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Weed management strategies and their influence on nutrient uptake by sunflower (*Helianthus annuus* L.) and weed flora under rice fallow conditions

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Abstract

Weed competition is one of the most critical biotic constraints limiting nutrient acquisition and productivity in sunflower (*Helianthus annuus* L.) cultivation, particularly under rice fallow conditions where residual soil nutrients are vulnerable to competitive depletion. A field experiment was conducted to evaluate the influence of eight contrasting weed management treatments comprising herbicide-based, mechanical, integrated, and unweeded control treatments on nitrogen (N), phosphorus (P), and potassium (K) uptake by the sunflower crop and associated weed flora. Results revealed highly significant differences among treatments for all nutrient uptake parameters in both seed and stover fractions. The weed-free treatment (T₇) recorded the highest total N, P, and K uptake of 57.29, 22.01, and 79.39 kg ha⁻¹, respectively, which were significantly superior to all other treatments. Mechanical weed management treatments two inter-cultivations (T₅) and one inter-cultivation combined with hand weeding (T₆) followed closely and were statistically comparable to each other. Among herbicide-based treatments, the combination of paraquat + pendimethalin + quizalofop ethyl (T₂) consistently outperformed other herbicide treatments for crop nutrient uptake across all three nutrients. The un-weeded control (T₈) recorded the lowest crop nutrient uptake, representing barely one-third to one-half of the values recorded under the weed-free treatment. Conversely, weed nutrient uptake was maximum in the control (N: 26.50, P: 5.20, K: 29.52 kg ha⁻¹) and minimum under the weed-free treatment, confirming a strong inverse relationship between weed nutrient immobilisation and crop nutrient acquisition. These findings underscore the paramount importance of timely and effective weed management in conserving applied and native soil nutrients for productive utilization by the sunflower crop in rice fallow systems.

Keywords: Sunflower, weed management, rice fallow, nutrient uptake, weed removal. Drymatter accumulation.

Introduction

Sunflower (*Helianthus annuus* L.), belonging to the family Asteraceae, is one of the most strategically important oilseed crops cultivated globally. It ranks among the world's four leading sources of Oilseeds alongside soybean, groundnut and rapeseed and is prized for its high proportion of polyunsaturated fatty acids, particularly linoleic acid (approximately 60–66%), and low saturated fat content. Beyond its oil value, sunflower contains an extensive array of bioactive phytochemicals including tocopherols, phytosterols, flavonoids, phenolic acids, carotenoids, chlorogenic acid, alkaloids, tannins, and saponins collectively positioning it as a crop of immense nutritional, medicinal, and economic value (kalaiyaran *et al.*, 2019) [2]. In India, sunflower occupy a considerable strategic importance in the national oilseed economy. It adapts well to diverse agro-climatic conditions and is grown across kharif, rabi, and zaid seasons, cultivated notably in Karnataka, Andhra Pradesh, Telangana, Maharashtra, Bihar, and Odisha. However, domestic production has declined sharply from about 12–15 lakh tonnes in the mid-2000s to a mere 1.7 lakh tonnes in 2023–24 resulting in consumption being almost entirely met through imports. India's edible oil imports reached a record 40.99 million tonnes during 2025–26, reflecting acute dependence on imported oils and an urgent national imperative to boost domestic oilseed production. This persistent productivity deficit stems from interacting

biotic and abiotic constraints, inadequate soil fertility management, and sub-optimal crop husbandry, of which weed infestation remains one of the most economically significant and agronomically destructive constraints (Anonymous, 2026)^[1].

Weeds are universally acknowledged as the most pervasive threat to crop production systems. In sunflower, weed infestation is especially acute due to wide inter-row spacing, slow initial canopy development, and a prolonged juvenile growth stage all of which create a favourable microenvironment for diverse weed species. Weeds compete with the sunflower crop for solar radiation, soil moisture, carbon dioxide, and mineral nutrients from the earliest stages of establishment. Uncontrolled weed infestation has been documented to cause yield losses of up to 62%, depending on weed species composition, density, and timing of emergence. Of particular concern is the nutritional dimension of weed competition, the extent to which weeds directly deplete soil nutrients that would otherwise support crop productivity (Stefanic *et al.*, 2023)^[6].

