/ plant	No. of leaves/ plant	No. of tubers/ plant	Root length (cm)	Root girth (cm)	Fresh root weight (g/plant)
Two rounds of manual weeding (at 1 and 2 MAP)	140	121	87	8	26.0	12.7	1525
Four rounds of manual weeding (at 1, 2, 3 and 4 MAP)	162	136	102	8	32.4	15.2	2062
Oxyfluorfen 0.06 kg/ha (pre-emergence application at 1 DAP)	130	110	76	6	24.2	12.4	1395
Oxyfluorfen 0.06 kg/ha (pre-emergence application at 1 DAP) + one rounds of manual weeding (at 3 MAP)	145	122	86	7	30.0	13.1	1718
Oxyfluorfen 0.06 kg/ha (pre-emergence application at 1 DAP) + two rounds of manual weeding (at 2 and 3 MAP)	152	130	94	7	30.7	14.3	1864
Glyphosate 2.0 kg/ha (post-emergence application at 1 MAP)	137	115		6	26.4	12.8	1565
One rounds of manual weeding (at 1 MAP) + glyphosate 2.0 kg/ha (post-emergence application at 2 MAP)	144	124	90	7	29.1	13.4	1790
Two rounds of manual weeding (at 1 and 2 MAP) + glyphosate 2.0 kg/ha (post-emergence application at 3 MAP)	148	129	92	8	30.2	13.8	1853
Black polythene mulching	156	132	108	8	31.8	14.0	1926
Weedy check	78	53	40	4	15.4	9.1	706
LSD (p=0.05)	13	11	8	1	2.1	1.3	172

MAP: Months after planting; DAP: Day after planting

Four rounds of manual weeding (at 1, 2, 3 and 4 MAP) and black polythene mulching resulted in significantly higher root yield compared to other treatments (**Table 3**). The root yield with black polythene mulching was just 6.6% lower compared to four rounds of manual weeding (at 1, 2, 3 and 4 MAP) (**Table 3**). Effective control of weeds (**Table 1**) and marked improvement in the crop growth and yield attributes (**Table 2**) led to more root yield in these treatments (**Table 3**). Nedunzhiyan *et al.* (1998) observed negative linear relationship between dry biomass of weeds and tuber yield. The root yield of pre-emergence application of oxyfluorfen + two rounds of manual weeding (at 2 and 3 MAP) and two rounds of manual weeding (at 1 and 2 MAP) + post-emergence application of glyphosate (at 3 MAP) was comparable and were the next best treatments. The root yield was lower by 9.6% with pre-emergence application of oxyfluorfen + two rounds of manual weeding (at 2 and 3 MAP) and 10.1% with two rounds of manual weeding (at 1 and 2 MAP) + post-emergence application of glyphosate (at 3 MAP) compared to four rounds of manual weeding (at 1, 2, 3 and 4 MAP) (**Table 3**). Keeping weed free relatively for longer period improved growth parameters which reûected on yield attributes as well as root yield in the above treatments. This provides farmers alternative weed management options. Stiff weed competition at later stages in post-emergence application of glyphosate (at 1 MAP) alone or two rounds of manual weeding (at 1 and 2 MAP) and pre emergence application of oxyûuorfen alone caused signiûcant reduction in growth and yield attributes, which ûnally led to lower root yields. The root yield reduction ranged between 24.1 and 32.3% in these treatments compared to four rounds of manual weeding (at 1, 2, 3 and 4 MAP). Though number of roots/plant was not affected, root length and girth was affected by the presence of weeds in two rounds of manual weeding (at 1 and 2 MAP) treatment. Whereas, in pre-emergence application of oxyfluorfen or post-emergence application of glyphosate (at 1 MAP), all the yield attributing factors (number of roots per plant, root length and girth) were affected by the weeds. Lower cassava growth and yield attributes due to suppression of weeds led to lower root yield (59.7-71.5% reduction) in weedy check in all the years. This may be due to season long crop-weed competition in weedy check plots, which was indicated by lower WCE (**Table 1**) as well as lower cassava growth and yield attributes (**Table 2**).

Shoot yield also followed similar trend of root yield with respect to weed management methods (**Table 3**). Partitioning efficiency (root: shoot ratio) indicated that the root yield increased in parallel with the shoot yield. The root: shoot ratio of cassava in four rounds of manual weeding (at 1, 2, 3 and 4 MAP) and black polythene mulching was ≥1, which indicated that the said treatments were efficient in partitioning dry matter to the economic part (root). The partitioning efficiency of cassava plants due to pre-emergence application of oxyfluorfen + two rounds of manual weeding (at 2 and 3 MAP) and two rounds of manual weeding (at 1 and 2 MAP) + post-emergence application of glyphosate (at 3 MAP) were also higher and equal. This indicated that these weed management methods were also having higher efficacy.

