



RESEARCH ARTICLE

Effect of herbicide mixture and mechanical weeding on weed dynamics and yield of kharif groundnut

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Abstract

Groundnut (*Arachis hypogaea* L.) is the major oilseed crop in India and it plays a major role in bridging the vegetable oil deficit in the country. Weed infestation poses a significant challenge and is a serious problem in reducing the productivity of groundnut. The sole application of herbicides is unable to control the later germinating weeds; hence, to mitigate the weed-related losses and increase the yield, an integrated weed management strategy needs to be studied. In view of the above, the present investigation was planned to evaluate the “effect of herbicide mixture and mechanical weeding on weed dynamics and yield of kharif groundnut”. The field experiment was conducted in the loamy sand soil of All India Coordinated Research Project on Weed Management (AICRP) on Weed Management Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, during three consecutive kharif seasons of 2022–24. The experiment was laid out in a randomised block design (RBD) with three replications. The treatments included T1: Pendimethalin 30 % emulsifiable concentrate (EC) 750 g active ingredient per hectare (a.i./ha), T2: Flumioxazin 50 % suspension concentrate (SC) 125 g a.i./ha, T3: Diclosulam 84 % water dispersible granules (WDG) 25.2 g a.i./ha, T4: Oxyfluorfen 23.5 % EC + pendimethalin 30 % EC (tank mix) 188 + 500 g a.i./ha, T5: Diclosulam 84 % WDG + pendimethalin 30 % EC (tank mix) 25.2 + 500 g a.i./ha, T6: Pendimethalin 30 % + imazethapyr 2 % EC (ready mix (RM)) 800 g a.i./ha, T7: Sodium acifluorfen 16.5 % + clodinafop propargyl 8 % EC (RM) 245 g a.i./ha, T8: Fluazifop-p-butyl 11.1 % w/w + fomesafen 11.1 % w/w soluble concentrate (SL) (RM) 250 g a.i./ha, T9: Propaquizafop 2.5 % + imazethapyr 3.75 % w/w micro-emulsion (ME) (RM) 125 g a.i./ha, T10: Quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC (RM) 90 g a.i./ha, T11: Intercultivation (IC) followed by hand weeding (HW) at 20 and 40 days after sowing (DAS) and T12: Weedy check. In treatments T₁–T₁₀, IC followed by HW at 40 DAS was carried out as a common practice. Results revealed that significantly lower density and dry biomass of weeds, weed index, higher weed control efficiency, shelling percentage, seed index, pod yield and benefit-to-cost ratio (B: C) were recorded in application of either diclosulam 25.2 g a.i./ha pre-emergence (PE) followed by IC + HW at 40 DAS or sodium acifluorfen + clodinafop propargyl 245 g a.i./ha post-emergence (PoE) followed by IC + HW at 40 DAS or fluazifop-p-butyl + fomesafen 250 g a.i./ha PoE followed by IC + HW at 40 DAS or propaquizafop + imazethapyr 125 g a.i./ha PoE followed by IC + HW at 40 DAS or IC followed by HW at 20 and 40 DAS. Residue of all the applied herbicides in groundnut mature pods, stover and in soil were found below the limit of quantification (LOQ) of 0.01 mg/kg at the time of harvest.

Keywords: groundnut; herbicide residue; pod yield; weed control efficiency; weed index

Introduction

Groundnut (*Arachis hypogaea* L.) is an important edible oilseed crop of India and known as peanut or monkey nut, belongs to the family Leguminosae. The kernels are consumed in various forms, including roasted, fried and salted. Groundnut kernels contain about 47–49 % oil and around 20 % protein and are highly digestible. In India, its cultivation is largely concentrated in the states of Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Madhya Pradesh, Uttar Pradesh, Rajasthan, Punjab and Odisha. One of the major constraints in limiting the productivity of groundnut is inadequate weed management, along with poor cultural practices. The crop is highly susceptible to weed infestation, particularly during early growth stages due to its slow initial growth rate, short plant height and underground

