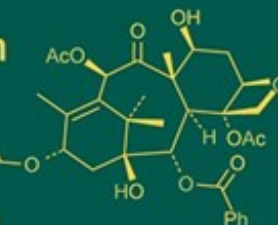
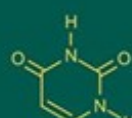


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Eco-friendly weed management for enhancing fruit yield and soil chemical properties of watermelon

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ABSTRACT

Weed competition is a major constraint to watermelon productivity, particularly where synthetic herbicides are restricted and cultural weed-management practices are emphasized. A field experiment was conducted during 2022–23 and 2023–24 at the AICRP on Weed Management Block, College Farm, Professor Jayashankar Telangana Agricultural University, Rajendranagar, Hyderabad, Telangana, India, to evaluate eco-friendly weed-management practices for improving fruit yield and selected soil chemical properties of watermelon. The experiment was laid out in a randomized block design with three replications on sandy-loam soil. Nine treatments comprising organic mulches, Polythene mulch, inter-crop-based management, hoeing, tamarind-leaf aqueous extract and an unweeded control were evaluated; pendimethalin followed by hand weeding was included as a non-organic chemical comparison. Fruit yield and soil pH, electrical conductivity (EC) and cation exchange capacity (CEC) were determined. Fruit yield differed markedly among treatments in both seasons. Polythene mulch combined with intra-row hand weeding at 30 days after sowing (T_3) produced 34.27 and 36.64 t ha⁻¹ in 2022–23 and 2023–24, respectively. Rice-straw mulch at 5 t ha⁻¹ followed by intra-row hand weeding (T_4) produced 33.97 and 34.64 t ha⁻¹ and was statistically at par with T_3 in both seasons. The unweeded control produced only 0.91 and 1.09 t ha⁻¹. Soil pH was not significantly affected, whereas EC and CEC differed significantly among treatments. T_3 recorded the highest EC (0.70 and 0.91 dS m⁻¹), while T_4 recorded the highest CEC (38.48 and 39.06 cmol(p⁺) kg⁻¹) in the two seasons. The results demonstrate that effective weed suppression through mulching combined with timely hand weeding can substantially improve watermelon productivity, while residue-based mulching can also contribute to improved soil chemical fertility. Rice-straw mulch followed by hand weeding therefore represents a practical option where synthetic herbicides are restricted.

Keywords: *Citrullus lanatus*, Organic-oriented production, Weed suppression, Mulching, Hand weeding, Fruit yield, Soil pH, Electrical conductivity, Cation exchange capacity

1. Introduction

Weeds are among the major biological constraints to crop production because they compete with crops for moisture, nutrients, light and physical space. Weed management is particularly challenging in organic production systems, where synthetic herbicides are restricted and greater reliance is placed on preventive, cultural and mechanical tactics. Organic farming practices have been associated with environmental benefits, although their effects vary with management system, soil conditions and production objectives (Gomiero *et al.*, 2011) [1]. Non-chemical weed management is most effective when multiple tactics are integrated rather than relying on a single intervention (Bond *et al.*, 2001; Liebman *et al.*, 2009) [2, 3]. More broadly, weed communities respond to crop rotation, residue cover, crop density, soil disturbance and other management factors, supporting the use of integrated strategies that suppress weed establishment and reduce the opportunity for seed production (Nichols *et al.*, 2015; Chauhan, 2020) [5, 4].

Mulching is particularly relevant to vegetable production because a soil-covering material can physically restrict weed emergence while modifying soil moisture and temperature. Plastic mulches have been associated with improved watermelon yield and water-use efficiency in environments where water is limiting, whereas organic and biodegradable mulches can suppress weed emergence while returning carbon-containing residues to the soil (Wang *et al.*, 2011; Parmar *et al.*, 2013; Gürbüz *et al.*, 2023) [7, 8, 6]. The performance of organic mulches depends on the material, application rate, thickness, decomposition characteristics and weed flora present. Organic mulches can suppress weed emergence while conserving soil moisture and protecting the soil surface, making them particularly relevant to organic vegetable production (Schonbeck, 2012) [9].

Organic management practices can improve soil fertility through enhanced nutrient cycling and organic matter inputs, with long-term organic systems also showing improvements in soil biological and fertility-related properties (Mäder *et al.*, 2002) [10]. Residue-based management may also influence soil chemical properties.

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Organic inputs can contribute carbon and nutrients to soil and can modify nutrient retention and exchange properties over time. Evidence from long-term organic systems and *meta*-analyses indicates that organic management and organic inputs can increase several indicators of soil biological activity and soil organic carbon, although responses vary with climate, soil type, crop and management history (Reganold *et al.*, 2010; Lori *et al.*, 2017; Crystal-Ornelas *et al.*, 2021) [12, 13, 11]. Such effects provide a rationale for evaluating weed-management practices not only for crop productivity but also for their implications for soil chemical fertility.

Watermelon (*Citrullus lanatus*) is an important cucurbit crop in India, and its sprawling growth habit leaves substantial soil surface exposed during early crop establishment. Consequently, weed interference can be severe before sufficient canopy development. Previous watermelon studies have demonstrated significant effects of mulching on growth, yield and weed suppression (Parmar *et al.*, 2013; Gürbüz *et al.*, 2023) [8, 6]. However, comparative information on locally available organic residues, cultural practices and their associated effects on soil pH, EC and CEC under Telangana conditions remains limited. The present study therefore evaluated nine weed-management treatments over two consecutive seasons, with emphasis on fruit yield and selected soil chemical properties.

