



## Bio-efficacy of ready-mix sodium acifluorfen + clodinafop-propargyl for weed management in groundnut

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### Article information

DOI: 10.5958/0974-8164.2021.00028.9

Type of article: Research article

Received : 26 September 2020

Revised : 31 May 2021

Accepted : 3 June 2021

### Key words

Clodinafop-propargyl, Groundnut,  
Sodium acifluorfen, Weed density, Yield

### ABSTRACT

Field experiments were conducted to evaluate the bio-efficacy and phytotoxicity of sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC as post-emergence against weed flora in groundnut during *Kharif* (rainy season) 2015 and summer 2016 at UAS, GKVK, Bengaluru, Karnataka. Different post-emergence herbicides were applied at 22 days after sowing (DAS) and compared with two rounds of hand weeding at 20 and 45 DAS. The results revealed that sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC (206.25 + 80 g/ha) recorded higher pod (1.44 and 1.65 t/ha) and haulm yield (1.59 and 1.89 t/ha) in 2015 and 2016. Higher economic yield under this treatment was attributed to the reduced weed density, weed dry weight, weed index and higher weed control efficiency and higher herbicide efficiency index. Post-emergence application of sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC was found non-phytotoxic to groundnut as well as succeeding crop (finger millet).

### INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop in India, occupying an area of 4.81 million hectares with a production of 6.69 million tonnes (GoI 2020). It is grown throughout the year during *Kharif* (rainfed), *Rabi* (winter) (residual moisture), summer (irrigated) and spring (irrigated) seasons although nearly 80% of total groundnut area is covered during *Kharif*. Productivity of groundnut in India is lower than the world average. Weed menace is considered as one of the major production constraints (Chaitanya *et al.* 2012). Weeds emerge fast, grow rapidly, and lead to severe competition with crop plants for different growth resources like nutrients, sunlight, space and soil moisture. In India, yield losses in groundnut due to weeds range from 17 to 96% (FAO 2002). In groundnut, the critical stage of crop-weed competition is around 25-35 days after sowing, cultural practices of weed control does not ensure the weed free environment to the crop for the longer time, so timely PoE application of herbicide ensures weed free environment during critical stage of crop-weed competition and later stages of the crop. Controlling weeds by hand or intercultural operation does not ensure weed-free environment to the rainfed crop, rather it involves higher cost of

cultivation and often becomes ineffective during *Kharif* because of incessant rains with adverse field conditions, causing hindrance to enter into the field. Weed management through conventional hand weeding in irrigated summer crop is also cost-prohibitive. With this background in view, the present investigation was undertaken to develop an effective recommendation on weed management with the use of post-emergence (PoE) herbicides for yield enhancement in both rainfed and irrigated groundnut.

### MATERIALS AND METHODS

Field experiments were conducted during *Kharif* and summer seasons of 2015-16 at the Eastern Dry Zone of Karnataka which is located between 13° 52' 183" N Latitude and 77° 332' 583" Longitude, Gandhi Krishi Vignan Kendra, University of Agricultural Sciences, Bengaluru, Karnataka, India. Groundnut variety '*ICGV-91114*' was sown at a spacing of 30 × 10 cm during *Kharif* (rainy season) 2015 which was sown on 07-07-2015 and harvested on 10-11-2015, the available N, P and K were 253, 32 and 260 kg/ha, respectively at harvest and summer crop was (2016) sown on 20-12-2015 and harvested on 02-05-2016, N, P, K were 259, 32.4 and 269 kg/ha, respectively at harvest. The recommended dose 25:50:25 kg NPK/ha application for seasons as

rained and irrigated crop, respectively. Eight treatments were assigned in a randomized complete block design with three replications. The treatments included sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC (123.75 + 60, 165 + 80 and 206.25 + 80 g/ha) as post-emergence (PoE), sodium acifluorfen 20% SL (165 g/ha) as PoE, clodinafop-propargyl 15% WP (80 g/ha) as PoE, imazethapyr 10% SL (150 g/ha) as PoE, hand weeding (twice) at 20 and 45 days after sowing (DAS), and weedy check (untreated). Herbicides were applied at a spray volume of 500 litres of water/ha at 22 DAS, using knapsack sprayer fitted with flat fan nozzle.

