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Two-Year Evaluation of Ecofriendly Weed Management Practices and their Influence on Soil Chemical Properties and Yield in Organic Tomato

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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

A two-year field experiment (2022-2024), conducted under an RBD with nine treatments, evaluated eco-friendly weed management practices at PJTAU Rajendranagar, Hyderabad. The study assessed their effects on soil properties, apart from weed suppression, and crop yield. The soil pH (7.54–8.13 in 2022–2023 and 7.77–8.16 in 2023–2024) and electrical conductivity (0.58–0.63 dS

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m^{-1}) remained statistically unaffected across treatments, indicating stable soil reaction and salinity under organic management. However, cation exchange capacity (CEC) showed significant variation, with rice straw mulch and hoeing treatments recording the highest values. Yield data revealed that among organic-compatible options, poly mulch with intra-row hand weeding (21.34 and 18.07 t ha^{-1}) and rice straw mulch with hand weeding (19.04 and 16.57 t ha^{-1}) were most effective, while the unweeded control resulted in the lowest yields (2.17 and 2.48 t ha^{-1}). The findings highlight the potential of mulching-based weed management as a sustainable alternative to chemical herbicides, contributing to soil health maintenance and enhanced productivity in organic tomato.

Keywords: pH; EC; CEC; organic farming; weed management.

1. INTRODUCTION

Organic agriculture has been seen as a potential solution to nutrient losses because of the aims of recycling and the restriction of nutrient imports to livestock and fields (Halberg, 2012). Recent studies emphasise the importance of weed management in sustaining soil quality and yield in organic vegetable systems. Organic farming systems are recommended to improve soil health and fruit quality, but they may not be the best choice for farmers whose main short-term objective is reaching a higher yield (Khasawneh and Othman, 2020). Soil organic matter is linked with other aspects of soil quality, such as nutrient retention and crop nutrient supply, water infiltration and water-holding capacity and soil tilth. Organic soils have been found to have higher levels of microbiological activity and/or diversity (Reganold et al. 2010).

Tomato is a vital vegetable crop in India, cultivated over 8.73 lakh hectares with an annual production of 212.4 lakh tonnes. Despite the increasing adoption of organic tomato cultivation, limited studies have simultaneously evaluated mulching-based ecological weed management and its multi-year impacts on soil chemical properties in semi-arid India. There is a growing demand for organically grown vegetables and the challenges of weed management in organic systems. So, to overcome the issue a two-year field study (2022-2023 and 2023-2024) was conducted at PJTAU, Rajendranagar, Hyderabad, to evaluate eco-friendly weed management practices in organic tomato cultivation.

2. MATERIALS AND METHODS

A field experiment was conducted during *kharif,* 2022-2023 and 2023-2024 at AICRP on the weed management block, college farm, PJTAU, Rajendranagar, Hyderabad. The experiment followed a randomized block design with three replications, and treatment effects were assessed using ANOVA at the 5% significance level. The soil of the experimental site was sandy loam in texture with a pH of 7.6, organic carbon 0.76%, bulk density 1.5 g/m^3, available nitrogen 255 kg/ha, available phosphorus 18.1 kg/ha and available potassium 615 kg/ha. The treatments comprised of “T_1-Live mulch with *dhiancha* and incorporation at 30 DAT, T_2- Stale seed bed *fb* HW at 20 & 40 DAT, T_3- Polymulch+intrarow hand weeding (HW) at 30 DAT, T_4- Rice straw mulch 5 t/ha *fb* intra-row HW at 30 DAT, T_5- Hoeing twice at 20&40 DAT, T_6- Intercrop (Fenugreek) green leaf vegetable *fb* HW at 40 DAT, T_7- Tamarind leaf aqueous extract @10 % at 3 and 30 DAT followed by hand weeding at 40 DAT, T_8-Unweeded control, T_9- Chemical weed control- Metribuzin70%WP@ 0.525 kg a.i./ha *fb* HW at 40 DAT (outside the layout). Data were analysed using ANOVA in R-software (version 4.2) following Gomez and Gomez (1984). Normality was checked using Shapiro–Wilk test, and percentage data were arcsine transformed when required.

2.1 Collection and Preparation of Soil Sample

Composite soil samples were collected randomly with the help of a soil auger before sowing and after harvesting of crop from each plot. The samples were mixed thoroughly and dried in air, crushed, and sieved through a 2 mm sieve. The samples of soil were prepared and analysed for fertility status.