Nutrient management is central to achieving high and sustainable sunflower productivity. Sunflower has particularly high demands for nitrogen (N), phosphorus (P), and potassium (K). Nitrogen drives vegetative growth, leaf area development, chlorophyll biosynthesis, and assimilate translocation into the developing seed. Phosphorus plays a critical role in energy metabolism, root development, and oil quality, while potassium governs stomatal regulation, water-use efficiency, and phloem transport of assimilates. However, a substantial portion of applied fertiliser is intercepted and assimilated by the weed community before the crop can utilise it, representing a direct and often underappreciated source of nutrient loss in the production system (Little NG *et al.*, 2021)^[3].

Integrated Weed Management (IWM) combining chemical, biological, mechanical, and cultural strategies is now recognised as the most effective and sustainable framework for weed management in oilseed crops. Growing concerns over herbicide resistance, driven by over-reliance on a narrow spectrum of active ingredients, have further reinforced the need for diversified approaches. Nath *et al.* (2024)^[5] comprehensively emphasised the need for integrated, sustainable strategies to ensure long-term oilseed crop productivity.

Materials and Methods

The field experiment entitled “Weed management strategies and their influence on nutrient uptake by Sunflower (*Helianthus annuus* L.) and weed flora under Rice fallow conditions.” was conducted at the instructional farm of Odisha University of Agriculture and Technology, Bhubaneswar during summer 2022. The experimental location is located 64 kilometres from the Bay of Bengal at 20°27' North Latitude and 85°07' East Longitude, with a height of 25.9 metres above mean sea level (MSL). The soil properties of the experimental field is sand 73.78%, silt 14.1% and clay 12.8%, and categorized as sandy loam soil with a pH of 5.12 with medium in nitrogen content (132.16 kg ha⁻¹), low in phosphorus content (2.50 kg ha⁻¹), high in available potassium (262.30 kg ha⁻¹). The experiment was consist of 8 treatments T₁-Paraquat spray before sowing +one inter-cultivation at 35 DAS, T₂- Paraquat spray before sowing+ pendimethalin @1kg a.i ha⁻¹ as pre-emergence spray + Quizalofop ethyl 10EC @37.5 g ai ha⁻¹ 2 at 20 DAS as directed postemergence spray on weeds, T₃-pendimethalin @1kg a.i ha⁻¹ as preemergence spray + one inter-cultivation at 30 DAS, T₄-pendimethalin @1kg a.i ha⁻¹as pre-emergence spray + Quizalofop ethyl 10EC @37.5 g ai ha⁻¹ at 20 DAS as directed postemergence spray on weeds, T₅- Two inter-cultivation at 20

& 40 DAS, T₆- one inter-cultivation at 20 DAS and 1 hand weeding at 30-35 DAS, T₇- weed free, T₈- Control. The crop was sown on 30th January 2022. Preemergence application of herbicide was done in 48 hours of sowing. Post-emergence application was done 20 DAS. The other operations were carried out as per the guidelines of OUAT. The crop was harvested on 02nd May 2022. The biometric observations were recorded by selecting five plants randomly per treatment, and treatment means were used for analysis.