Weed counts were taken in a quadrat of 50 × 50 cm at 20, 45, 60 DAS and harvest, and expressed as weed density (no./m<sup>2</sup>). Category-wise dry weights (g/m<sup>2</sup>) of weeds (sedges, grasses and broad-leaved) were also recorded at 20, 45, 60 DAS and at harvest. Data on weed density and weed dry weight were analyzed using ( $\sqrt{x+1}$ ) square root transformation. Weed control efficiency (WCE) of different treatments were calculated. Per cent weed infestation of different weed categories, *i.e.* sedges, grasses and broad-leaved weeds were also calculated for different treatments. Data on seed yield, haulm yield and weed index were recorded at harvest. Herbicide efficiency index (HEI) and weed management index (WMI) were calculated as per the formula suggested by Krishnamurthy *et al.* (1975) and Walia (2003), respectively.

$$\text{HEI} = \frac{\text{Yield of treated plot} - \text{Yield in control}}{\text{Yield in control}}$$

$$\text{WCE} = \frac{\text{Weed dry weight in control} - \text{Weed dry weight in treated}}{\text{Weed dry weight in control}} \times 100$$

After the harvest of the groundnut crop, the residual crop Finger millet was grown to know the phytotoxicity effect on succeeding crop.

## RESULTS AND DISCUSSION

### Weed flora

The experimental field was mostly infested with grasses (61.18%), followed by broad-leaved weeds (32.91%) and sedges (5.98%) in both seasons. Major weeds in the experimental field in both the seasons were *Cyperus rotundus* (sedges from initial stages), *Eleusine indica*, *Dactyloctenium aegyptium* (from initial stages), and *Echinochloa colona* (from 30 days onwards). Broad-leaved weeds were *Alternanthera*

*sessilis*, *Commelina benghalensis*, *Borreria articularis*, *Cleome viscosa*, *Euphorbia geniculata*. Other weeds as observed in lesser number were *Amaranthus viridis*, *Cleome monophylla* and *Acanthospermum hispidum*. Similar weed species associated with groundnut crop were reported by Mudalagiriappa *et al.* (2001) and Sathya Priya *et al.* (2017).

### Effect on weeds

All the weed management practices recorded significantly lower weed density than that of weedy check at different stages of crop growth (**Table 1**). Before application of sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC at different doses, *viz.* 123.75 + 60, 165 + 80, and 206.25 + 100, the respective plots recorded weed densities of 47.2, 47.1 and 41.0/m<sup>2</sup> in 2015 and 59, 52.9 and 56.4/m<sup>2</sup> in 2016 at 20 DAS. At 45 DAS, post-emergence application of sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC at 123.75 + 60 g/ha recorded lower weed density (19.8/m<sup>2</sup>), followed by same herbicidal combination at 165 + 80 and 123.75 + 60 g/ha (31.6 and 31.8/m<sup>2</sup>) as compared to the weedy check (69.6/m<sup>2</sup>). Similar trend of treatment effect on weed density was recorded at 60 DAS and harvest (**Table 1**). Lower weed densities under these treatments were attributed to effective control of weeds at later stages of crop growth with the PoE application of sodium acifluorfen 16.5% and clodinafop-propargyl 8% EC. These results corroborated the findings of Jha *et al.* (2014). The weed density could significantly be lowered down with hand weeding due to manual removal of all the weeds (Wani *et al.* 2010).

There were no significant differences in weed dry weights at 20 DAS due to non-imposition of treatments (**Table 2**). At 45 and 60 DAS, application of sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC at 206.5 + 100 g/ha recorded lower weed dry weight (2.39 and 2.13 g/m<sup>2</sup>, respectively) which remained statistically on par with the same herbicide applied at 165+80 g/ha, whereas maximum weed dry weight was recorded in the weedy check (3.84 and 4.49 g/m<sup>2</sup>, respectively). Similar results were recorded in year 2016. Reduced weed dry weight with PoE application of sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC was mainly due to effective control of grasses and broad-leaved weeds throughout the crop growth stages. These results were in conformity with Choudhary *et al.* (2017).

Data on WCE at harvest showed that hand weeding (twice) recorded the highest WCE (82.99 and 90.11%), followed by sodium acifluorfen 16.5%

+ clodinafop-propargyl 8% EC applied at 206.25 + 100 g/ha (87.41 and 90.22%) and at 165 + 80 g/ha (85.98 and 89.90%). (Table 4). Improved WCE with the use of sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC at higher doses was due to effective reduction in dry weight of grasses and broad-leaved weeds. These results were in confirmatory with the findings of Jha *et al.* (2014).

