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Impact of Herbicidal Weed Management on Weed Flora, Productivity, and Soil Microbial Population in Groundnut (*Arachis hypogaea* L.) and its Residual Effect on Lathyrus (*Lathyrus sativus* L.)

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ABSTRACT

The experiment was conducted during the months of July-February of 2022–23 and 2023–24 at the Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India to study the best weed management practice in groundnut crop (*kharif* season) and its residual effect on succeeding lathyrus crop (*rabi* season). The study had seven treatments replicated thrice namely; T_1: Fluazifop-p-butyl 13.4% EC @ 1000 ml ha^{-1}; T_2: Fluazifop-p-butyl 13.4% EC @ 1250 ml ha^{-1}; T_3: Fluazifop-p-butyl 13.4% EC @1562.5 ml ha^{-1}, T_4: Quizalofop ethyl 5% EC@1000 ml ha^{-1}, T_5: Fluazifop-p-butyl 13.4% EC @ 2500 ml ha^{-1}, T_6: Hand weeding control (20 and 40 days after sowing), T_7: Weedy check control. The results revealed that Fluazifop-p-butyl 13.4% EC @ 2500 ml ha^{-1} provided effective control of all weed categories but caused severe phytotoxicity, resulting in marked yield reduction in groundnut. The twice hand weeding at 20 and 40 DAS recorded the highest weed control efficiency and maximum groundnut yield; however, its higher labour cost led to a comparatively lower benefit-cost ratio. However, among the herbicidal treatments, Fluazifop-p-butyl 13.4% EC @ 1562.5 ml ha^{-1} produced the best overall performance with effective weed suppression, higher pod, kernel, and haulm yields, and the maximum benefit-cost ratio. The germination, yield, and yield-attributing traits of the succeeding lathyrus crop were not significantly influenced by the preceding herbicidal treatments. Hence, Fluazifop-p-butyl 13.4% EC @ 1562.5 ml ha^{-1} might be safely recommended for effective weed management in groundnut in the lower Gangetic alluvial zone of West Bengal.

KEYWORDS: Fluazifop-p-butyl, groundnut, lathyrus, quizalofop-p-ethyl, weed control efficiency

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1. INTRODUCTION

Groundnut is widely regarded as the "king of oilseeds" and is mainly grown in tropical and subtropical regions (Kamal et al., 2023). It is one of the sixth most important oilseed crops in India belonging to the family leguminosae, containing 48–50% oil and 26–28% protein (Mehriya et al., 2020; Reager et al., 2022). India has 4.91 mha area under groundnut cultivation with a production of 9.18 million tonnes (Anonymous, 2018). Groundnut production in India is limited by several biotic and abiotic factors such as drought, poor soil fertility, and salinity (Tadesse and Nepir, 2024) with weeds being a major constraint. Inadequate weed management can cause yield losses of 17–96% due to competition for essential resources (Rao and Chauhan, 2015; Kumar et al., 2019). Additionally, some weeds show allelopathic effects and act as hosts for pests and diseases, further reducing crop productivity (Priyanka et al., 2023). Hence, weeds must be removed either manually or chemically throughout important stages of crop development (Jat et al., 2011; Kundu et al., 2021) to minimize production losses. However, hand weeding does not guarantee a weed-free environment for a rainfed crop; rather, it is associated with greater cultivation costs and a shortage of labour as a result of industrialization and urbanization in the area (Ram and Singh, 2011; Das et al., 2023, Ravi et al., 2023; Singh et al., 2023; Mehriya et al., 2024). Also, maintaining a weed-free environment during the critical crop growth period is essential for improving groundnut productivity but intercultural operations should be avoided at 45–50 days after sowing, as this stage coincides with the initiation of pegging and may damage developing pegs (Sharma et al., 2015). Therefore, the use of various types of pre-emergence and post-emergence herbicides into the groundnut field can serve as a cost-effective option (Vaghasia et al., 2013; Regar et al., 2021). Additionally, in the context of the country's rapidly growing population and the consequent pressure on food and natural resources, there is a need for crop diversification, which offers a sustainable and resilient option for improving productivity while maintaining soil health (Hatti et al., 2018). Therefore, the best viable option will be growing lathyrus after the groundnut as it is a legume crop and is still untapped in terms of its potential of containing chemicals that are beneficial to human health. The lathyrus gives many low-income populations food and nutrition security since it is a nutrient-dense food crop with a high level of drought tolerance and little input requirements for its cultivation (Mahapatra et al., 2020). Thus, the groundnut–lathyrus cropping sequence emerges as a highly efficient and cost-effective system that enhances food security as well as soil fertility. The chemical family aryloxy-phenoxy propionate, which includes the fluazifop-p-butyl herbicide with systemic activity, is a potent inhibitor of the enzyme acetyl-coenzyme A carboxylase (ACCase). Fluazifop's inhibition of ACCase prevents the production of malonyl-CoA, which is necessary for plants to make fatty acids, and hence controls weedy species (Cieslik et al., 2013).

