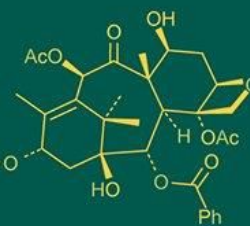


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Meesala Srija
AICRP on Weed Management
Unit, Hyderabad, Telangana,
India

B Padmaja
AICRP on Weed Management
Unit, Hyderabad, Telangana,
India

M Malla Reddy
Controller of Examinations,
Rajendranagar, Hyderabad,
Telangana, India

T Ram Prakash
Principle Scientist, RARS,
Palem, Telangana, India

M Venkateshwara Reddy
College of Agriculture,
Professor Jayashankar
Telangana Agricultural
University (PJTUAU),
Hyderabad, Telangana, India

Corresponding Author:
Meesala Srija
AICRP on Weed Management
Unit, Hyderabad, Telangana,
India

Influence of eco-friendly weed management practices on soil chemical health and productivity of organic beetroot

Meesala Srija, B Padmaja, M Malla Reddy, T Ram Prakash and M Venkateshwara Reddy

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Abstract

A field experiment was conducted during *rabi* seasons of 2022-2023 and 2023-2024 at PJTSAU, Hyderabad, to assess the effect of eco-friendly weed management practices on soil chemical properties and root yield of beetroot (*Beta vulgaris* L.) under an organic tomato-beetroot-watermelon cropping system. The experiment was laid out in a randomized block design with nine treatments comprising organic mulches, intercropping, mechanical and botanical weed management practices, chemical weed control, and an unweeded control. Soil chemical properties such as pH, electrical conductivity (EC), and cation exchange capacity (CEC) were evaluated at harvest, along with beetroot root yield. Soil pH remained slightly alkaline (7.45-7.90) and was not significantly influenced by weed management practices during both years. Electrical conductivity varied significantly among treatments, with relatively higher values observed under organic mulch treatments, particularly groundnut shell mulch, though all values remained within safe, non-saline limits. Cation exchange capacity was significantly improved under rice straw mulch at 5 t ha⁻¹ followed by intra-row hand weeding, indicating enhanced soil nutrient retention and chemical health. Beetroot root yield was significantly influenced by weed management practices, with poly mulch combined with intra-row hand weeding recording the highest yields (24.11 and 25.99 t ha⁻¹ during 2022-2023 and 2023-2024, respectively), which were statistically comparable to rice straw mulch with hand weeding and chemical weed control. Unweeded control resulted in severe yield losses in both years. The study concludes that eco-friendly weed management practices integrating organic mulching with timely hand weeding effectively improve soil chemical properties and beetroot productivity, offering a sustainable alternative to chemical weed control in organic farming systems.

Keywords: pH, EC, CEC, organic farming, weed management

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) [6]. Organic farming systems are recommended to improve soil health and fruit quality, but it may not be the best choice for farmers whose main short-term objective is reaching a higher yield (Khasawneh and Othman, 2020) [1]. 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 and organic soils have been found to have higher levels of microbiological activity and/or diversity (Reganold *et al.* 2010) [11].

A nutritional powerhouse, beetroot (*Beta vulgaris* L.) is high in fiber, manganese, potassium, iron, folate (vitamin B9), and vitamin C (Kumar *et al.*, 2022; Adaora *et al.*, 2022) [8, 3]. Beetroot, which contains flavonoids, phenolic acids including gallic, syringic, and caffeic acids, and betalain pigment. Its antioxidant and anti-inflammatory properties scavenge free radicals from cells, preventing cancer by preventing the growth of tumor cells, lowering the risk of cardiovascular disease, and removing kidney stones. In addition to vitamins like biotin, niacin, and folate, beetroot is regarded as an excellent source of minerals including iron, calcium, phosphorus, potassium, salt, and zinc (Abdo *et al.*, 2020) [12].