pod-bearing habit. The critical period crop-weed competition in kharif ranges from 4–9 weeks after sowing for grassy weeds and 2–8 weeks for broad leaf weeds (1). Similarly, it was observed that uncontrolled weed growth can reduce the pod yield by 54–71 %, especially during the early period of crop growth, kharif groundnut (2). Weed flora in groundnut fields is diverse and varies with agro-ecological conditions and management practices, comprising grasses, broadleaf weeds and sedges. Although grassy weeds are often dominant, broadleaf weeds also compete significantly with the crop. Pre-emergence (PE) herbicides play an important role in suppressing the initial flush of weeds; however, their effectiveness is often limited to a specific period depending on their persistence, soil moisture and environmental conditions. Consequently, late-emerging weeds frequently escape from

applied herbicides and continue to compete with the crop during critical growth stages. Moreover, reliance on a single herbicide or mode of action may not provide adequate control over the complex weed flora. Therefore, a more comprehensive approach involving the integration of pre and post-emergence (PoE) herbicides, along with cultural and mechanical practices such as intercultivation (IC) and hand weeding (HW), is essential to achieve season-long weed control and to sustain higher productivity in groundnut. Looking at this, an experiment was conducted to study the efficacy of herbicide mixture on weed dynamics and yield of kharif groundnut (*A. hypogaea*).

Materials and Methods

A field experiment was conducted during three consecutive kharif seasons of the year 2022–24 in loamy sand soil. The average mean, minimum and maximum temperature range from 16.8–38.2, 18.5–37.5 and 13.7–34.0, total rainfall 911, 928 and 1172 mm and mean relative humidity of 73.88, 74.5 and 74.7 were observed in the crop period during the year 2022–24, respectively. The soil of the experimental field was low in available nitrogen (N) (239.12 kg/ha) and medium in available phosphorus (P) (45.40 kg/ha) and high in potassium (K) (329.64 kg/ha). The experiment was carried out to study the bio-efficiency of the herbicide mixture on the weed and yield of kharif groundnut. Twelve weed management practices consisted of T₁: Pendimethalin 30 % emulsifiable concentrate (EC) 750 g active ingredient per hectare (a.i./ha) followed by IC + HW at 40 DAS, T₂: Flumioxazin 50 % suspension concentrate (SC) 125 g a.i./ha followed by IC + HW at 40 DAS, T₃: Diclosulam 84 % water dispersible granules (WDG) 25.2 g a.i./ha followed by IC + HW at 40 DAS, T₄: Oxyfluorfen 23.5 % EC + pendimethalin 30 % EC (tank mix) 188 + 500 g a.i./ha followed by IC + HW at 40 DAS, T₅: Diclosulam 84 % WDG + pendimethalin 30 % EC (tank mix) 25.2 + 500 g a.i./ha followed by IC + HW at 40 DAS, T₆: Pendimethalin 30 % + imazethapyr 2 % EC (ready mix (RM)) 800 g a.i./ha followed by IC + HW at 40 DAS, T₇: Sodium acifluorfen 16.5 % + clodinafop propargyl 8 % EC (RM) 245 g a.i./ha followed by IC + HW at 40 DAS, T₈: Fluazifop-p-butyl 11.1 % w/w + fomesafen 11.1 % w/w soluble concentrate (SL) (RM) 250 g a.i./ha followed by IC + HW at 40 DAS, T₉: Propaquizafop 2.5 % + imazethapyr 3.75 % w/w micro-emulsion (ME) (RM) 125 g a.i./ha followed by IC + HW at 40 DAS, T₁₀: Quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC (RM) 90 g a.i./ha followed by IC + HW at 40 DAS, T₁₁: IC followed by HW at 20 and 40 DAS and T₁₂: Weedy check were laid out in randomised block design (RBD) with three replications. The groundnut variety GG 34 was sown on 16th June, 23rd June and 20th July 2022, 2023 and 2024, respectively, keeping a spacing of 30 x 10 cm by using a seed rate of 120 kg/ha. The crop was harvested on 15, 03 and 27 October, 2022, 2023 and 2024, respectively. The crop was fertilised with the recommended rate of fertiliser with 12.5 kg N and 25 kg phosphorus pentoxide (P₂O₅/ha) in the form of urea and single super phosphate, respectively, as a basal dose. The rest of the recommended package of practices was adopted to raise the crop. Pre-emergence herbicide was applied on the next day of sowing and PoE herbicides at 20 DAS by using a battery-operated knapsack sprayer fitted with a flat-fan nozzle by mixing in 500 L of water/ha as per treatments. The observations on density and dry weight of weeds were recorded from randomly selected four spots by using a 0.25 m² iron