With this context in mind, the current experiment was carried out in 2022–23 and 2023–24 at the Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya, West Bengal to evaluate the effectiveness of various herbicidal treatments on weed flora, productivity and soil microbial population in groundnut and its residual effect on lathyrus crop. The experiment focused on assessing the herbicidal effect of Fluazifop-p-butyl 13.4% EC, applied at multiple dosage levels, in comparison with a commonly used herbicide of the same family, Quizalofop ethyl 5% EC, and the standard practice of hand weeding twice.

2. MATERIALS AND METHODS

A field experiment was conducted during 2022–23 and 2023–24 at the Instructional Farm, Jaguli, Bidhan Chandra Krishi Viswavidyalaya Mohanpur, Nadia, West Bengal (23.5° N latitude, 89.0° E longitude; 9.75 m above mean sea level). The soil was sandy loam in texture with a pH of 7.1 and the site was classified as medium land. The surface soil (0–15 cm) was clay loam, containing available N, P, and K of 282.6, 28.4, and 19.8 kg ha^{-1}, respectively, with 0.45% organic carbon. The experiment was replicated thrice with seven treatments- T_1: Fluazifop-p-butyl 13.4% EC @ 1000 ml ha^{-1}; T_2: Fluazifop-p-butyl 13.4% EC @ 1250 ml ha^{-1}; T_3: Fluazifop-p-butyl 13.4% EC @1562.5 ml ha^{-1}, T_4: Quizalofop ethyl 5% EC @ 1000 ml ha^{-1}, T_5: Fluazifop-p-butyl 13.4% EC @ 2500 ml ha^{-1}, T_6: Hand weeding control (20 and 40 days after sowing), T_7: Weedy check control. The groundnut variety 'TAG 24' was sown in the second fortnight of August at a spacing of 30×50 cm^2 with a plot size of 3×4 m^2. The succeeding lathyrus variety 'Ratan' was sown without disturbing the main layout. The herbicides were applied once at 20 DAS as an early post-emergence spray (2-4 leaf stage of weeds) using a knapsack sprayer fitted with a flat-fan nozzle at a spray volume of 500 l ha^{-1}. Weed observations were recorded at 45 and 60 DAS using a 50×50 cm^2 quadrat placed four times per plot and expressed on an m^2 basis. Weed dry weight was determined after sun-drying for 48 hours, followed by oven-drying at 70°C for 72 hours. Visually the phytotoxicity symptoms were observed in the experimental field at 7, 14, 21 and 28 days after application of the herbicides and rated using a 0–10 rating scale based on the percentage of crop injury, where 0 = no injury (0%), 1=1–10%, 2=11–20%, 3=21–30%, 4=31–40%, 5=41–50%, 6=51–60%, 7=61–70%, 8=71–80%, 9=81–90%, and 10=91–100% injury (Rao, 2000). Severe yield loss can be seen after 5 scales. Observations on yield and yield attributes of groundnut and the germination, growth, and yield parameters of the succeeding lathyrus crop were recorded at harvest and analysed statistically after suitable transformation wherever required. Weed control efficiency (WCE) was calculated as per the formula (Mani et al., 1973) given below:

Weed Control Efficiency (%) =(WDC-WDT)/ WDC)×100

where, WDC=Weed dry weight in untreated control plot (g m^{-2}); WDT=Weed dry weight in treated plot (g m^{-2})

Soil samples from the experimental plots were collected twice (before groundnut sowing and after lathyrus harvesting) from the space between the rows at a depth of 0–15 cm, for microbial analysis using the pour plate method in accordance with Pramer and Schmidt (1965). The data recorded for all parameters from the experimental site were pooled and analyzed in ANOVA following the procedures described by Gomez and Gomez (1984). To satisfy the assumptions necessary for valid statistical inference, the weed data were transformed using the square root method as suggested by Panse and Sukhatme (1978).

