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Weed Management Effects on Yield and Nutrient Uptake in Tomato: A Two-Year Field Study

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

Weed competition is a major constraint to productivity and nutrient acquisition in tomato production, where non-chemical weed-management options are important. A two-year field experiment was conducted during the kharif seasons of 2022-23 and 2023-24 at the AICRP on Weed Management Block, College Farm, Professor Jayashankar Telangana Agricultural University, Rajendranagar, Hyderabad, to evaluate weed-management practices to improve tomato yield and N, P and K acquisition. The experiment used a randomised block design with three replications and nine treatments: live mulch with dhaincha, stale seedbed, polyethene mulch, rice-straw mulch, hoeing, fenugreek intercropping, tamarind-leaf aqueous extract, an unweeded control and a

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metribuzin-based chemical benchmark. Weed-management practices significantly affected fruit yield, nutrient concentration and nutrient uptake in both seasons. The chemical benchmark (T_9) recorded the highest fruit yields, 234.3 and 244.3 q ha^{-1} in 2022 and 2023, respectively. Among the non-chemical treatments, polyethene mulch plus intra-row hand weeding at 30 days after transplanting (DAT) (T_3) recorded 213.4 and 208.2 q ha^{-1}, followed by rice-straw mulch @ 5 t ha^{-1} plus intra-row hand weeding at 30 DAT (T_4), which produced 190.4 and 184.7 q ha^{-1}. T3 also recorded the highest N, P and K uptake among the non-chemical treatments in both seasons, with 40.62, 8.12 and 47.39 kg ha^{-1}, respectively, in 2022 and 40.19, 8.04 and 46.89 kg ha^{-1} in 2023. The results indicated that polyethene mulch combined with timely intra-row hand weeding was the most productive non-chemical treatment. In contrast, rice-straw mulch plus hand weeding provides a residue-based option where suitable residues and labour are locally available.

Keywords: *Solanum lycopersicum; weed management; polyethene mulch; rice-straw mulch; hand weeding; fruit yield; nutrient uptake; low-input production.*

1. Introduction

Weed interference is a major constraint to profitable vegetable production because weeds compete with crops for light, moisture, nutrients and physical space. The challenge is particularly important where herbicide use is restricted and weed control relies on physical, mechanical, cultural and biological methods (Swanton & Vazan, 2022). A recent meta-analysis reported greater weed density and diversity in organic farming systems than in conventional systems and emphasised integrated approaches such as crop rotation, intercropping and mulching to maintain weed pressure at manageable levels (Mwangi *et al*., 2024). Mulching provides a physical barrier to weed emergence and reduces light availability at the soil surface. Organic mulches also return residues to the soil, whereas polyethene mulch can provide effective weed suppression but presents end-of-season collection, recycling and disposal considerations.

Tomato (*Solanum lycopersicum* L.) is an important vegetable crop in India, and weed interference during early crop growth can adversely affect establishment and yield. Field studies have demonstrated beneficial effects of black polyethene and rice-straw mulches on weed suppression and tomato productivity (Kavitha *et al*., 2021; Kumar *et al*., 2021; Patel *et al*., 2021; Agarwal *et al*., 2022).

Recent tomato studies have evaluated mulching and integrated non-chemical approaches for weed management and crop performance (Jeeva et al., 2020). Mulching treatments have been investigated for weed suppression and yield improvement (Rahmani *et al.*, 2021), while Kavitha *et al.* (2023) reported effective weed suppression and higher tomato yield with hand weeding and black polythene mulch among the non-chemical treatments examined. An integrated approach incorporating plastic mulching with soil steaming and winter cover crops also reduced weed populations and improved tomato yield under the study conditions (de Oliveira *et al.*, 2023). Recent work has further examined effects of photo-selective polyethylene mulch on tomato yield and quality (Sifola *et al.*, 2024) and effects of organic versus inorganic mulches on tomato fruit quality attributes (Kumar *et al.*, 2026; Meesala *et al*.,2025).

Within this context, the study addresses a specific gap by comparing several predominantly non-chemical weed-management practices across two seasons and by evaluating fruit yield together with plant N, P and K concentrations and uptake, while using a metribuzin-based treatment only as a chemical benchmark.

Therefore, the present two-year study evaluated live mulch, stale seedbed, polyethene mulch, rice-straw mulch, hoeing, intercropping, botanical extract and a chemical weed-control benchmark. Fruit yield, N, P and K concentrations, and nutrient uptake were used to compare treatment performance.