Materials and Methods

A field experiment entitled “Assessment of ecofriendly weed management practices in organic beetroot” was conducted during *rabi*, season of 2022-2023 and 2023-2024 at AICRP on weed management block, college farm, PJTSAU, Rajendranagar, Hyderabad. The experiment was laid out in a randomised block design with three replications. 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/m³, available nitrogen 255 kg/ha, available phosphorus 18.1 kg/ha and available potassium 615 kg/ha. The treatments comprised of “Groundnut shell mulch 5 t ha⁻¹, T₂-Rice husk mulch 3 t ha⁻¹, T₃-Poly mulch + intra row hand weeding (HW) at 30 DAS, T₄-Rice straw mulch 5 t ha⁻¹ fb intra row HW at 30 DAS, T₅-Hoeing twice at 15 & 30 DAS, T₆-Intercrop (Fenugreek) green leaf vegetable fb HW at 30 DAS, T₇-Tamarind leaf aqueous extract @ 10% at 3 and 20 DAT fb HW at 30 DAS, T₈-Unweeded control, T₉-Chemical weed control-pendimethalin 30% EC @ 1.0 kg a.i ha⁻¹ fb HW at 30 DAS (outside the layout).

Collection and Preparation of Soil Sample

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

Soil reaction (pH)

Soil pH was determined by using digital pH meter described by Jackson, 1973 [7]. In 50 ml beaker 1 g of soil sample was taken and to that 25 ml of distilled water was added in 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) [13] reported that soil pH increased by 1.2 unit under organic management.

Electrical conductivity (EC)

The electrical conductivity of the soil was determined in the supernatant of 1:2.5 soil water suspension that was used for the pH determined by using Systronics direct digital conductivity meter-304 (Jackson, 1973) [7].

Cation Exchange Capacity

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

Root yield (t/ha)

Roots which attained good size, colour and maturity were harvested manually. Roots collected from each plot in each replication were weighed and yield was represented in kg per plot. The yield per plot was multiplied with a factor to get assessed yield per hectare and expressed in tonnes per hectare.

Statistical analysis

The data collected from the experiment were analyzed statistically by analysis of variance method for randomised block design (Gomez and Gomez, 1984) [5]. Whenever the treatment differences were found significant (F test), critical differences were worked out at five percent probability level. Treatment differences that were non-significant were denoted by NS. If the difference between two treatments was more than critical difference, the value was indicated for comparison by treatment means.

Results and Discussion

The soil chemical properties of organic beetroot, namely soil pH, electrical conductivity (EC) and cation exchange capacity (CEC), as influenced by different ecofriendly weed management practices during 2022-2023 and 2023-2024 are presented in Table 1.

pH

Soil pH ranged from 7.47 to 7.90 during 2022-2023 and 7.45 to 7.80 during 2023-2024, indicating a slightly alkaline soil reaction under all treatments. Statistical analysis revealed that the differences in soil pH among treatments were non-significant in both years, suggesting that ecofriendly weed management practices had no marked effect on soil reaction within the short duration of the crop. However, relatively higher pH values were observed under rice straw mulch at 5 t ha⁻¹ followed by intra-row hand weeding (T₄) and hoeing twice at 15 and 30 DAS (T₅), whereas comparatively lower pH values were recorded under poly mulch combined with hand weeding (T₃) and rice husk mulch (T₂). The marginal variations in soil pH may be attributed to the buffering capacity of the soil and the slow decomposition of organic residues, which did not drastically alter soil reaction (Wang *et al.*, 2011) [14] and (Yordanova and Gerasimova, 2016) [15].

EC (dSm⁻¹)

Electrical conductivity of soil varied significantly among treatments and ranged from 0.49 to 0.76 dS m⁻¹ in 2022-2023 and 0.47 to 0.75 dS m⁻¹ in 2023-2024. The highest EC values were recorded under groundnut shell mulch at 5 t ha⁻¹ (T₁), while the lowest EC was observed in chemical weed control (T₉) and intercrop green leaf vegetable followed by hand weeding (T₆). The increase in EC under organic mulch treatments could be due to the release of soluble salts and nutrients during decomposition of organic residues, whereas lower EC under chemical and intercrop-based treatments may be attributed to minimal addition of soluble organic compounds. However, the EC values under all treatments remained within safe limits, indicating no risk of salinity development (Six *et al.*, 2022) [12]; (Yordanova and Gerasimova, 2016) [15].

CEC

Cation exchange capacity was significantly influenced by weed management practices during both years of study. Among the treatments, rice straw mulch at 5 t ha⁻¹ followed by intra-row hand weeding (T₄) recorded the highest CEC values of 41.35 and 40.30 cmol (P⁺) kg⁻¹, which were significantly superior to most other treatments. This was followed by intercropping with green leafy vegetable followed by hand weeding (T₆) and chemical weed control

(T₉), similar results were found with Bhattacharyya *et al.*, (2008) [4].