3. RESULTS AND DISCUSSION

3.1. Weed flora

The cultivable land of groundnut was overrun with a diverse weed flora that included mostly grassy weeds (69%), followed by broad-leaf weeds (31%). The species-specific weed data were recorded at 60 DAS, which revealed that the predominant grassy weeds were *Echinochloa* spp.>*Dinebra retroflexa*>*Brachiaria* spp. The most common broadleaf weeds were *Commelina benghalensis*>*Phyllanthus niruri*>*Euphorbia hirta*>*Digera arvensis*>*Indigofera glabrescens*>*Tridax procumbens*. The preponderance of such weeds during the *kharif* season was noted by several researchers like Pal et al. (2016), Mundra and Maliwal (2012), and Rabari et al. (2024).

3.2. Weed density and biomass

Observations on weed density after 45 and 60 days of crop sowing clearly indicated that herbicidal treatments were better than the untreated check condition in the reduction of all categories of weeds (Table 1). Among all the treatments, it was observed twice hand weeding treatment recorded the minimum total weed density and total weed biomass (1.58 m^{-2}, 1.29 g m^{-2} and 1.61 m^{-2}, 1.36 g m^{-2}, respectively) at 45 and 60 DAS, followed by the herbicidal treatments, T_5 (2.11 m^{-2}, 1.36 g m^{-2} and 2.15 m^{-2}, 1.43 g m^{-2}, respectively) and T_3 (2.13 m^{-2}, 1.43 g m^{-2} and 2.19 m^{-2}, 1.45 g m^{-2}, respectively). Similar effects of post-emergence herbicides on weed growth and the efficiency of manual hand weeding in controlling weeds across different herbicidal treatments had also been reported by Ravi et al. (2023), Adhikary and Patra (2024), and Chitale et al. (2024).

3.3. Weed control efficiency

It also followed a similar trend (Table 1) with twice-hand weeding treatment being the most efficient in controlling

Table 1: Effect of weed management treatments on total weed density, weed biomass, weed control efficiency of groundnut during *kharif* seasons

Treatments	Total weed density (no. m^{-2})		Total weed dry weight (g m^{-2})		Weed control efficiency (%)	
	45 DAS	60 DAS	45 DAS	60 DAS	45 DAS	60 DAS
Fluazifop-p-butyl 13.4% EC @ 1000 ml ha^{-1}	2.21 (4.38)	2.29 (4.74)	1.58 (1.99)	1.62 (2.12)	75.79	82.00
Fluazifop-p-butyl 13.4% EC @ 1250 ml ha^{-1}	2.14 (4.07)	2.23 (4.47)	1.51 (1.78)	1.56 (1.93)	78.35	83.62
Fluazifop-p-butyl 13.4% EC @ 1562.5 ml ha^{-1}	2.13 (4.03)	2.19 (4.23)	1.43 (1.54)	1.45 (1.60)	81.27	86.42
Quizalofop-p-ethyl 5% EC @ 1000 ml ha^{-1}	2.23 (4.47)	2.27 (4.65)	1.53 (1.84)	1.65 (2.22)	77.62	81.15
Fluazifop-p-butyl 13.4% EC @ 2500 ml ha^{-1}	2.11 (3.95)	2.15 (4.12)	1.36 (1.34)	1.43 (1.54)	83.70	86.93
Hand weeding control (20 and 40 days after sowing)	1.58 (1.99)	1.61 (2.09)	1.29 (1.12)	1.36 (1.34)	86.37	88.62
Weedy check	4.38 (18.68)	4.41 (18.94)	2.95 (8.22)	3.50 (11.78)	-	-
SEm±	0.01	0.1	0.01	0.01	-	-
CD (p=0.05)	0.03	0.32	0.05	0.04	-	-

all categories of weeds (86.37% and 88.62%, respectively), followed by treatments T_5 (83.70% and 86.93%, respectively) and T_3 (81.27% and 86.42%, respectively). The high dose of the herbicide Fluazifop-p-butyl caused phytotoxicity, resulting in effective weed control. The dominance of hand-weeding in controlling weeds over other chemical treatment in groundnut in *kharif* season was reported by Malunjkar et al. (2012), and Mudalagiriyappa et al. (2021).