**Effect on crop**

The pod yield of groundnut differed significantly due to different weed management practices (Table 3). Two rounds of hand weeding recorded the highest pod yield (1.48 t/ha), which was at par with the application of sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC at 206.25 + 100 g/ha

(1.44 t/ha) at 165 + 80 g/ha (1.41 t/ha), whereas it was the lower in the weedy check plots (0.62 t/ha). Yield advantages due to weed management with the use of PoE herbicides were reported by Singh *et al.* (2012) and Choudhary *et al.* (2017). Weed index (WI) had a direct relation with the yield reduction due to weed infestation. Lower WI was recorded under hand weeding (20 and 45 DAS), followed by PoE application of sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC (206.25 + 100 and 165 + 80 g/ha), whereas it was the highest under weedy check (58.45%). Reduction in yield was attributed to the higher density of weeds and dry matter production, leading to higher WI (Patel *et al.* 1997 and Jayaram 2001).

Higher herbicide efficiency index (HEI) was

**Table 1. Effect of different weed management treatments on weed density (no./m<sup>2</sup>) at different stages in groundnut**

Treatment	20 DAS		45 DAS		60 DAS		Harvest	
	2015	2016	2015	2016	2015	2016	2015	2016
Sodium-acifluorfen 16.5% + clodinafop-propargyl 8% EC (123.75 + 60 g/ha)	6.87 (47.2)	7.68 (59.0)	5.52 (30.5)	6.0 (36.0)	4.11 (16.9)	4.56 (20.8)	3.94 (13.9)	3.81 (14.5)
Sodium-acifluorfen 16.5% + clodinafop-propargyl 8% EC (165 + 80 g/ha)	6.73 (47.1)	7.28 (52.9)	5.18 (26.8)	5.17 (26.7)	3.95 (15.6)	4.14 (17.1)	3.70 (14.2)	3.58 (12.8)
Sodium-acifluorfen 16.5% + clodinafop-propargyl 8% EC (206.25 + 80 g/ha)	6.40 (41.0)	7.51 (56.4)	4.92 (24.2)	4.81 (23.4)	3.59 (12.9)	3.92 (13.98)	3.41 (12.9)	3.38 (11.4)
Sodium-acifluorfen 20% SL (165 g/ha)	6.30 (39.8)	7.27 (52.9)	6.67 (44.5)	7.10 (50.4)	6.95 (48.3)	7.37 (54.3)	7.24 (52.5)	7.76 (60.2)
Clodinafop-propargyl 15% WP (80 g/ha)	6.00 (36.0)	7.20 (51.9)	5.81 (33.7)	6.36 (54.2)	5.34 (28.5)	6.40 (41.0)	5.81 (54.2)	6.70 (44.9)
Imazethapyr 10% SL (150 g/ha)	5.84 (34.2)	7.22 (52.1)	5.99 (35.8)	6.72 (45.1)	6.16 (38.0)	6.82 (46.6)	6.25 (39.2)	6.97 (48.6)
Hand weeding (twice)20 and 45 DAS	6.35 (40.3)	7.46 (55.6)	4.10 (16.8)	4.56 (20.8)	3.72 (13.8)	3.47 (12.1)	4.04 (16.3)	3.40 (11.6)
Weedy check (untreated)	6.36 (40.5)	7.48 (56.0)	7.79 (60.7)	8.86 (78.6)	8.19 (67.2)	9.40 (88.3)	9.85 (97.0)	10.82 (117.1)
LSD (p=0.05)	0.49	NS	0.28	0.36	0.24	0.32	0.33	0.26

DAS: Days after sowing; Original figures in parentheses were subjected to square root transformation

**Table 2. Effect of different weed management treatments on weed dry weight (g/m<sup>2</sup>) at different stages in groundnut**