quadrant from the net plot through destructive sampling. Weed control efficiency (WCE) was calculated on the basis of the standard formula (3). The yield reduction (%) owing to the presence of weeds was estimated by using the standard formula and expressed as weed index (WI) (4). Other growth and yield attributing observations were also recorded from the net plot area. Data on various observations recorded during the experimental period were statistically analysed as per the standard procedure and weed data were transformed by square root transformation $\sqrt{X + 1}$ and the transformed data were subjected to analysis of variance (ANOVA) (5). For soil bacterial count, representative soil samples were collected from each plot before sowing at 0, 10 and 30 DAS as well as at harvest. All the soil samples were analysed for total bacterial populations using standard methodology in which soil samples were serially diluted and inoculated on nutrient agar media and after incubation, the bacterial count in terms of CFU was recorded (6).

The QuEChERS (quick, easy, cheap, effective, rugged and safe) method for pesticide residue analysis involves the extraction of the sample with acetonitrile and simultaneous liquid-liquid partitioning by adding anhydrous magnesium sulfate (MgSO₄) plus sodium chloride (NaCl), followed by a simple cleanup step known as dispersive solid-phase extraction (d-SPE) (7). Groundnut mature pod, haulm and soil samples were subjected to analysis through Gas chromatography-mass spectrometry (GC-MS) and Liquid chromatography-mass spectrometry (LC-MS).

Results and Discussion

Weed flora

The experimental field was invaded with diverse weed flora consisting of both broad-leaf and grassy weeds. Among the total weeds, grassy weeds account 47 %, dominated by broad-leaf weeds (43 %). In the experimental field *Digitaria sanguinalis* (19.6 %), *Commelina benghalensis* (10.2 %), *Dactyloctenium aegyptium* (6.50 %) *Eleusine indica* (7.83), *Setaria glauca* (2.17 %) and *Eragrostis major* (1.24 %) as monocot weed while *Digera arvensis* (13.1 %), *Phyllanthus niruri* (8.04), *Oldenlandia umbellata* (17.5 %) *Trianthema monogyna* (1.44), *Boerhavia erecta* (1.34 %) and *Mollugo nudicaulis* (2.47 %) as dicot weed dominated in the field during 3 years of experimentation.

Phytotoxicity of herbicide

Phytotoxicity of applied herbicide on groundnut was recorded at 7 days after application in respective treatment, assessed using a visual score scale of 0–10. Three-year mean data of phytotoxicity rating revealed that application of oxyfluorfen + pendimethalin (tank mix), sodium acifluorfen + clodinafop propargyl and fluazifop-p-butyl + fomesafen showed phytotoxic effect on chlorosis (Score-1), but it was recovered at 14 days after herbicide application. Other applied herbicides, either PE or PoE, do not show any symptoms of chlorosis, necrosis, leaf curling or stunting of growth on groundnut.

Effect on weed

The 3-year pooled result revealed a significant reduction in dry biomass of weeds in all the weed control treatments over the unweeded control (Table 1). The highest reduction in dry biomass of weed with higher weed control efficiency was observed under two interculturing followed by HW carried out at 20 and 40 DAS

Table 1. Dry biomass of weeds, growth and yield attributes as influenced by weed management practices in kharif groundnut (Pooled data 2022–24)