Results and Discussion

Effect of Weed Management Treatments on Dry Matter Accumulation

Dry matter accumulation (g m⁻²) at 30, 60 DAS and at Harvest

Dry matter accumulation of sunflower was significantly influenced by weed management treatments at all growth stages (Table 1). At 30 DAS, the weed-free treatment (T₇) recorded the highest dry matter accumulation (4.2 g m⁻²), followed by two intercultivations (T₅: 3.5 g m⁻²), while T₂ and T₆ (3.3 g m⁻² each) were at par. The unweeded control (T₈) recorded the lowest value (1.7 g m⁻²). A similar trend was observed at 60 DAS, where T₇ produced the maximum dry matter (62.7 g m⁻²), followed by T₅ (60.6 g m⁻²) and T₆ (58.5 g m⁻²), whereas T₈ recorded the minimum (41.4 g m⁻²). At harvest, T₇ again registered the highest dry matter accumulation (112.0 g m⁻²), followed by T₅ (106.5 g m⁻²) and T₆ (100.5 g m⁻²). Among herbicide-based treatments, T₂ performed better than T₁, T₃, and T₄, while the unweeded control (T₈) recorded the lowest dry matter accumulation (81.6 g m⁻²). The superior biomass production under weed-free and effective weed management treatments may be attributed to reduced crop–weed competition and improved availability of nutrients, moisture, and light, whereas unrestricted weed growth in the control plots markedly reduced dry matter accumulation throughout the crop growth period (Sujathamma *et al.*, 2026)^[7]

Stem girth

Stem girth was significantly influenced by weed management practices throughout the crop growth period (Table.1). The weed-free treatment (T₇) consistently recorded the highest stem girth, followed by two intercultivations (T₅) and one intercultivation coupled with hand weeding (T₆). Among the herbicide-based treatments, T₂ produced greater stem girth than T₁, T₃, and T₄, while the unweeded control (T₈) recorded the lowest values. Enhanced stem girth under effective weed management treatments may be attributed to reduced crop–weed competition and improved availability of growth resources, resulting in greater assimilate accumulation and crop vigour. These findings are inline with Thambiyannan *et al.*, (2024)^[9] and Sujathamma *et al.*, (2026)^[7].

Days to 50% flowering

Days to 50% flowering was significantly affected by weed management practices (Table 1). The weed-free treatment (T₇) recorded the earliest flowering, while the unweeded control (T₈) exhibited delayed flowering. Herbicide-based treatments, particularly T₂ and T₄, also promoted relatively earlier flowering compared with the other treatments. Delayed flowering under weedy conditions may be attributed to competition for nutrients, moisture, and light, which adversely affected crop growth and postponed reproductive development. Effective weed management thus facilitated timely flowering by providing a favourable environment for crop growth. [Thambiyannan *et*

al.,2024.]^[9].

Nitrogen Uptake by the Sunflower crop (kg ha⁻¹)

Nitrogen uptake in seed, stover, and total crop uptake was significantly influenced by weed management practices (Table 2). The weed-free treatment (T₇) recorded the highest nitrogen uptake in seed (33.84 kg ha⁻¹), stover (23.45 kg ha⁻¹), and total uptake (57.29 kg ha⁻¹), and was significantly superior to all other treatments. Among the weed management options, one intercultivation followed by hand weeding (T₆) and two intercultivations (T₅) recorded comparable nitrogen uptake and ranked next to the weed-free treatment. Among the herbicide-based treatments, T₂ (paraquat + pendimethalin + quizalofop-ethyl) registered higher nitrogen uptake than T₁, T₃, and T₄. The unweeded control (T₈) recorded the lowest nitrogen uptake in seed (11.94 kg ha⁻¹), stover (6.65 kg ha⁻¹), and total uptake (18.59 kg ha⁻¹). The higher nitrogen uptake under weed-free and effectively managed treatments may be attributed to reduced crop-weed competition and greater availability of soil nitrogen to the crop, whereas unchecked weed growth in the control plots resulted in substantial nutrient depletion and consequently lower nitrogen uptake by sunflower. The higher nitrogen uptake observed under weed-free and effective weed management treatments may be attributed to reduced crop-weed competition and greater availability of soil nitrogen to the crop. In contrast, lower nitrogen uptake in the unweeded control and less effective treatments reflects increased nitrogen removal by weeds, resulting in reduced nutrient availability and uptake by sunflower. The results are in conformity with the findings of Nagamani (2010)^[4] and Sunil *et al.*, (2015)^[8].