2.2 Soil Reaction (pH)

Soil pH was determined by using a digital pH meter described by Jackson (1973). In a 50 ml beaker, 1 g of soil sample was taken and to that, 25 ml of distilled water was added in a ratio of 1: 2.5 soil to water suspension after stirring the samples intermittently for half an hour using a pH meter and readings were noted down. Suja et al. (2017) reported that soil pH increased by 1.2 units under organic management.

2.3 Electrical Conductivity (EC)

The electrical conductivity of the soil was determined in the supernatant of a 1:2.5 soil water suspension that was used for the pH determined by using a Systronics direct digital conductivity meter-304 (Jackson, 1973).

2.4 Cation Exchange Capacity (CEC)

Ten grams of soil was leached several times with neutral normal ammonium acetate solution, followed by washing with alcohol to remove excess electrolyte. The adsorbed ammonium ions were replaced by potassium ions by leaching the soil with a 10 percent potassium chloride solution. Finally, in the leachate of KCl, ammonia was determined by the distillation method as described by Page et al. (1982).

2.5 Yield Per Hectare (t ha^{-1})

The obtained yield of individual treatment was used to compute per hectare and expressed in tonnes. The total weight of matured fruits harvested from each picking in the respective treatments was recorded until the final harvest. The total yield of fruits per hectare under different treatments was computed.

2.6 Statistical Analysis

The data collected from the experiment were analysed statistically by analysis of variance method for a randomised block design (Gomez and Gomez, 1984). Whenever the treatment differences were found significant (F test), critical differences were worked out at a five per cent probability level. Treatment differences that were non-significant were denoted by NS. If the difference between two treatments was more than the critical difference, the value was indicated for comparison by treatment means.

3. RESULTS AND DISCUSSION

3.1 Soil pH

Soil pH during 2022–2023 ranged from 7.54 to 8.13, while in 2023–2024 it varied between 1.77 and 1.86 (Table 1). The lowest pH in 2022–2023 was recorded under chemical weed control with metribuzin 70% WP @ 0.525 kg a.i ha^{-1} PE fb HW at 40 DAT (T_9), which registered 7.54, indicating a slight acidifying effect compared to other treatments. Organic treatments such as rice straw mulch (T_4)**,** poly mulch + intra-row HW (T_3)**,** and live mulch with d*haincha* incorporation (T_1) maintained higher pH values (7.85–8.13), suggesting minimal alteration in soil reaction. However, the differences in pH across treatments were statistically non-significant. Nagar et al. (2016) reported lower pH and electrical conductivity in legume based intercropping systems of pigeon pea-black gram and pigeon pea-green gram. Stable pH values indicate low acidification potential and limited decomposition-driven proton release under organic mulching (Zhang et al., 2024)."

3.2 Electrical Conductivity (EC)

Electrical conductivity (EC) values were relatively stable across treatments, ranging from 0.59 to 0.62 dS m^{-1} in 2022-2023 and 0.58 to 0.63 dS m^{-1} in 2023–2024 (Table.1). Organic treatments such as tamarind leaf aqueous extract (T_7)**,** poly mulch (T_3)**,** and live mulch (T_1) recorded slightly higher EC values, reflecting possible gradual mineralisation of organic matter. The slight EC increase under organic residues aligns with gradual release of soluble ions through mineralization (Hussain et al., 2023). However, EC remained within safe limits (<0.8 dS m^{-1}), indicating no salinity risk. However, EC differences among treatments were non-significant. Organic and low-input farming practices after 4 years led to an increase in the organic carbon, soluble phosphorus, exchangeable potassium, pH, enhanced reserve pool of stored nutrients, nutrient/water use efficiency and maintained relativity stable EC level (Clark et al. 1998; Gaur, 2002).