Treatment	20 DAS		45 DAS		60 DAS		Harvest	
	2015	2016	2015	2016	2015	2016	2015	2016
Sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC (123.75 + 60 g/ha)	3.19 (9.20)	3.51 (11.30)	2.80 (6.84)	3.10 (8.59)	2.41 (4.80)	2.54 (5.46)	2.32 (4.37)	2.02 (3.06)
Sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC (165 + 80 g/ha)	3.17 (9.03)	3.34 (10.18)	2.47 (5.08)	2.68 (6.20)	2.22 (3.92)	2.41 (4.81)	2.01 (3.16)	1.98 (2.92)
Sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC (206.25 + 80 g/ha)	3.00 (8.01)	3.44 (10.82)	2.39 (4.69)	2.51 (5.30)	2.13 (3.55)	2.25 (4.07)	1.93 (2.73)	1.88 (2.53)
Sodium acifluorfen 20% SL (165 g/ha)	2.93 (7.57)	3.34 (10.15)	3.34 (10.14)	3.62 (12.13)	4.03 (15.27)	3.91 (14.27)	3.60 (11.94)	3.78 (13.30)
Clodinafop-propargyl 15% WP (80 g/ha)	2.82 (6.94)	3.31 (9.95)	2.67 (6.11)	3.12 (8.75)	2.67 (15.27)	2.93 (7.59)	2.69 (6.21)	2.84 (13.75)
Imazethapyr 10% SL (150 g/ha)	2.75 (6.57)	3.31 (9.99)	3.03 (8.21)	3.44 (10.85)	3.57 (11.75)	3.64 (12.24)	3.15 (8.89)	3.43 (10.73)
Hand weeding 20 and 45 DAS	2.97 (7.80)	3.41 (10.66)	2.10 (3.42)	2.45 (5.00)	2.23 (3.97)	2.04 (3.17)	2.17 (3.69)	1.88 (2.56)
Weedy check (untreated)	2.96 (7.74)	3.43 (10.73)	3.84 (13.76)	4.46 (18.90)	4.49 (19.17)	4.92 (23.21)	4.76 (21.69)	5.18 (25.88)
LSD (p=0.05)	NS	0.12	0.41	0.29	0.24	0.22	0.18	0.14

DAS= Days after sowing; Data subjected to square root transformation; data with in parentheses are original values

recorded under sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC at 206.25 + 100 g/ha (10.64), followed by same herbicide combination at 165 + 80 g/ha (8.83%) and 123.75 + 60 g/ha (5.70%). Higher HEI was achieved due to lower weed dry weight as well as higher pod yield with the imposition of these treatments (**Table 3**).

Weed management index (WMI) was significantly influenced by different weed management treatments (**Table 4**). Higher WMI was recorded in hand weeding at 20 and 45 DAS (1.45), which was followed by PoE application of sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC at 206.25 + 100 g/ha (1.37) and clodinafop-propargyl 15% WP at 80 g/ha (1.29). Similar findings were reported by Kumar *et al.* (2013) and Siddhu *et al.* (2018) in garlic.

**Economics**

Higher net returns and B: C ration were observed with application of sodium acifluorfen 16.5% + clodinafop-propargyl 8% 80 EC at 206.25 + 100 g/ha ₹ 32330/ha and 2.15, respectively) and at 165 + g/ha

(₹ 31570/ha and 2.14, respectively). However, two rounds of hand weeding recorded higher gross returns (₹ 62160/ha) as compared to other treatments. The lower cost of cultivation, gross returns, net returns and B:C ratio were recorded in the weedy check plots (₹ 23200/ha, ₹ 26040/ha, ₹ 2840/ha and 1.12, respectively). The similar results were obtained during 2016 (**Table 5**). The highest net returns and B:C ratio with application of sodium acifluorfen 16.5% + clodinafop-propargyl 8% 80 EC at 206.25 + 100 g/ha was due to higher pod yield with lesser cost of weeding with herbicide application. Even though higher gross returns were recorded in two hand weeding, higher labour wages increased the cost of cultivation and lowered the B:C ratio. Similar results were reported by Kalhapure *et al.* (2013).

Growth and yield of succeeding finger millet was not affected due to imposition of weed management practices in preceding groundnut. This was in accordance with Sathya Priya and Chinnusamy (2020). The germination percentage was recorded and other physiological factors like yellowing, stunting, wilting and deformities *i.e.*,

**Table 3. Effect of different weed management treatments on pod yield, haulm yield, weed index and herbicide efficiency index at harvest in groundnut**