Phosphorus Uptake (kg ha⁻¹)

Phosphorus uptake in seed, stover, and total crop uptake was significantly influenced by weed management practices (Table 2). The weed-free treatment (T₇) recorded the highest phosphorus uptake in seed (17.57 kg ha⁻¹), stover (4.88 kg ha⁻¹), and total uptake (22.01 kg ha⁻¹), and was significantly superior to all other treatments. Among the weed management practices, two intercultivations (T₅) and one intercultivation followed by hand weeding (T₆) recorded higher phosphorus uptake and ranked next to the weed-free treatment. Among the herbicide-based treatments, T₂ (paraquat + pendimethalin + quizalofop-ethyl) registered greater phosphorus uptake than T₁, T₃, and T₄. The unweeded control (T₈) recorded the lowest phosphorus uptake in seed (6.46 kg ha⁻¹), stover (1.96 kg ha⁻¹), and total uptake (8.42 kg ha⁻¹). Enhanced phosphorus uptake under effective weed management treatments may be attributed to reduced crop-weed competition and improved nutrient availability, whereas uncontrolled weed growth markedly restricted phosphorus acquisition by the crop. The results are in line with the findings of Kalaiyarasan *et al.* (2019)^[2] and Sunil *et al.*, (2015)^[8].

Potassium Uptake (kg ha⁻¹)

Potassium uptake in seed, stover, and total crop uptake was significantly affected by weed management practices (Table 2). The weed-free treatment (T₇) recorded the highest potassium uptake in seed (13.32 kg ha⁻¹), stover (66.07 kg ha⁻¹), and total uptake (79.39 kg ha⁻¹), and was significantly superior to all other treatments. Among the weed management options, two intercultivations (T₅) and one intercultivation followed by hand weeding (T₆) recorded higher potassium uptake and were comparable to each other. Among the herbicide-based treatments, T₂ (paraquat + pendimethalin + quizalofop-ethyl)

registered greater potassium uptake than T₁, T₃, and T₄. The unweeded control (T₈) recorded the lowest potassium uptake in seed (5.84 kg ha⁻¹), stover (33.49 kg ha⁻¹), and total uptake (39.30 kg ha⁻¹). Potassium uptake was highest in the stover fraction, indicating the predominant accumulation of potassium in vegetative tissues. Effective weed management enhanced potassium uptake by minimizing crop-weed competition, whereas uncontrolled weed growth substantially reduced potassium acquisition by the crop. Higher potassium uptake under weed-free and effective weed management treatments may be attributed to reduced crop-weed competition and greater biomass production. Improved potassium acquisition enhances physiological processes such as photosynthate translocation, enzyme activation, and water regulation, thereby contributing to increased dry matter accumulation and yield of sunflower [Kalaiyarasan *et al.* (2019) and Sunil *et al.*, (2015)]^[2, 8].

Nutrient removal by weeds

Nutrient Uptake by Weeds (kg ha⁻¹)

Nutrient uptake by weeds, expressed in kg ha⁻¹, represents the actual quantum of plant-available nutrients immobilised in weed biomass and thereby denied to the sunflower crop. This parameter integrates both the nutrient concentration in weed tissue and the total weed dry matter accumulated, and is therefore a more realistic measure of the competitive drain imposed by weeds on soil fertility than tissue concentration alone

Nitrogen uptake by weeds (kg ha⁻¹)

The data reveal highly significant and economically important differences in nitrogen uptake by weeds among treatments (Table.3). The maximum nitrogen uptake by weeds was recorded in the unweeded control (T₈: 26.50 kg ha⁻¹), which was dramatically and significantly higher than all other treatments, underscoring the enormous nitrogen drain imposed by uncontrolled weed growth on the sunflower crop. This was followed by T₄ (18.19 kg ha⁻¹) and T₃ (5.84 kg ha⁻¹), which were significantly higher than the remaining treatments. Treatment T₁ recorded 3.61 kg ha⁻¹, followed by T₂ (2.69 kg ha⁻¹), T₆ (2.58 kg ha⁻¹), T₅ (1.89 kg ha⁻¹), and the weed-free treatment (T₇: 1.53 kg ha⁻¹), which recorded the lowest nitrogen uptake by weeds, significantly inferior to all other treatments. The near-17-fold difference in weed nitrogen uptake between the control and the weed-free treatment vividly illustrates the scale of nitrogen depletion from the soil under uncontrolled weed infestation conditions. The results are in line with the findings of Kalaiyarasan *et al.* (2019)^[2] and Nagamani (2010)^[4].