Treatment	Weed dry biomass (g/m²)		Weed control efficiency (%)				Plant stand (No./m row length) at 15 DAS	Plant height (cm)		Shelling percentage (%)	Seed index (g)
	At harvest		At harvest		At 60 DAS	At harvest					
	30 DAS	60 DAS	30 DAS	60 DAS							
Pendimethalin 30 % EC 750 g a. i./ha followed by IC + HW at 40 DAS	7.40 (55.3)	4.66 (22.1)	7.18 (53.4)	40.0	92.4	82.08	9.27	54.7	63.5	69.0	49.7
Flumioxazin 50 % SC 125 g a. i./ha followed by IC + HW at 40 DAS	6.03 (37.8)	4.08 (17.1)	6.95 (50.8)	76.8	94.1	82.95	9.87	54.2	63.7	68.0	49.8
Diclosulam 84 % WDG 25.2 g a. i./ha followed by IC + HW at 40 DAS	5.35 (28.0)	4.81 (22.9)	6.90 (47.3)	82.8	92.1	84.13	9.69	54.2	65.9	67.9	50.7
Oxyfluorfen 23.5% EC + pendimethalin 30% EC (tank mix) 188+ 500 ga. i./ha followed by IC + HW at 40 DAS	3.07 8.82)	3.32 (10.8)	5.95 (35.6)	94.6	96.3	88.05	9.60	55.4	65.4	67.7	50.8
Diclosulam 84% WDG+ pendimethalin 30% EC (tank mix) 25.2 + 500 g a. i./ha followed by IC + HW at 40 DAS	4.54 (20.4)	4.18 (17.3)	6.82 (46.4)	87.5	94.0	84.43	10.4	56.7	67.3	68.1	51.1
Pendimethalin 30 % + imazethapyr 2 % EC (RM) 800 g a. i./ha followed by IC + HW at 40 DAS	3.91 (14.5)	3.69 13.2)	5.99 (36.9)	91.1	95.4	87.62	10.4	55.9	67.3	68.2	51.6
Sodium acifluorfen 16.5% + clodinafop propargyl 8% EC (RM) 245 ga. i./ha followed by IC + HW at 40 DAS	4.77 (21.9)	4.67 (22.1)	6.89 (47.7)	86.6	92.4	83.99	10.0	54.9	66.7	67.1	50.2
Fluazifop-p-butyl 11.1% w/w + fomesafen 11.1 % w/w SL (RM) 250 ga. i./ha followed by IC + HW at 40 DAS	4.49 (19.9)	4.14 (17.1)	7.03 (49.8)	87.8	94.1	83.29	9.96	53.2	66.5	66.4	52.5
Propaquizafop 2.5 % + imazethapyr 3.75 % w/w ME (RM) 125 ga. i./ha followed by IC + HW at 40 DAS	3.18e (9.33)	4.06 (16.8)	7.05 (51.0)	94.3	94.2	82.89	9.42	54.9	68.0	69.4	52.0
Quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC (RM) 90 ga. i./ha followed by IC + HW at 40 DAS	3.45 (11.8)	4.38 (18.5)	7.56 (57.0)	92.8	93.6	80.87	9.76	55.2	68.4	66.8	48.2
IC followed by HW at 20 and 40 DAS	1.66 (2.05)	4.14 (16.6)	7.31 (53.3)	98.7	94.3	82.11	9.93	55.3	68.0	69.9	50.4
Weedy check	9.52 (92.2)	17.0 (289)	17.2 (298)	-	-	-	9.98	60.8	75.5	62.4	44.5
S. Em +	0.53	0.28	0.65	-	-	-	0.238	1.17	1.31	0.59	1.02
CD (5 %)	1.56	0.83	1.91	-	-	-	NS	3.30	3.68	1.66	2.99

Note: Data subjected to $\sqrt{(X + 1)}$ transformation. Figure in parentheses are means of original values. a. i./ha: active ingredient per hectare; DAS: days after sowing; EC: emulsifiable concentrate; ME: micro-emulsion; IC: intercultivation; HW: hand weeding; SC: suspension concentrate; NS: Non-significant; RM: ready mix; SL: soluble concentrate; WDG: water dispersible granules.

followed by oxyfluorfen + pendimethalin (tank mix) 188 + 500 g a.i./ha followed by IC + HW at 40 DAS diclosulam 25.2 g a.i./ha followed by IC + HW at 40 DAS, sodium acifluorfen + clodinafop propargyl 245 g a.i./ha PoE followed by IC + HW at 40 DAS, propaquizafop + imazethapyr 125 g a.i./ha PoE followed by IC + HW at 40 DAS and quizalofop ethyl + imazethapyr 90 g a.i./ha PoE followed by IC + HW at 40 DAS at all the growth stages. Similarly, two interculturing and HW provide effective control of the weeds in groundnut (8). The lower dry biomass with higher WCE could be attributed to lesser weed competition faced by the groundnut crop due to the applied herbicide, which reduced the crop weed competition during the initial stages of crop growth and the later germinated weeds were checked by interculturing and HW at 40 DAS, which provide weed free situation throughout the crop growth period. Higher weed control efficiency with pendimethalin + quizalofop-ethyl in groundnut was also observed (9). In general, more than 80 % reduction in dry biomass of weed in comparison to the weedy check could be attributed to the combination of both herbicides showing longer effect on controlling weed population and integration of mechanical weeding provide control of later germinated weeds. However, maximum density and dry biomass of weeds was noticed under the weedy check treatment.