2. Materials and Methods

2.1 Experimental Site and Design

The field experiment was conducted during the kharif seasons of 2022-23 and 2023-24 at the AICRP on Weed Management Block, College Farm, Professor Jayashankar Telangana Agricultural University, Rajendranagar, Hyderabad, Telangana, India. The soil was sandy loam with pH 7.6, organic carbon 0.76%, bulk density 1.5 g cm^{-3}, available N 255 kg ha^{-1}, available P 18.1 kg ha^{-1} and available K 615 kg ha^{-1}. The experiment was laid out in a randomised block design with three replications. The study included predominantly non-chemical weed-management treatments together with one chemical benchmark (T_9); therefore, the entire treatment set should not be interpreted as a certified organic production system.

List 1. Weed-management treatments

Treatment	Description
T_1	Live mulch with dhaincha and incorporation at 30 DAT
T_2	Stale seedbed followed by hand weeding at 20 and 40 DAT
T_3	Polyethene mulch + intra-row hand weeding at 30 DAT
T_4	Rice-straw mulch @ 5 t ha^{-1} + intra-row hand weeding at 30 DAT
T_5	Hoeing twice at 20 and 40 DAT
T_6	Fenugreek green-leaf-vegetable intercrop + hand weeding at 40 DAT
T_7	Tamarind-leaf aqueous extract @ 10% at 3 and 30 DAT + hand weeding at 40 DAT
T_8	Unweeded control
T_9	Metribuzin 70% WP @ 0.525 kg a.i. ha^{-1} pre-emergence + hand weeding at 40 DAT

2.2 Yield, Plant Analysis and Statistics

Mature fruits were harvested at successive pickings and total fruit weight was recorded until final harvest. Yield was expressed in quintals per hectare (q ha^{-1}). Plant samples collected at harvest were dried, ground and analysed for N, P and K. Nitrogen was determined by the micro-Kjeldahl method, phosphorus by the vanadomolybdophosphoric acid method after tri-acid digestion at 420 nm and potassium by flame photometry according to Piper (1966). Nutrient uptake was calculated from nutrient concentration and the corresponding plant dry matter and expressed in kg ha^{-1}. Data for each season were analysed by analysis of variance for a randomised block design as described by Gomez and Gomez (1984). Standard error of the mean [SE(m)] and critical difference (CD) at the 5% probability level were used for treatment mean comparisons. Because the supplied dataset contained season-wise treatment means and error statistics rather than plot-level observations, we did not re-estimate the treatment × year interaction from the submitted file; consequently, we interpreted seasonal results separately.

3. Results and Discussion

3.1 Fruit Yield

Weed-management treatments significantly influenced fruit yield in both seasons. In 2022, T_9 recorded the highest fruit yield (234.3 q ha^{-1}), followed by T_3 (213.4 q ha^{-1}) and T_4 (190.4 q ha^{-1}). The difference between T_9 and T_3 was 20.9 q ha^{-1}, which was smaller than the CD of 23.7 q ha^{-1}, indicating that the two treatments were statistically at par in the first season. T_2 produced 152.7 q ha^{-1}, while T_1, T_5, T_6 and T_7 produced 112.9, 108.0, 76.0 and 77.7 q ha^{-1}, respectively. T_8 recorded the lowest yield (21.6 q ha^{-1}).

In 2023, T_9 again recorded the highest fruit yield (244.3 q ha^{-1}), followed by T_3 (208.2 q ha^{-1}) and T_4 (184.7 q ha^{-1}). The difference between T_9 and T_3 was 36.1 q ha^{-1}, exceeding the CD of 22.40 q ha^{-1} and indicating a significant advantage of T_9 in the second season. T_3 also significantly exceeded T_4 because the difference between them (23.5 q ha^{-1}) was slightly greater than the CD. T_8 again recorded the lowest yield (24.8 q ha^{-1}).