Phosphorus uptake by weeds (kg ha⁻¹)

Phosphorus uptake by weeds also differed significantly among treatments (Table.3). The highest phosphorus uptake by weeds was recorded in the control (T₈: 5.20 kg ha⁻¹), significantly superior to all other treatments. This was followed by T₄ (2.66 kg ha⁻¹) and T₃ (2.22 kg ha⁻¹), which were significantly higher than the remaining treatments. Treatment T₁ (1.20 kg ha⁻¹) recorded a moderately higher phosphorus uptake by weeds, while T₂ (0.96 kg ha⁻¹), T₆ (0.78 kg ha⁻¹), T₅ (0.36 kg ha⁻¹), and the weed-free treatment (T₇: 0.29 kg ha⁻¹) recorded successively lower values. The minimum phosphorus uptake by weeds in T₇ confirms that a completely weed-free environment effectively eliminates phosphorus loss through weed competition, preserving available phosphorus for productive crop utilization. Sunil *et al.*, (2015)^[8] and Kalaiyarasan *et al.*, (2019)^[2].

Potassium uptake by weeds (kg ha⁻¹)

Potassium uptake by weeds showed the most pronounced and economically significant differences among treatments (Table.3). The control (T₈) recorded the maximum potassium uptake by weeds of 29.52 kg ha⁻¹, which was significantly higher than all other treatments by a very wide margin. This was followed by T₄ (22.74 kg ha⁻¹) and T₃ (8.95 kg ha⁻¹). Treatment T₁ (5.56 kg ha⁻¹) recorded a moderate potassium drain, while T₂ (5.24 kg ha⁻¹), T₆ (3.55 kg ha⁻¹), T₅ (2.89 kg ha⁻¹), and the weed-free treatment (T₇: 1.98 kg ha⁻¹) recorded progressively lower potassium uptake by weeds. The nearly 15-fold difference in potassium uptake by weeds between the control and weed-free treatments highlights the critical importance of potassium conservation through effective weed management, particularly in rice fallow conditions where residual soil potassium from the preceding crop may constitute an important nutritional resource

for sunflower. Nagamani (2010) [4] and Kalaiyarasan *et al.* (2019) [2].

Weed nutrient uptake for N, P, and K followed a similar trend, with the unweeded control recording the highest nutrient removal, followed by T₄ and T₃ among the managed treatments. The relatively higher nutrient uptake by weeds under T₄ (pendimethalin + quizalofop-ethyl) suggests incomplete weed suppression, possibly due to limitations in weed control spectrum or herbicide efficacy, resulting in greater weed biomass accumulation. In contrast, mechanical weed management treatments (T₅ and T₆) and the weed-free treatment (T₇) recorded the lowest nutrient removal by weeds, indicating effective suppression of weed growth and improved nutrient availability to the crop. These results highlight the importance of efficient weed management in minimizing nutrient losses and enhancing nutrient-use efficiency in rice-fallow sunflower.

Table 1: Stem girth, Dry-matter accumulation and days to flowering in Rice fallow Sunflower Crop