Effect on crop

Plant stand (no./m row length) recorded at 15 DAS was non-significant, while it was significant due to weed management practices at harvest in pooled results (Table 2). At harvest, significantly the lowest plant stand (6.42/m row length) was observed under the weedy check treatment. Significantly the highest plant height (60.8 and 75.5 cm) at 60 DAS and at harvest, respectively was measured under weedy check treatment on a pooled basis. In a weedy check, weeds grow densely around the groundnut plants and compete severely for light. This creates a shaded environment where the quality of light changes, especially a reduction in the red to far-red light ratio due to filtering by weed canopies. The energy is diverted toward elongation rather than biomass accumulation; hence, higher plant height in weedy conditions is due to an etiolation-like elongation triggered by light competition with weeds. Twice interculturing followed by HW carried out at 20 and 40 DAS recorded significantly higher shelling percentage (69.9 %), but it was statistically comparable with all other treatments except weedy check and sodium acifluorfen + clodinafop propargyl 245 g a.i./ha followed by IC + HW at 40 DAS. In the next order, application of fluazifop-p-butyl + fomesafen 250 g a.i./ha followed by IC + HW at 40 DAS recorded significantly higher seed index (52.5 g), but it was at par with all other treatments except application of quizalofop ethyl + imazethapyr 90 g a.i./ha followed by IC + HW at 40 DAS and weedy check. Significantly, the lowest shelling percentage and seed index in the weedy check might be due to severe crop weed competition leading to a poor source-to-sink relationship, resulting in poor nourishment of the seed (8).

Results of pooled analysis showed that different weed management practices revealed a significant increase in pod yield of groundnut as compared to the weedy check (Table 2). Twice interculturing followed by hand weeding carried out at 20 and 40 DAS recorded significantly higher pod and haulm yield (3399 and 4162 kg/ha, respectively), but it was statistically comparable with all other treatments except the weedy check. The higher pod yield under these treatments is ascribed to the lower density and dry biomass of

weeds prevent the crop-weed competition, facilitating the utilisation of available nutrients, moisture, light and space than that of the weedy check. These results are in accordance with the previous results (10). Further, application of herbicide provide broad spectrum control of weeds during the initial stage of crop and subsequent flush of weeds was managed by interculturing and HW, which provide a congenial environment for growth and development of the crop for a longer period, which leads to improvement in yields. Yield reduction due to the presence of weeds was observed to be maximum, to the extent of 85.9 % in the weedy check. Among other treatments, minimum yield reduction was noticed under application of pendimethalin 750 g a.i./ha, followed by IC + HW at 40 DAS, followed by application of propaquizafop + imazethapyr 125 g a.i./ha, followed by IC + HW at 40 DAS and diclosulam + pendimethalin (tank mix) 25.2 + 500 g a.i./ha, followed by IC + HW at 40 DAS.

Soil bacterial population

Initially, there was some harmful effect of herbicides on the soil bacterial population, but gradually it was reduced. Significant differences were recorded in soil bacterial population, particularly for treatments receiving application of pre-emergence herbicides in comparison to IC followed by HW at 20 and 40 DAS and weedy check (Table 3). Post-emergence applied herbicides showed less effect on the soil bacterial population in comparison to PE applied herbicides. Initially, at 0 DAS, PE application of oxyfluorfen + pendimethalin showed a significant reduction of soil bacterial population in comparison to other treatments. There is temporary suppression in bacterial populations, but with the advancement of time, bacterial populations again recovered in this biological soil environment (11, 12).

Herbicide residue

Chromatograms of different PE and PoE herbicides applied on groundnut crop showed that residues of applied herbicides, that is, pendimethalin, flumioxazin, diclosulam, oxyfluorfen, imazethapyr, sodium acifluorfen, clodinafop propargyl, fluazifop-p-butyl, fomesafen, propaquizafop and quizalofop ethyl in groundnut mature pods, stover and in soil were below the limit of quantification (LOQ) of 0.01 mg/kg at the time of harvest (Fig. 1).