3.3 Cation Exchange Capacity (CEC)

CEC exhibited significant variation among treatments in both years, suggesting that weed-management- induced changes in organic matter input played a critical role in shaping soil exchange properties. In 2022–2023, the highest CEC was recorded in rice straw mulch (T_4) (33.67 meq 100 g^{-1}), closely followed by live mulch with *dhaincha* incorporation (T_1) (32.62 meq 100 g^{-1}) (Table.1). In 2023–2024, the maximum CEC was observed in hoeing twice (T_5) (35.51 meq 100 g^{-1}) and chemical weed control (T_9) (34.40 meq 100 g^{-1}). Among organic

Table 1. Soil chemical properties as influenced by ecofriendly weed management practices in organic tomato

Tr. No	Treatment	pH		EC (dS m^{-1})		CEC (meq 100 g^{-1})	
		2022-2023	2023-2024	2022-2023	2022-2023	2022-2023	2022-2023
T_1	Live mulch with *dhiancha* and incorporation at 30 DAT	7.85	1.83	0.61	0.58	32.62	17.47
T_2	Stale seedbed *fb* HW at 20 & 40 DAT	7.86	1.77	0.59	0.59	25.44	30.07
T_3	Poly mulch + intra row hand weeding (HW) at 30 DAT	7.95	1.83	0.61	0.61	24.80	26.83
T_4	Rice straw mulch (5 t ha^{-1}) *fb* intra row HW at 30 DAT	8.13	1.80	0.60	0.59	33.67	23.14
T_5	Hoeing twice at 20 & 40 DAT	8.05	1.86	0.62	0.61	21.94	35.51
T_6	Intercrop green leaf vegetable *fb* HW at 40 DAT	7.96	1.83	0.61	0.60	28.51	26.15
T_7	Tamarind leaf aqueous extract @ 10% at 3 and 30 DAT *fb* HW at 40 DAT	7.9	1.83	0.61	0.63	20.84	25.78
T_8	Unweeded control	7.83	1.77	0.59	0.58	24.45	21.98
T_9	Chemical weed control-metribuzin 70% WP @ 0.525 kg a.i ha^{-1} PE *fb* HW at 40 DAT	7.54	1.80	0.60	0.61	19.41	34.40
SE(m)±		**NS**	**NS**	**NS**	**NS**	**0.68**	**0.48**
C.D. (P=0.05)		**NS**	**NS**	**NS**	**NS**	**2.04**	**1.45**

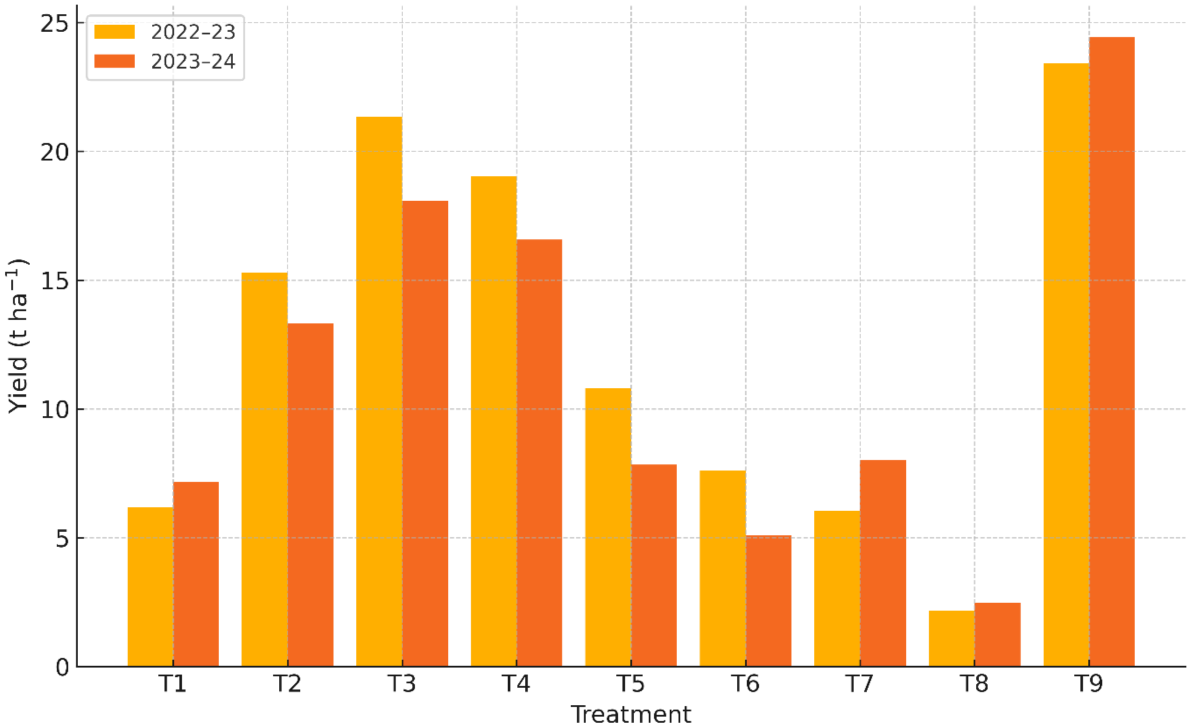

Fig. 1. Tomato Yield as influenced by eco-friendly weed management practices under organic cultivation