Economics

Maximum cost of cultivation was incurred in four rounds of manual weeding (at 1, 2, 3 and 4

Table 3. Cassava root and shoot yield, and root: shoot ratio as influenced by weed management practices

Treatment	Fresh root yield (t/ha)				Shoot yield (t/ha)				Root: shoot ratio
	2010-11	2011-12	2012-13	Mean	2010-11	2011-12	2012-13	Mean	
Two rounds of manual weeding (at 1 and 2 MAP)	27.0	27.8	26.2	27.0	32.2	28.4	28.2	29.6	0.91
Four rounds of manual weeding (at 1, 2, 3 and 4 MAP)	38.0	34.5	36.9	36.5	35.8	33.8	34.2	34.6	1.05
Oxyfluorfen 0.06 kg/ha (pre-emergence application at 1 DAP)	25.3	23.7	25.0	24.7	27.8	26.5	27.0	27.1	0.91
Oxyfluorfen 0.06 kg/ha (pre-emergence application at 1 DAP) + one rounds of manual weeding (at 3 MAP)	31.7	28.7	30.7	30.4	32.6	31.9	31.5	32.0	0.95
Oxyfluorfen 0.06 kg/ha (pre-emergence application at 1 DAP) + two rounds of manual weeding (at 2 and 3 MAP)	35.3	30.5	33.1	33.0	34.4	32.4	34.6	33.8	0.98
Glyphosate 2.0 kg/ha (post-emergence application at 1 MAP)	30.6	25.5	26.9	27.7	29.6	30.4	30.3	30.1	0.92
One rounds of manual weeding (at 1 MAP) + glyphosate 2.0 kg/ha (post-emergence application at 2 MAP)	31.8	30.7	32.5	31.7	32.8	33.6	32.6	33.0	0.96
Two rounds of manual weeding (at 1 and 2 MAP) + glyphosate 2.0 kg/ha (post-emergence application at 3 MAP)	34.3	30.0	34.2	32.8	33.1	33.0	34.4	33.5	0.98
Black polythene mulching	34.4	33.1	34.9	34.1	34.2	33.5	34.3	34.0	1.00
Weedy check	13.0	13.9	10.5	12.5	14.8	13.8	14.0	14.2	0.88
LSD (p=0.05)	4.3	2.6	1.8	2.7	3.1	2.9	2.6	2.8	-

Table 4. Cassava economics as influenced by weed management practices (3 years pooled analysis)

Treatment	Cost of cultivation (x10^3 `/ha)	Gross return (x10^3 `/ha)	Net return (x10^3 `/ha)	B:C ratio
Two rounds of manual weeding (at 1 and 2 MAP)	51.10	108.00	56.90	2.11
Four rounds of manual weeding (at 1, 2, 3 and 4 MAP)	69.95	146.00	76.05	2.09
Oxyfluorfen 0.06 kg/ha (pre-emergence application at 1 DAP)	34.20	98.80	64.60	2.89
Oxyfluorfen 0.06 kg/ha (pre-emergence application at 1 DAP) + one rounds of manual weeding (at 3 MAP)	46.05	121.60	75.55	2.64
Oxyfluorfen 0.06 kg/ha (pre-emergence application at 1 DAP) + two rounds of manual weeding (at 2 and 3 MAP)	56.25	132.00	75.75	2.35
Glyphosate 2.0 kg/ha (post-emergence application at 1 MAP)	36.75	110.80	74.05	3.01
One rounds of manual weeding (at 1 MAP) + glyphosate 2.0 kg/ha (post-emergence application at 2 MAP)	48.55	126.80	78.25	2.61
Two rounds of manual weeding (at 1 and 2 MAP) + glyphosate 2.0 kg/ha (post-emergence application at 3 MAP)	58.40	131.20	72.80	2.25
Black polythene mulching	62.45	136.40	73.95	2.18
Weedy check	27.75	50.00	22.25	1.80
LSD (p=0.05)	3.25	7.48	5.14	0.12

*sale price of tuber ` 4/kg

MAP) treatment and it was followed by black polythene mulching (**Table 4**). Inclusion of herbicide reduced the cost of cultivation. Maximum gross return was obtained with four rounds of manual weeding (at 1, 2, 3 and 4 MAP) and it was followed by black polythene mulching. Though, higher gross return was obtained with four rounds of manual weeding (at 1, 2, 3 and 4 MAP) and black polythene mulching due to higher root yields, net returns and B:C ratio were lower because of higher human labour requirement and their wages in the former case and higher cost of black polythene in the latter case. However, net returns and B:C ratio was higher with the inclusion of herbicides which reduced the cost of cultivation (**Table 4).**

It was concluded that black polythene mulching is considered a good weed management option, where weeds are a serious problem and drip irrigation facilities are available. Pre-emergence application of oxyfluorfen (0.06 kg/ha) (1 DAP) + two hand weeding (at 2 and 3 MAP) or two hand weeding (at 1 and 2 MAP) + post-emergence application of glyphosate (2.0 kg/ha) (at 3 MAP) can be a weed management option, where labourers are scarce. However, alternative herbicides should be rotated, along with cultural management to prevent herbicide resistance weeds.

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