Economics

Based on pooled data, economics presented in Table 2 revealed that maximum gross returns were observed under twice interculturing followed by HW carried out at 20 and 40 DAS however, maximum net returns and B: C was recorded in application of diclosulam + pendimethalin (tank mix) 25.2 + 500 g a.i./ha followed by IC + HW at 40 DAS followed by application of propaquizafop + imazethapyr 125 g a.i./ha followed by IC + HW at 40 DAS and pendimethalin 750 g a.i./ha followed by IC + HW at 40 DAS. As the cost of herbicide was lower in the case of pendimethalin 750 g a.i./ha (₹2321/ha), while labour charges for mechanical weeding treatment were ₹18200/ha, this reflected in the variation in B: C. The results in accordance with the observation on differences in gross, net returns and benefit cost ratio may be due to variation in the cost of herbicides, labour required and yield recorded in the respective treatments (8, 13).

Conclusion

From the results of 3-year experimentations, it can be concluded that application of either pendimethalin 30 % EC 750 g a.i./ha,

Table 2. Yield and economics as influenced by weed management practices in kharif groundnut (Pooled data 2022–24)

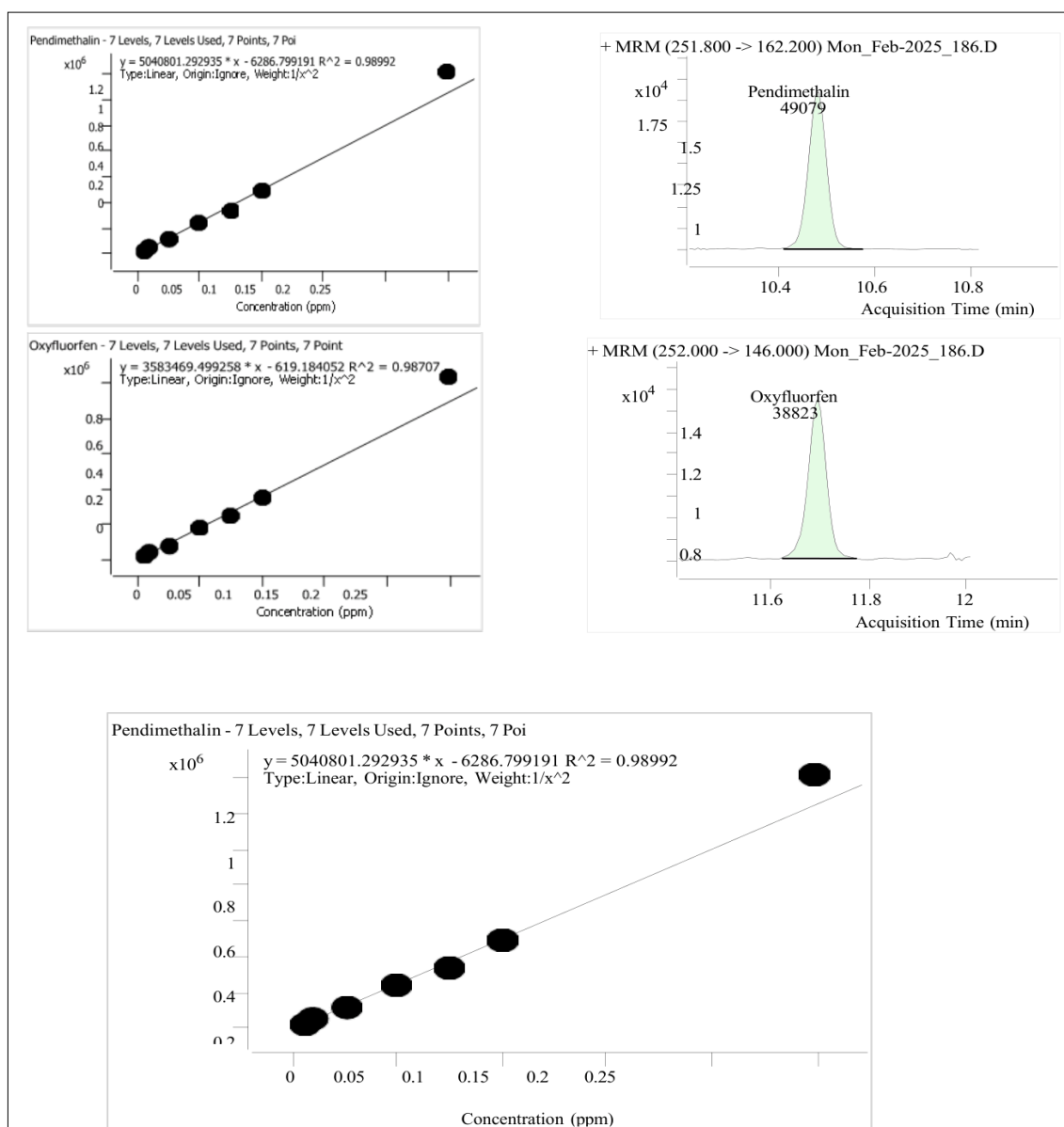
Treatments	Pod yield (kg/ha)	Haulm yield (kg/ha)	Herbicide cost including application charge (₹/ha)	Labour charge for IC + HW (₹/ha)	Total cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C	Weed index (%)
Pendimethalin 30 % EC 750 g a. i./ha followed by IC + HW at 40 DAS	3289	4126	2321	9100	92873	231345	138472	2.49	3.24