The lowest CEC was observed under unweeded control (T₈) and hoeing twice at 15 and 30 DAS (T₅), indicating poorer soil nutrient retention capacity in the absence of organic residue addition. The enhancement of CEC under organic mulching and intercropping treatments may be attributed to increased soil organic matter content, improved humus formation, and greater availability of negatively charged colloidal surfaces. These factors collectively enhance nutrient holding capacity and soil fertility (Yordanova and Gerasimova, 2016) [15].

Improved CEC under ecofriendly weed management practices reflects better soil chemical health and nutrient buffering capacity, which is essential for sustained productivity in organic farming systems. These findings are in agreement with earlier studies, which reported significant improvement in CEC with the application of organic mulches and crop residues.

Overall, the results indicate that ecofriendly weed management practices involving organic residues and botanical extracts improved soil EC and CEC without adversely affecting soil pH. Among the treatments, organic mulches and botanical-based weed management practices were particularly effective in enhancing soil cation exchange capacity, thereby improving nutrient retention and soil fertility under organic beetroot cultivation Majhi *et al.* (2024) [9].

Root yield (t/ha)

Root yield of beetroot was significantly influenced by different eco-friendly weed management practices during both 2022-2023 and 2023-2024 under the organic tomato-beetroot-watermelon cropping system (Table .2).

During 2022-2023, root yield varied widely among treatments, ranging from 0.39 to 24.11 t ha⁻¹. The highest tuber yield was recorded under poly mulch + intra-row hand weeding at 30 DAS (T₃) (24.11 t ha⁻¹), which was statistically on par with rice straw mulch @ 5 t ha⁻¹ followed by intra-row hand weeding at 30 DAS (T₄) (23.59 t ha⁻¹) and chemical weed control with pendimethalin followed by hand weeding at 30 DAS (T₉) (22.40 t ha⁻¹). These treatments produced significantly higher yields compared to all other weed management practices. The enhanced yield under these treatments can be attributed to effective weed suppression during the critical crop-weed competition period, resulting in improved availability of nutrients, moisture and light to the crop.

Moderate root yields were recorded under groundnut shell mulch @ 5 t ha⁻¹ (T₁) (16.95 t ha⁻¹), hoeing twice at 15 and 30 DAS (T₅) (13.88 t ha⁻¹) and intercropping with green leaf vegetable followed by hand weeding at 30 DAS (T₆) (13.00 t ha⁻¹). These treatments, though effective in reducing weed pressure to some extent, were inferior to mulching combined with hand weeding and chemical weed control. Lower yields in these treatments may be due to comparatively less effective weed suppression and higher competition during early crop growth stages.

The lowest root yield during 2022-2023 was recorded in tamarind leaf aqueous extract @ 10% applied at 3 and 20 DAT followed by hand weeding at 30 DAS (T₇) (3.20 t ha⁻¹) and unweeded control (T₈) (0.39 t ha⁻¹). Severe yield reduction in the unweeded control highlights the detrimental effect of uncontrolled weed growth, leading to intense competition for resources and poor tuber development.

During 2023-2024, a similar trend was observed, with root yield ranging from 0.56 to 25.99 t ha⁻¹. Poly mulch + intra-row hand weeding (T₃) again recorded the highest tuber yield (25.99 t ha⁻¹), which was statistically comparable with T₄ and T₉, both recording 24.56 t ha⁻¹. The consistency of these treatments across years indicates their reliability and effectiveness under varying seasonal conditions.

Treatments such as groundnut shell mulch (T₁) (18.51 t ha⁻¹) and intercropping with green leaf vegetable *fb* hand weeding (T₆) (14.23 t ha⁻¹) recorded moderate yields, while hoeing twice (T₅) showed comparatively lower yield (8.06 t ha⁻¹), possibly due to regrowth of weeds between hoeing operations. The tamarind leaf aqueous extract treatment (T₇) recorded a low root yield (4.21 t ha⁻¹), indicating limited efficacy of botanical extract alone in suppressing weeds throughout the crop growth period.

The unweeded control (T₈) consistently recorded the lowest tuber yield in both years (0.39 and 0.56 t ha⁻¹), reflecting severe yield losses due to unchecked weed competition.

Overall, the results clearly demonstrate that eco-friendly weed management practices involving mulching combined with timely hand weeding significantly enhanced root yield of beetroot and were comparable to chemical weed control. The superiority of these treatments may be attributed to effective weed suppression, improved soil moisture conservation, enhanced nutrient availability and better partitioning of photosynthates towards tuber formation, resulting in higher and more stable yields across seasons. The results are accordance with Majhi *et al.* (2024) [9] and Yordanova and Gerasimova (2016) [15].