3.4. *Yield and yield attributes of groundnut*

The highest pod yield (22.01 q ha^{-1}), kernel yield (17.21 q ha^{-1}) and haulm yield (58.51 q ha^{-1}) of groundnut were obtained from twice hand weeding treatment, followed by T_3 (19.51, 15.62, 54.22 q ha^{-1}, respectively). The lowest pod, kernel, and haulm yield (11.65, 6.90 and 26.52 q ha^{-1}, respectively) were recorded from the weedy check (Table 2). Severe weed infestation in the weedy check plots drastically reduced crop yield due to intense crop-weed competition for essential resources such as water, nutrients, and sunlight. Additionally, the phytotoxic effect of the higher dose of Fluazifop-p-butyl suppressed crop growth and further contributed to a substantial decline in yield. The effects of various weed management practices to control weeds and improve the productivity in legumes like groundnut was reported by Yadav et al. (2014) and in green gram by Rabari et al. (2024).

3.5. *Phytotoxicity*

The treatment T_5 recorded the highest crop injury (30-60%) up to 30 days after application (DAA), primarily due to the higher herbicide dose. Although this dose provided effective weed control, it adversely affected the crop (Table 3). In contrast, the other herbicidal treatments showed only minimal and short-lived phytotoxicity during the initial days after application, likely because of their lower application rates, as being concluded by Kalaichelvi et al. (2015) and Kakade et al. (2023) in groundnut crop.

3.6. *Microbial properties*

The impact on soil microflora, viz., total bacteria (*Pseudomonas fluorescens*, *Bacillus* spp.), fungi (*Trichoderma viride*, *Trichoderma harzianum*), and actinomycetes, is presented in Table 4. The herbicide fluazifop-p-butyl 13.4% EC did not exert any significant effect on the total soil microbial population at the later stage, i.e., after harvesting of the lathyrus crop. This may be attributed to the initial phytotoxic effects of herbicidal doses on soil microorganisms; however, over time, the microbial community likely developed the capacity to degrade herbicide residues, thereby facilitating detoxification, minimizing residual effects, and restoring microbial proliferation. The ability of soil microorganisms to metabolize herbicides and utilize them as sources of essential nutrients has also been reported by Bera et al. (2016) in *boro* rice and by Sah (2022) in legumes such as chickpea.

3.7. *Succeeding crop*

The herbicide application in the groundnut crop did not exert any residual adverse effect on the succeeding lathyrus crop (Table 5). Compared with the weedy check and hand-weeded control plots, herbicidal treatments showed no significant influence on germination percentage, growth attributes (such as plant height), or yield parameters

Table 2: Effect of weed management treatments on yield and production economics of groundnut during *kharif* seasons

Treatments	Yield (q ha^{-1})			Production economics (₹ ha^{-1})		
	Pod yield	Kernel yield	Haulm yield	Cost of cultivation	Gross return	B:C ratio
Fluazifop-p-butyl 13.4% EC @ 1000 ml ha^{-1}	16.03	9.21	40.21	43250	53879	1.25
Fluazifop-p-butyl 13.4% EC @ 1250 ml ha^{-1}	18.77	12.66	51.01	43475	74061	1.70
Fluazifop-p-butyl 13.4% EC @ 1562.5 ml ha^{-1}	19.51	15.62	54.22	43756	91377	2.09
Quizalofop-p-ethyl 5% EC @ 1000 ml ha^{-1}	17.27	12.35	42.52	43050	72248	1.68
Fluazifop-p-butyl 13.4% EC @ 2500 ml ha^{-1}	15.62	7.43	36.81	44,600	43466	0.97
Hand weeding control (20 and 40 days after sowing)	22.01	17.21	58.51	53120	100679	1.90
Weedy check	11.65	6.90	26.52	39189	40365	1.03
SEm±	1.35	3.89	0.66	--	--	--
CD (p=0.05)	4.05	10.9	1.9	--	--	--

Table 3: Effect of weed management treatments on phytotoxicity in groundnut crop

Treatment	Chlorosis								Wilting								Necrosis							
	2022–23				2023–24				2022–23				2023–24				2022–23				2023–24			
DAA	7	15	22	30	7	15	22	30	7	15	22	30	7	15	22	30	7	15	22	30	7	15	22	30
Fluazifop-p-butyl 13.4% EC @ 1000 ml ha^{-1}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fluazifop-p-butyl 13.4% EC @ 1250 ml ha^{-1}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0
Fluazifop-p-butyl 13.4% EC @ 1562.5 ml ha^{-1}	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0
Quizalofop-p-ethyl 5% EC @ 1000 ml ha^{-1}	1	1	1	0	0	1	1	0	1	1	0	0	1	1	0	0	1	0	0	0	1	0	0	0
Fluazifop-p-butyl 13.4% EC @ 2500 ml ha^{-1}	6	5	4	3	6	5	4	2	5	5	3	2	5	3	3	2	6	6	4	3	6	6	3	3