Flumioxazin 50 % SC 125 g a. i./ha followed by IC + HW at 40 DAS	3148	3911	3821	9100	94510	221351	126841	2.34	7.38
Diclosulam 84 % WDG 25.2 g a. i./ha followed by IC + HW at 40 DAS	2900	3738	2296	9100	92845	204183	111338	2.20	14.7
Oxyfluorfen 23.5% EC + pendimethalin 30% EC (tank mix) 188 + 500 g a. i./ha followed by IC + HW at 40 DAS	2948	3730	2983	5350	89501	207423	117922	2.32	13.3
Diclosulam 84% WDG + pendimethalin 30% EC (tank mix) 25.2 + 500 g a. i./ha followed by IC + HW at 40 DAS	3255	4004	3213	5350	89753	228795	139042	2.55	4.24
Pendimethalin 30 % + imazethapyr 2 % EC (RM) 800 g a. i./ha followed by IC + HW at 40 DAS	2971	3813	2946	5350	89461	209149	119688	2.34	12.6
Sodium acifluorfen 16.5% + clodinafop propargyl 8% EC (RM) 245 g a. i./ha followed by IC + HW at 40 DAS	2947	3868	2896	8350	92681	207631	114950	2.24	13.3
Fluazifop-p-butyl 11.1% w/w + fomesafen 11.1% w/w SL (RM) 250 g a. i./ha followed by IC + HW at 40 DAS	2912	3878	3046	8650	92845	205277	112432	2.21	14.3
Propanil 2.5% + imazethapyr 3.75% w/w ME (RM) 125 g a. i./ha followed by IC + HW at 40 DAS	3276	4040	3446	7225	92054	230291	138237	2.50	3.62
Quizalofop ethyl 7.5% + imazethapyr 15% w/w EC (RM) 90 g a. i./ha followed by IC + HW at 40 DAS	3174	3970	3026	7225	91595	223232	131637	2.44	6.62
IC followed by HW at 20 and 40 DAS	3399	4162	0	18200	100273	238878	138605	2.38	-
Weedy check	478	1205	-	0	80405	34833	-45572	0.43	85.9
S. Em. ±	166	176	-	-	-	-	-	-	-
CD (5 %)	487	517	-	-	-	-	-	-	-