S. No.	Treatment	Stem girth			Dry matter accumulation (g m ⁻²) of sunflower			Days to 50% flowering
		30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	
01.	Paraquat spray before sowing +one Inter-cultivation at 35 DAS	1.9	3.5	3.8	3.0	52.0	92.9	60.3
02.	Paraquat spray before sowing+pendimethalin@1.0kg.a.i.ha ⁻¹ as pre emergence spray + Quizalofop ethyl10EC (Targa super) @37.5g a.i.ha ⁻¹ at 20 DAS as directed post emergence spray on weeds	1.9	3.8	3.9	3.3	55.9	93.6	56.6
03.	Pendimethalin@1.0kg.a.i.ha ⁻¹ as pre-emergence spray+one intercultivation at 30DAS	1.9	3.5	3.8	2.6	50.7	87.4	61.3
04.	Pendimethalin@1.0kg.a.i.ha ⁻¹ as pre-emergence spray + Quizalofop ethyl10EC (Targa super) @37.5g a.i.ha ⁻¹ at 20 DAS as directed post-emergence spray on weeds	1.8	3.2	3.5	1.9	50.0	85.1	56.6
05.	Two inter-cultivation at 20 & 40 DAS	2.1	3.9	4.3	3.5	60.6	106.5	58.6
06.	one inter-cultivation at 20 DAS and 1 hand weeding at 30-35 DAS	2.0	3.8	4.0	3.3	58.5	100.5	60.0
07.	Weed free	2.2	4.2	4.4	4.2	62.7	112.0	54.3
08.	Control	1.5	3.2	3.5	1.7	41.4	81.6	60.6
	S.Em (±)	0.11	0.20	0.23	0.20	2.92	4.28	3.38
	CD (p=0.05)	0.3	0.6	0.7	0.60	8.85	12.9	10.2

Table 2: Nutrient uptake by the in the rice fallow Sunflower Crop at harvest

Treatments	Nitrogen (kg ha ⁻¹)			Phosphorus (kg ha ⁻¹)			Potassium (kg ha ⁻¹)		
	Seed	Stover	Total	Seed	Stover	Total	Seed	Stover	Total
T ₁	24.81	15.83	40.64	11.13	3.29	14.42	9.70	51.74	61.14
T ₂	26.01	16.95	42.96	11.81	3.43	15.34	10.29	55.51	65.8
T ₃	21.53	13.40	34.93	10.73	2.76	13.49	9.18	50.49	59.67
T ₄	19.71	13.07	32.78	9.14	2.70	11.84	7.94	48.08	56.02
T ₅	28.09	18.39	46.48	15.30	3.74	19.04	12.15	58.81	70.96
T ₆	29.13	19.15	48.28	12.86	3.48	16.34	11.52	55.44	66.96
T ₇	33.84	23.45	57.29	17.57	4.88	22.01	13.32	66.07	79.39
T ₈	11.94	6.65	18.59	6.46	1.96	8.42	5.84	33.49	39.3
	0.261	0.512	2.542	0.431	0.134	0.491	0.516	1.438	1.741
	1.53	1.48	7.46	1.25	0.37	1.44	1.49	4.19	5.11

Table 3: Nutrient content (%) and uptake (kg ha⁻¹) by the weeds in the rice fallow Sunflower Crop

S. No.	Treatment	N (%)	P (%)	K (%)	N (kg ha ⁻¹)	P (kg ha ⁻¹)	K (kg ha ⁻¹)
01.	Paraquat spray before sowing +one Inter-cultivation at 35 DAS	1.35	0.22	1.59	3.61	1.2	5.56
02.	Paraquat spray before sowing pendimethalin 1.0 kg a.i ha ⁻¹ as pre-emergence spray + Quizalofop ethyl 10EC @37.5 g ai ha ⁻¹ at 20 DAS as directed postemergence spray on weeds	1.29	0.20	1.53	2.69	0.96	5.24
03.	Pendimethalin @1.0 kg a.i ha ⁻¹ as pre-emergence spray + one inter-cultivation at 30DAS	1.36	0.23	1.60	5.84	2.22	8.95
04.	pendimethalin 1.0 kg a.i ha ⁻¹ as pre-emergence spray + Quizalofop ethyl 10EC @37.5 g ai ha ⁻¹ at 20 DAS as directed postemergence spray on weeds	1.38	0.26	1.66	18.19	2.66	22.74
05.	Two inter-cultivation at 20 & 40 DAS	1.25	0.19	1.39	1.89	0.36	2.89
06.	1 inter-cultivation at 20 DAS and 1 hand weeding at 30-35 DAS	1.29	0.19	1.42	2.58	0.78	3.55
07.	Weed free	1.19	0.17	1.31	1.53	0.29	1.98
08.	Control	1.46	0.29	1.73	26.5	5.2	29.52
	SEm(±)	0.038	0.012	0.018	0.372	0.134	1.172
	CD (p=0.05)	0.11	0.03	0.05	1.07	0.37	3.44