The superior performance of T_3 is consistent with published tomato studies showing that polyethene mulch can strongly suppress weed density and biomass and improve fruit yield (Kavitha *et al*., 2021; Kumar *et al*., 2021; Patel *et al*., 2021). Agarwal *et al.* (2022) likewise reported substantial weed suppression and improved tomato productivity under black polyethene mulch compared with the unmulched control. The present results therefore support mulch-based weed suppression combined with timely hand weeding as an effective non-chemical approach. Rice-straw mulch plus hand weeding (T_4) was the second-highest non-chemical treatment in both seasons and represents a residue-based option where straw is readily available. Soil moisture, soil temperature and weed biomass were not measured in the present experiment; therefore, these variables are considered possible mechanisms rather than measured explanatory factors.

The very low fruit yield under the unweeded control demonstrates the adverse effect of uncontrolled weed competition. This interpretation is consistent with the established principle that weeds compete with crops for essential resources and can reduce crop productivity (Zimdahl, 2004; Chauhan, 2020). The results also agree with evidence that integrated weed-management practices can improve weed suppression compared with reliance on a single control measure (Bond & Grundy, 2001; Mwangi *et al*., 2024).

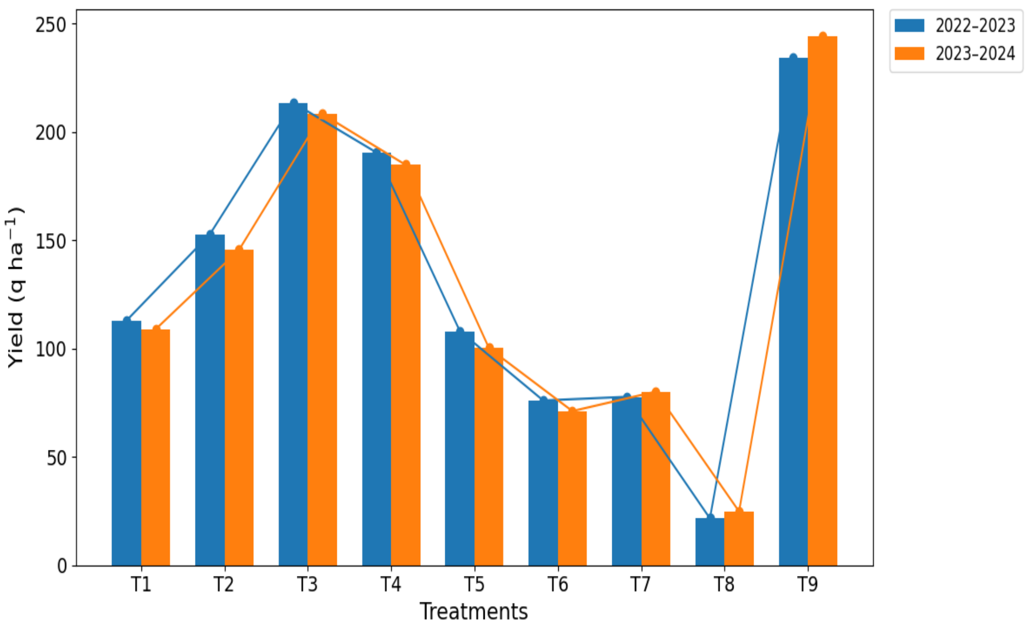

Fig. 1. Graph showing Fruit yield (q ha^{-1}) of tomato as influenced by weed-management practices

Table 1. Fruit yield (q ha^{-1}) of tomato as influenced by weed-management practices

Treatment		Year	
		2022	2023
T_1	Live mulch with *dhaincha* and incorporation at 30 DAT	112.9	108.9
T_2	Stale seedbed *fb* HW at 20 & 40 DAT	152.7	145.5
T_3	Poly mulch + intra row hand weeding (HW) at 30 DAT	213.4	208.2
T_4	Rice straw mulch (5 t ha^{-1}) *fb* intra row HW at 30 DAT	190.4	184.7
T_5	Hoeing twice at 20 & 40 DAT	108.0	100.1
T_6	Intercrop green leaf vegetable *fb* HW at 40 DAT	76.0	71.1
T_7	Tamarind leaf aqueous extract @ 10% at 3 and 30 DAT *fb* HW at 40 DAT	77.7	80.1
T_8	Unweeded control	21.6	24.8
T_9	Chemical weed control - metribuzin 70% WP @ 0.525 kg a.i ha^{-1} PE *fb* HW at 40 DAT	234.3	244.3
SE(m)±		7.9	7.47
CD (p=0.05)		23.7	22.40