Note: Selling price: groundnut pod: ₹67.83/kg, haulm: ₹2.0/kg and Labour rate: ₹375/day, Herbicide application rate: ₹946 (treatment T₁-T₁₀). a. i./ha: active ingredient per hectare; DAS: days after sowing; EC: emulsifiable concentrate; ME: micro-emulsion; IC: intercultivation; HW: hand weeding; SC: suspension concentrate; NS: Non-significant; RM: ready mix; SL: soluble concentrate; WDG: water dispersible granules.

Table 3. Soil bacterial count as influenced by different weed management practices in kharif groundnut (Pooled data 2022–24)

Treatments	Total bacterial count (CFU/g soil)			
	0 DAS	10 DAS	30 DAS	At harvest
Initial Count: 2.5×10^4				
Pendimethalin 30 % EC 750 g a. i./ha followed by IC + HW at 40 DAS	3.80 (6.6×10^3)	5.32 (2.7×10^5)	6.30 (2.7×10^6)	5.69 (4.9×10^5)
Flumioxazin 50 % SC 125 g a. i./ha followed by IC + HW at 40 DAS	3.77 (6.1×10^3)	5.32 (2.7×10^5)	6.27 (2.4×10^6)	5.68 (4.8×10^5)
Diclosulam 84 % WDG 25.2 g a. i./ha followed by IC + HW at 40 DAS	3.77 (6.2×10^3)	5.33 (2.7×10^5)	6.29 (2.5×10^6)	5.70 (5.0×10^5)
Oxyfluorfen 23.5 % EC + pendimethalin 30 % EC (tank mix) 188 + 500 g a. i./ha followed by IC + HW at 40 DAS	3.75 (5.9×10^3)	5.31 (2.6×10^5)	6.26 (2.4×10^6)	5.66 (4.6×10^5)
Diclosulam 84 % WDG + pendimethalin 30 % EC (tank mix) 25.2 + 500 g a. i./ha followed by IC + HW at 40 DAS	3.76 (5.9×10^3)	5.26 (2.5×10^5)	6.24 (2.3×10^6)	5.64 (4.4×10^5)
Pendimethalin 30 % + imazethapyr 2 % EC (RM) 800 g a. i./ha followed by IC + HW at 40 DAS	3.79 (6.4×10^3)	5.33 (2.7×10^5)	6.30 (2.6×10^6)	5.68 (4.7×10^5)
Sodium acifluorfen 16.5 % + clodinafop propargyl 8 % EC (RM) 245 g a. i./ha followed by IC + HW at 40 DAS	4.06 (1.2×10^4)	5.42 (3.5×10^5)	7.04 (1.1×10^7)	5.71 (5.2×10^5)
Fluazifop-p-butyl 11.1 % w/w + fomesafen 11.1 % w/w SL (RM) 250 g a. i./ha followed by IC + HW at 40 DAS	4.01 (1.0×10^4)	5.41 (3.4×10^5)	7.00 (1.0×10^7)	5.67 (4.7×10^5)
Propaquizafop 2.5 % + imazethapyr 3.75 % w/w ME (RM) 125 g a. i./ha followed by IC + HW at 40 DAS	4.08 (1.2×10^4)	5.44 (3.6×10^5)	7.01 (1.0×10^7)	5.69 (4.9×10^5)
Quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC (RM) 90 g a. i./ha followed by IC + HW at 40 DAS	4.07 (1.2×10^4)	5.43 (3.6×10^5)	7.02 (1.0×10^7)	5.68 (4.8×10^5)
IC followed by HW at 20 and 40 DAS	4.67 (4.8×10^4)	5.75 (1.0×10^6)	7.01 (1.0×10^7)	5.70 (5.0×10^5)
Weedy check	4.67 (4.8×10^4)	5.75 (1.0×10^6)	6.97 (9.3×10^6)	5.69 (4.9×10^5)
S. Em. $\pm$	0.041	0.062	0.132	0.013
CD (5 %)	0.120	0.181	0.386	NS

Note: Data subjected to log transformation. Figure in parentheses are means of original values. a. i./ha: active ingredient per hectare; DAS: days after sowing; EC: emulsifiable concentrate; ME: micro-emulsion; IC: intercultivation; HW: hand weeding; SC: suspension concentrate; NS: Non-significant; RM: ready mix; SL: soluble concentrate; WDG: water dispersible granules.

**Fig. 1.** Chromatograms of herbicides.

followed by IC + HW at 40 DAS or diclosulam 84 % WDG + pendimethalin 30 % EC (tank mix) 25.2 + 500 g a.i./ha followed by IC + HW at 40 DAS or propaquizafop + imazethapyr 125 g a.i./ha PoE followed by IC + HW at 40 DAS or quizalofop ethyl + imazethapyr 90 g a.i./ha PoE DAS followed by IC + HW at 40 DAS or IC followed by HW at 20 and 40 DAS recorded a higher pod yield of groundnut, effective weed management and net returns without any herbicide residue in produce and in soil.

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Authors' contributions

PVJ conceptualised the study, performed the analysis of all agronomical aspects and contributed to manuscript preparation. CDD contributed to the conceptualisation of the study, data recording and data analysis. PHK was responsible for data recording, data analysis of microbial aspects and manuscript preparation. CNN contributed to data recording, data analysis of pesticide residue aspects and manuscript preparation. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

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