Table 1: Soil chemical properties in organic beetroot as influenced by ecofriendly weed management practices

Treatment	pH		EC (dS m ⁻¹)		CEC (cmol (P ⁺) kg ⁻¹)	
	2022-23	2023-24	2022-23	2022-23	2022-23	2022-23
T ₁ Groundnut shell mulch 5 t ha ⁻¹	7.63	7.56	0.76	0.75	34.58	39.65
T ₂ Rice husk mulch 3 t ha ⁻¹	7.55	7.45	0.73	0.74	32.96	33.75
T ₃ Poly mulch + intra row hand weeding (HW) at 30 DAS	7.47	7.6	0.74	0.74	35.08	36.03
T ₄ Rice straw mulch 5 t ha ⁻¹ <i>fb</i> intra row HW at 30 DAS	7.90	7.53	0.62	0.58	41.35	40.30
T ₅ Hoeing twice at 15 & 30 DAS	7.82	7.69	0.65	0.54	31.15	29.81
T ₆ Intercrop green leaf vegetable <i>fb</i> HW at 30 DAS	7.74	7.8	0.57	0.5	37.35	39.17
T ₇ Tamarind leaf aqueous extract @ 10% at 3 and 20 DAT <i>fb</i> HW at 30 DAS	7.79	7.78	0.58	0.47	34.55	32.67
T ₈ Unweeded control	7.79	7.73	0.53	0.5	29.67	25.00
T ₉ Chemical weed control-pendimethalin 30% EC @ 1.0 kg a.i ha ⁻¹ <i>fb</i> HW at 30 DAS	7.63	7.64	0.49	0.56	37.82	36.98
SE(m)±	0.22	0.09	0.01	0.01	1.72	1.30
CD (p = 0.05)	NS	NS	0.03	0.03	5.14	3.89

Table 2: Beetroot Yield as influenced by ecofriendly weed management practices under organic cultivation

Treatment		Yield (t/ha)	
		2022-2023	2023-2024
T ₁	Groundnut shell mulch 5 t ha ⁻¹	16.95	18.51
T ₂	Rice husk mulch 3 t ha ⁻¹	6.50	8.06
T ₃	Poly mulch + intra row hand weeding (HW) at 30 DAS	24.11	25.99
T ₄	Rice straw mulch 5 t ha ⁻¹ /b intra row HW at 30 DAS	23.59	24.56
T ₅	Hoeing twice at 15 & 30 DAS	13.88	8.06
T ₆	Intercrop green leaf vegetable /b HW at 30 DAS	13.00	14.23
T ₇	Tamarind leaf aqueous extract @ 10% at 3 and 20 DAT /b HW at 30 DAS	3.20	4.21
T ₈	Unweeded control	0.39	0.56
T ₉	Chemical weed control-pendimethalin 30% EC @ 1.0 kg a.i ha ⁻¹ /b HW at 30 DAS	22.40	24.56
SE(m)±		0.97	0.91
CD (p = 0.05)		2.90	2.72

Conclusion

The present study clearly demonstrated that eco-friendly weed management practices significantly influenced soil chemical properties and root yield of beetroot under an organic tomato-beetroot-watermelon cropping system. Soil pH remained relatively stable and slightly alkaline across treatments, indicating that short-term adoption of organic weed management practices does not adversely affect soil reaction. Electrical conductivity showed significant variation among treatments, with higher values under organic mulches due to gradual nutrient release during residue decomposition, although all values remained within non-saline limits. Cation exchange capacity was markedly improved under treatments involving organic mulching and intercropping, particularly rice straw mulch at 5 t ha⁻¹ followed by intra-row hand weeding, reflecting enhanced soil organic matter status and improved nutrient buffering capacity.

Root yield of beetroot was highly responsive to weed management practices, with poly mulch combined with intra-row hand weeding consistently producing the highest yields across both seasons and performing on par with chemical weed control. Organic mulches and intercropping systems also resulted in moderate yields, whereas botanical extract alone and unweeded control proved ineffective due to poor weed suppression. The findings highlight that integration of organic mulches with timely hand weeding effectively suppresses weeds, improves soil chemical health, and enhances crop productivity. Therefore, such eco-friendly weed management practices can be recommended as viable and sustainable alternatives to chemical weed control for organic beetroot cultivation.

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