3.2 N, P and K Concentration at Harvest

The N, P and K concentrations differed significantly among weed-management treatments in both years (Table 2). In 2022, the highest N (1.00%) and P (0.30%) concentrations were observed in treatment T9, followed closely by T_3, with N (0.99%) and P (0.29%) concentrations. However, the highest K concentration (1.18%) was recorded in T_4, followed by T_2 (1.16%) and T_1 (1.15%). The unweeded treatment (T_8) had the lowest N (0.80%) and P (0.20%) concentrations, while its K concentration was 1.10%. In 2023, T_9 recorded the highest N (0.98%) and P (0.29%) concentrations, followed by T_3 with N (0.97%) and P (0.28%) concentrations. T_3 and T_9 recorded the highest K concentration (1.19%) in 2023.

The relatively higher N and P concentrations under effective weed-management treatments may be associated with reduced crop–weed competition for nutrients, water and other growth resources. Similar improvements in nutrient uptake under effective weed-management treatments have been reported in tomato by Saravanane and Kandasamy (2002). Mulching can further help control weeds and reduce weed biomass, thereby reducing crop–weed competition at crucial stages of crop development (Agarwal *et al.*, 2022; Petrikovszki *et al.*, 2020). Thus, higher nutrient concentrations under T_3 could be due to the combined effect of polyethene mulch along with hand weeding. In addition, rice-straw mulch plus hand weeding (T_4) also helped to maintain higher nutrient concentrations, especially K in 2022. However, this study did not measure nutrient availability in soil, soil moisture or microbial activities; hence, these factors cannot be identified as direct mechanisms underlying the nutrient responses. Overall, effective weed-management treatments improved plant N and P concentrations compared with the unweeded control, whereas K showed greater treatment- and season-dependent variation.

Table 2. N, P and K concentration (%) at harvest in tomato as influenced by weed-management practices

Treatment		2022			2023		
		N	P	K	N	P	K
T_1	Live mulch with *dhaincha* and incorporation at 30 DAT	0.90	0.24	1.15	0.88	0.23	1.14
T_2	Stale seedbed *fb* HW at 20 & 40 DAT	0.93	0.25	1.16	0.91	0.24	1.15
T_3	Poly mulch + intra row hand weeding (HW) at 30 DAT	0.99	0.29	1.12	0.97	0.28	1.19
T_4	Rice straw mulch (5 t ha^{-1}) *fb* intra row HW at 30 DAT	0.96	0.27	1.18	0.95	0.26	1.17
T_5	Hoeing twice at 20 & 40 DAT	0.87	0.23	1.13	0.85	0.22	1.12
T_6	Intercrop green leaf vegetable *fb* HW at 40 DAT	0.88	0.24	1.14	0.86	0.23	1.13
T_7	Tamarind leaf aqueous extract @ 10% at 3 and 30 DAT *fb* HW at 40 DAT	0.84	0.22	1.12	0.82	0.21	1.11
T_8	Unweeded control	0.80	0.2	1.1	0.79	0.2	1.1
T_9	Chemical weed control- metribuzin 70% WP @ 0.525 kg a.i ha^{-1} PE *fb* HW at 40 DAT	1.00	0.3	1.12	0.98	0.29	1.19
SE(m)±		0.01	0.01	0.01	0.01	0.02	0.01
CD (p=0.05)		0.03	0.02	0.03	0.04	0.06	0.04

3.3 N, P and K Uptake at Harvest

Uptake of N, P and K varied significantly among the weed-management treatments in both seasons (Table 3). In 2022, the highest N, P and K uptake was observed in T_9 (42.61, 8.52 and 49.82 kg ha^{-1}), while the second and third highest values were observed in T_3 (40.62, 8.12 and 47.39 kg ha^{-1}) and T_4 (37.98, 7.60 and 43.02 kg ha^{-1}), respectively. In 2023, the highest N, P and K uptake was observed in T_9 (42.12 kg N, 8.42 kg P and 49.28 kg K ha^{-1}), while the second and third highest values were observed in T_3 (40.19, 8.04 and 46.89 kg ha^{-1}) and T_4 (37.50, 7.50 and 42.57 kg ha^{-1}), respectively. Because the differences between T9 and T3 were smaller than the corresponding CD values for N, P and K in both seasons, the two treatments were statistically at par for nutrient uptake. The unweeded control (T_8) recorded lower N, P and K uptake, with values of 30.91, 6.18 and 35.20 kg ha^{-1} in 2022 and 28.16, 5.63 and 32.03 kg ha^{-1} in 2023, respectively. The increased nutrient uptake under T9 and T3 could be attributed mainly to their improved fruit yield. Mulching and enhanced weed control could also limit competition between the crop and weeds and benefit the growth and nutrient uptake of the crop (Petrikovszki *et al.*, 2020; Agarwal *et al.*, 2022). The lower nutrient uptake recorded in the unweeded treatment indicates the adverse effect of weed interference on crop performance; nevertheless, because no measurements were taken for weed biomass and nutrient extraction by weeds, their role cannot be estimated directly.