Table 4: Effect of weed management treatments on microbial properties of soil

Treatments	Population before sowing g^{-1} soil			Population after harvest g^{-1} soil		
	Bacterial (CFU ×10^{6})	Fungal (CFU ×10^{4})	Actinomycetes (CFU ×10^{5})	Bacterial (CFU ×10^{6})	Fungal (CFU ×10^{4})	Actinomycetes (CFU ×10^{5})
Fluazifop-p-butyl 13.4% EC @ 1000 ml ha^{-1}	2.42	1.87	2.34	4.72	3.36	3.78
Fluazifop-p-butyl 13.4% EC @ 1250 ml ha^{-1}	2.56	1.95	2.21	4.97	3.35	3.71
Fluazifop-p-butyl 13.4%EC @ 1562.5 ml ha^{-1}	2.27	2.04	2.41	4.71	3.23	3.66
Quizalofop-p-ethyl 5% EC @ 1000 ml ha^{-1}	2.19	1.86	2.56	4.68	3.25	3.67
Fluazifop-p-butyl 13.4% EC @ 2500 ml ha^{-1}	2.25	1.79	2.24	4.62	3.18	3.58
Hand weeding control (20 and 40 days after sowing)	2.17	1.94	2.51	4.92	3.43	3.89
Weedy check	2.34	1.88	2.38	4.97	3.41	3.95
SEm±	0.11	0.15	0.02	0.81	0.31	0.21
CD (p=0.05)	NS	NS	NS	NS	NS	NS

(including number of pods per plant, number of seeds per pod, and seed yield) of lathyrus. This may be attributed to the detoxification and degradation of herbicide residues in the soil by microbial activity, thereby preventing any negative impact on the growth and productivity of the succeeding crop. Such residual effect of herbicide on germination, growth and yield of succeeding legume crop like black gram was reported by Paul et al. (2022).

3.8. Production economics

The twice hand-weeding treatment recorded the highest gross return (₹ 100,679 ha^{-1}) due to its superior weed control

Table 5: Effect of weed management treatments on growth and yield of succeeding lathyrus crop

Treatments	Germination % at 30 DAS	Plant height (cm) at harvest	Pod length (cm)	No. of pods plant^{-1}	No. of seeds pod^{-1}	Seed yield (q ha^{-1})	Stover yield (q ha^{-1})
Fluazifop-p-butyl 13.4% EC @ 1000 ml ha^{-1}	92	113.65	2.81	44.93	2.83	15.31	19.78
Fluazifop-p-butyl 13.4% EC @ 1250 ml ha^{-1}	93	116.53	2.62	49.35	2.63	15.56	19.65
Fluazifop-p-butyl 13.4% EC @ 1562.5 ml ha^{-1}	95	115.88	2.89	46.32	2.89	15.89	19.93
Quizalofop-p-ethyl 5% EC @ 1000 ml ha^{-1}	91	112.36	2.53	47.89	2.53	15.02	19.36
Fluazifop-p-butyl 13.4% EC @ 2500 ml ha^{-1}	95	115.29	2.56	48.81	2.56	15.96	19.63
Hand weeding control (20 and 40 days after sowing)	95	118.36	2.93	48.63	3.02	15.49	19.36
Weedy check	90	119.49	2.65	42.19	2.65	15.62	19.29
SEm±	0.41	3.10	0.14	1.80	0.15	1.41	1.33
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS

efficiency, which facilitated maximum groundnut yield and consequently higher market returns. However, the high cost and limited availability of labour resulted in a comparatively lower benefit-cost ratio (1.90). Among the treatments, T_3 registered the highest benefit-cost ratio (2.09) with a gross return of ₹ 91,377 ha^{-1}, next only to the hand-weeding treatment. The effects of various post-emergence herbicides on production economics, along with the superiority of hand-weeding in terms of gross returns in groundnut, had been reported by Dixit et al. (2016) and Naik et al. (2025).

4. CONCLUSION

The experiment revealed that T_5 (Fluazifop-p-butyl 13.4% EC @ 2500 ml ha^{-1}) effectively controlled all weed categories but caused severe phytotoxicity, reducing groundnut yield. Hand weeding twice (20 and 40 DAS) achieved high weed control efficiency and higher yield but had a lower benefit-cost ratio due to high labour requirements. Therefore, T_3 (Fluazifop-p-butyl 13.4% EC @ 1562.5 ml ha^{-1}) showed the best overall performance with effective weed control and hence, can be safely recommended for effective weed management in groundnut.

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