Conclusion

The present study demonstrated that weed management significantly influences nutrient uptake and nutrient-use efficiency of sunflower under rice-fallow conditions. The weed-free treatment recorded the highest uptake of N, P, and K, followed closely by mechanical weed management practices involving intercultivation and hand weeding. Among the herbicide-based treatments, paraquat + pendimethalin + quizalofop-ethyl proved most effective in enhancing crop nutrient uptake. In contrast, the unweeded control exhibited the lowest nutrient uptake due to substantial nutrient removal by weeds. The results highlight that effective weed management not only minimizes nutrient losses but also improves nutrient availability and utilization by the crop, thereby enhancing productivity. Therefore, weed control should be considered an integral component of nutrient management strategies in rice-fallow sunflower production systems.

Future Scope of Research

Further research should focus on determining the critical weed-free period in rice-fallow sunflower to optimize the timing of weed management interventions and reduce production costs. Evaluation of newer herbicide molecules and integrated weed management strategies involving cultural, mechanical, and biological approaches is required to enhance weed control efficiency and sustainability. Long-term studies assessing the impact of weed management practices on soil nutrient dynamics, nutrient-use efficiency, and crop productivity would provide valuable insights for refining nutrient management recommendations. Additionally, the integration of precision weed management technologies may offer opportunities for improving resource-use efficiency and environmental sustainability in rice-fallow sunflower production systems.

References

1. Anonymous. Edible oil scenario. Department of Food and Public Distribution, Ministry of Consumer Affairs, Food and Public Distribution, Government of India. <https://dfpd.gov.in/edible-oil-scenario/en>
2. Kalaiyarasan C, Vaiyapuri V, Suseendran K, Jawahar S. Response of sunflower to integrated nutrient and weed management practices on weeds, growth, yield, quality and nutrient uptake. *Plant Archives*. 2019;19(1):526-533.
3. Little NG, DiTommaso A, Westbrook AS, Ketterings QM, Mohler CL. Effects of fertility amendments on weed growth and weed-crop competition: a review. *Weed Science*. 2021;69:132-146. doi:10.1017/wsc.2021.1
4. Nagamani C. Effect of planting pattern and weed management practices on sunflower in southern agro-climatic zone of Andhra Pradesh [MSc (Ag) thesis]. Tirupati, Andhra Pradesh, India: Sri Venkateswara Agricultural College, Acharya N.G. Ranga Agricultural University; 2010.
5. Nath CP, Singh RG, Choudhary VK, Datta D, Nandan R, Singh SS. Challenges and alternatives of herbicide-based weed management. *Agronomy*. 2024;14(1):126. doi:10.3390/agronomy14010126
6. Stefanic E, Rasic S, Lucic P, Zimmer D, Mijic A, Antunovic S, *et al.* The critical period of weed control influences sunflower (*Helianthus annuus* L.) yield, yield components but not oil content. *Agronomy*. 2023;13:2008. doi:10.3390/agronomy13082008
7. Sujathamma P, Prabhakar K, Ravikishore M, Visalakshmi V. Integrated weed management (IWM) for sunflower

(*Helianthus annuus* L.) under modified spacing. *Plant Science Today*. 2026;13(Suppl 1):1-7. doi:10.14719/pst.11390

8. Sunil A Satyareddi, Devasenapathy P, Chinnusamy C, Kaleeswari RK, Mynavathi V. Influence of non-chemical weed management practices on nutrient uptake in sunflower and weeds. *Trends in Biosciences*. 2015;8(13):3503-3507.
9. Thambyannan S, Lingam R, Ramasamy S, Ramasamy K, Rajendhiran N, Kaliyannagounder S, *et al.* Sustainable integrated weed control strategies to reduce herbicide use in sunflower production. *Plant Science Today*. 2024;11(4):570-579. doi:10.14719/pst.4833
10. Wanjari RH, Yaduraju NT, Ahuja KN. Nutrient uptake by sunflower and associated weeds during rainy season. *Indian Journal of Agronomy*. 2001;46(3):541-546.