Table 3. N, P and K uptake at harvest (kg ha^{-1}) in tomato as influenced by weed-management practices

Treatment		2022			2023		
		N	P	K	N	P	K
T_1	Live mulch with *dhaincha* and incorporation at 30 DAT	33.45	6.69	37.91	33.01	6.60	37.41
T_2	Stale seedbed *fb* HW at 20 & 40 DAT	37.75	7.55	44.13	37.00	7.40	43.22
T_3	Poly mulch + intra row hand weeding (HW) at 30 DAT	40.62	8.12	47.39	40.19	8.04	46.89
T_4	Rice straw mulch (5 t ha^{-1}) *fb* intra row HW at 30 DAT	37.98	7.60	43.02	37.50	7.50	42.57
T_5	Hoeing twice at 20 & 40 DAT	32.80	6.56	38.26	30.67	6.13	35.73
T_6	Intercrop green leaf vegetable *fb* HW at 40 DAT	25.46	5.09	28.85	20.92	4.18	23.72
T_7	Tamarind leaf aqueous extract @ 10% at 3 and 30 DAT *fb* HW at 40 DAT	21.78	4.36	25.27	18.89	3.78	21.92
T_8	Unweeded control	30.91	6.18	35.20	28.16	5.63	32.03
T_9	Chemical weed control- metribuzin 70% WP @ 0.525 kg a.i ha^{-1} PE *fb* HW at 40 DAT	42.61	8.52	49.82	42.12	8.42	49.28
SE(m)±		1.96	0.39	2.27	2.05	0.41	2.18
CD (p=0.05)		5.86	1.17	6.79	6.14	1.23	6.53

3.4 Integrated Interpretation

Across both seasons, T_3 was the most consistent non-chemical treatment for fruit yield and nutrient uptake, followed by T_4 among the mulch-based treatments. T_2 also performed comparatively well. T9 recorded the highest values overall for yield and nutrient uptake, but it should be interpreted strictly as a conventional chemical benchmark rather than an organic recommendation because it included metribuzin. Polyethene mulch should likewise not be labelled universally eco-friendly: its agronomic advantage in weed suppression and yield must be considered alongside end-of-season collection, recycling and disposal requirements. Rice-straw mulch therefore represents a relevant residue-based option for low-input or organic systems where suitable residues are available and hand-weeding labour is feasible. Because plot-level data required for a formal treatment × year interaction analysis were not available, the two seasons were interpreted separately.

4. Conclusion

In this two-year field study, weed-management treatments substantially influenced tomato yield and plant N, P and K nutrition. The metribuzin-based treatment (T_9) produced the highest fruit yield and nutrient uptake overall, but it served only as a conventional chemical benchmark and should not be considered an organic-management recommendation. Among the non-chemical practices, polyethene mulch combined with intra-row hand weeding at 30 DAT (T_3) consistently produced the highest fruit yield and nutrient uptake, followed by rice-straw mulch @ 5 t ha^{-1} plus intra-row hand weeding (T_4). T3 was the most productive non-chemical treatment, whereas T4 provides a residue-based option for low-input and organically oriented tomato production. The unweeded control resulted in the lowest fruit yield in both seasons. Thus, T_3 was the most productive non-chemical treatment, whereas T_4 provides a residue-based option for low-input and organically oriented tomato production where suitable crop residues are available.

5. Limitation

The study was conducted at one field location over two kharif seasons. Weed biomass, soil moisture, soil temperature, soil nutrient availability and microbial activity were not measured, so these factors cannot be identified as direct mechanisms underlying treatment responses. In addition, only season-wise treatment means and error statistics were available; plot-level observations required for a formal treatment × year interaction analysis were not available. Accordingly, treatment effects were interpreted separately for each season.

Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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