treatments, stale seedbed fb HW (T_2) (30.07 meq 100 g^{-1}) and poly mulch (T_3) (26.83 meq 100 g^{-1}) maintained relatively high CEC values, comparable to chemical treatment. The lowest CEC in 2022–2023 was observed in chemical weed control (T_9) (19.41 meq 100 g^{-1}) and in 2023–2024 in live mulch with *dhaincha* incorporation (T_1) (17.47 meq 100 g^{-1}). Higher CEC in mulched treatments is attributable to increased surface-negative charges as organic matter decomposes (Srinivasarao et al., 2023), enhancing nutrient retention. The increase in CEC is due to the increase in organic matter content in those treatments. Sihi et al. (2017) reported that long-term incorporation of FYM, neem cake and green manuring resulted in higher cation exchange capacity (CEC) in soil under organic management.

3.4 Yield

The results of the study clearly indicated that ecofriendly weed management practices had a significant influence on the yield of organic tomato during both the 2022-2023 and 2023-2024 growing seasons (Fig. 1). Among all treatments, the highest yield was recorded with chemical weed control using metribuzin 70% WP @ 0.525 kg a.i ha^{-1} PE followed by hand weeding at 40 DAT (T_9), which produced 23.43 t/ha and 24.43 t/ha, respectively. However, among the organic-compatible approaches, poly mulch combined with intra-row hand weeding (T_3) resulted in the highest yields of 21.34 t/ha in 2022–2023 and 18.07 t/ha in 2023–2024, followed closely by rice straw mulch at 5 t/ha followed by intra-row hand weeding (T_4), which yielded 19.04 t/ha and 16.57 t/ha, respectively. The stale seedbed followed by hand weeding at 20 and 40 DAT (T_2) also showed promising results with yields of 15.28 t/ha and 13.33 t/ha, indicating its effectiveness as a sustainable weed management strategy. Lower yields were observed in treatments involving live mulch with *dhaincha* (T_1), intercropping with leafy vegetables (T_6), and tamarind leaf extract application (T_7), while the unweeded control (T_8) exhibited the lowest yields at 2.17 t/ha and 2.48 t/ha, emphasizing the negative impact of weed competition. The results underline the effectiveness of organic mulching techniques, particularly poly and straw mulch, as eco-friendly alternatives to chemical weed control in organic tomato production. Kavitha et al. (2023) also reported that in tomato, significantly higher plant height, no. of branches and higher fruit yield per plant and fruit yield were recorded with hand weeding twice at 15 and 30 DAT followed application of black polythene mulch and mechanical weeding at 15 and 30 DAT, followed by the treatments with organic mulches. In another study on tomato crop, mulching resulted in a significant increase in total yield, *i.e.,* 27.9%, 25.6%, and 11.6% respectively in PM (pine needle mulch), RM (rice straw mulch) and WM (wheat straw mulch) as compared to NM (no mulch) (Goel et al., 2020). Mulching enhances tomato yield by conserving moisture, moderating soil temperature and reducing weed competition (Kumar et al., 2023; Goel et al., 2020).

4. CONCLUSION

The study demonstrated that weed management practices influenced soil properties and tomato productivity under organic cultivation. Soil pH and electrical conductivity remained largely unaffected by treatments, indicating stability in soil reaction and salinity. However, cation exchange capacity varied significantly, with mulching and hoeing practices contributing to higher CEC through improved organic matter dynamics. Yield performance revealed that while chemical weed control with metribuzin achieved the highest productivity, organic-compatible strategies such as poly mulch with intra-row hand weeding and rice straw mulch, followed by hand weeding, offered competitive yields, significantly outperforming the un-weeded control. Although chemical control recorded the highest yields, organic mulching strategies offer economically viable and sustainable alternatives for smallholder systems, particularly where input restrictions apply. These findings indicate that mulching-based strategies represent viable and environmentally sustainable alternatives to chemical herbicides, particularly for organic production systems that prioritise long-term soil health over chemical herbicides, ensuring sustainable weed management and enhanced tomato productivity in organic systems.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this 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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