Treatment	Pod yield (t/ha)		Haulm yield (t/ha)		Weed index (%)		Herbicide efficiency index at harvest	
	2015	2016	2015	2016	2015	2016	2015	2016
	Sodium acifluorfen + clodinafop-propargyl (123.75 + 60 g/ha)	1.25	1.42	1.45	1.57	16.03	17.62	5.07
Sodium acifluorfen + clodinafop-propargyl (165 + 80 g/ha)	1.41	1.62	1.55	1.78	5.19	5.81	8.80	8.86
Sodium acifluorfen + clodinafop-propargyl (206.25 + 80 g/ha)	1.44	1.65	1.59	1.89	2.69	4.07	10.66	10.61
Sodium acifluorfen 20% SL (165 g/ha)	0.86	1.05	1.11	1.31	42.29	38.95	0.71	0.58
Clodinafop-propargyl 15% WP (80 g/ha)	1.04	1.34	1.21	1.54	30.10	22.09	2.38	1.23
Imazethapyr 10% SL (150 g/ha)	0.94	1.18	1.10	1.38	36.57	31.57	1.29	1.09
Hand weeding 20 and 45 DAS	1.48	1.72	1.61	1.91	0.00	0.00	-	-
Weedy check (untreated)	0.62	0.81	0.85	1.05	58.45	52.91	-	-
LSD (p=0.05)	0.15	0.18	0.12	0.23	-	-	-	-

**Table 4. Effect of different weed management treatments on weed management index (WMI), weed infestation (%) and weed control efficiency (WCE) at harvest in groundnut**

Treatment	WMI		Weed infestation (%)								WCE	
	2015	2016	2015				2016				2015	2016
			Sedges	Grasses	BLWs	Total	Sedges	Grasses	BLWs	Total		
Sodium acifluorfen + clodinafop-propargyl (123.75 + 60 g/ha)	1.19	0.85	20.14	46.04	33.81	13.9	15.86	43.45	40.69	14.5	79.85	87.94
Sodium acifluorfen + clodinafop-propargyl (165 + 80 g/ha)	1.50	1.13	17.61	41.55	40.85	14.2	15.63	42.19	42.18	12.8	85.98	89.90
Sodium acifluorfen + clodinafop-propargyl (206.25 + 80 g/ha)	1.54	1.20	17.83	39.53	32.56	12.9	17.54	38.60	43.86	11.4	87.41	90.22
Sodium acifluorfen 20% SL (165 g/ha)	0.86	0.61	6.67	84.19	9.14	52.5	6.64	85.55	7.81	60.2	44.95	48.61
Clodinafop-propargyl 15% WP (80 g/ha)	1.38	1.21	8.30	35.42	56.27	54.2	4.90	12.47	82.63	44.9	71.37	72.72
Imazethapyr 10% SL (150 g/ha)	0.89	0.77	7.14	81.12	11.48	39.2	5.35	85.8	8.85	48.6	59.01	58.54
Hand weeding 20 and 45 DAS	1.65	1.25	18.40	55.21	26.38	16.3	8.62	50	41.38	11.6	82.99	90.11
Weedy check (untreated)	-	-	6.91	61.55	31.65	97	5.04	60.80	34.16	117.1	00.0	00.0

**Table 5. Effect of different weed management treatments on economics of groundnut**

Treatment	Cost of cultivation ( $\times 10^3$ /ha)		Gross returns ( $\times 10^3$ /ha)		Net returns ( $\times 10^3$ /ha)		B:C Ratio	
	2015	2016	2015	2016	2015	2016	2015	2016
Sodium acifluorfen + clodinafop-propargyl (123.75 + 60 g/ha)	27.15	27.50	52.50	62.48	25.35	34.98	1.93	2.27
Sodium acifluorfen + clodinafop-propargyl (165 + 80 g/ha)	27.65	28.00	59.22	71.28	31.57	43.28	2.14	2.55
Sodium acifluorfen + clodinafop-propargyl (206.25 + 80 g/ha)	28.15	28.50	60.48	72.60	32.33	44.10	2.15	2.55
Sodium acifluorfen 20% SL (165 g/ha)	27.15	27.50	36.12	46.20	8.97	18.70	1.33	1.68
Clodinafop-propargyl 15% WP (80 g/ha)	28.15	28.50	43.68	58.96	15.53	30.46	1.55	2.07
Imazethapyr 10% SL (150 g/ha)	26.00	26.40	39.48	51.92	13.48	25.52	1.52	1.97
Hand weeding 20 and 45 DAS	33.25	33.75	62.16	75.68	28.91	41.93	1.87	2.24
Weedy check (untreated)	23.20	23.50	26.04	35.64	2.84	12.14	1.12	1.52

epinasty, hyponasty and necrosis *etc.* were not noticed

Being comparable with hand weeding twice (20 and 45 DAS), post-emergence application of sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC at 206.25 + 100 g/ha be an effective tool for weed management in groundnut.

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