2. Materials and methods

2.1 Experimental site and design

The field experiment was conducted during 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 an initial pH of 7.6, organic carbon of 0.76%, bulk density of 1.5 g cm⁻³, available nitrogen of 255 kg ha⁻¹, available phosphorus of 18.1 kg ha⁻¹ and available potassium of 615 kg ha⁻¹. The experiment followed a randomized block design with three replications. The experiment was conducted under organic production practices; however, pendimethalin was included in *T*₉ as a chemical comparison. Accordingly, *T*₉ is treated here as a conventional chemical comparator and is not considered an organic treatment. The supplied experimental record does not specify the watermelon cultivar, plot dimensions, irrigation schedule or organic-certification status; these details should be verified from the field record before journal submission.

2.2 Weed-management treatments

2.3 Fruit-yield measurement and plant nutrient analysis

Fruits were harvested at the marketable stage and fruit yield was expressed in tonnes per hectare. Plant samples collected at fruiting were dried, pulverized and analysed for total nitrogen, phosphorus and potassium. Nitrogen was determined using the micro-Kjeldahl procedure after acid digestion; phosphorus was estimated by the vanado-molybdophosphoric acid method after tri-acid digestion at 420 nm; and potassium was determined using a flame photometer. The analytical procedures followed Piper (1945) [14].

Treatment	Description
<i>T</i> ₁	Groundnut-shell mulch @ 5 t ha ⁻¹
<i>T</i> ₂	Rice-husk mulch @ 3 t ha ⁻¹
<i>T</i> ₃	Polythene mulch + intra-row hand weeding at 30 DAS
<i>T</i> ₄	Rice-straw mulch @ 5 t ha ⁻¹ followed by intra-row hand weeding at 30 DAS
<i>T</i> ₅	Hoeing twice at 15 and 30 DAS
<i>T</i> ₆	Fenugreek green-leaf vegetable intercrop followed by hand weeding at 30 DAS
<i>T</i> ₇	Tamarind-leaf aqueous extract @ 10% at 3 and 20 DAT followed by hand weeding at 30 DAS
<i>T</i> ₈	Unweeded control

Treatment	Description
<i>T</i> ₉	Pendimethalin 30% EC @ 1.0 kg a.i. ha ⁻¹ followed by hand weeding at 30 DAS

2.4 Soil sampling and analysis

Composite soil samples were collected randomly using a soil auger before sowing and after harvest from each plot. Samples were thoroughly mixed, air-dried, crushed and passed through a 2-mm sieve before analysis. Soil pH was measured in a 1:2.5 soil-to-water suspension using a digital pH meter. Electrical conductivity was measured in the corresponding supernatant using a digital conductivity meter. Cation exchange capacity was determined by ammonium acetate saturation followed by replacement of adsorbed ammonium with potassium chloride and distillation-based estimation, following the methods described by Jackson (1973) [15].

2.5 Statistical analysis

Data were subjected to analysis of variance appropriate for a randomized block design following Gomez and Gomez (1984). Treatment means were compared using the critical difference (CD) at the 5% probability level when the *F*-test was significant. Non-significant differences were denoted as NS.

3. Results and discussion

3.1 Fruit yield

Weed-management practices significantly influenced watermelon fruit yield in both seasons (Table 1; Fig. 1). During 2022–23, *T*₃ (Polythene mulch + intra-row hand weeding at 30 DAS) recorded the highest fruit yield of 34.27 t ha⁻¹, followed by *T*₄ (rice-straw mulch + hand weeding) with 33.97 t ha⁻¹. The difference between *T*₃ and *T*₄ was only 0.30 t ha⁻¹, which was smaller than the CD of 2.96 t ha⁻¹, indicating that the two treatments were statistically at par. *T*₉ produced 17.57 t ha⁻¹, while *T*₁, *T*₂, *T*₅, *T*₆ and *T*₇ produced 16.44, 8.59, 10.82, 10.12 and 7.75 t ha⁻¹, respectively. The unweeded control produced only 0.91 t ha⁻¹. During 2023–24, *T*₃ again recorded the highest yield (36.64 t ha⁻¹), followed by *T*₄ (34.64 t ha⁻¹). Their numerical difference was 2.00 t ha⁻¹, which was smaller than the CD of 3.21 t ha⁻¹; hence, the two treatments were statistically at par. *T*₉ produced 18.21 t ha⁻¹, whereas the unweeded control produced 1.09 t ha⁻¹. The large yield advantage under *T*₃ and *T*₄ is consistent with the expected effects of mulch cover and timely weed removal in reducing competition for soil moisture, nutrients, light and space.

The response agrees with earlier watermelon research showing that mulching can improve crop performance by modifying soil moisture and temperature and by suppressing weeds. Parmar *et al.* (2013) [8] reported significant effects of different mulching materials on watermelon growth, yield and quality, while Wang *et al.* (2011) [7] showed that plastic mulch combined with rainwater-harvesting configurations could improve watermelon water-use efficiency and yield in a semi-arid environment. More recently, Gürbüz *et al.* (2023) [6] demonstrated that biodegradable mulches could reduce weed pressure and affect watermelon fruit yield. The present results extend these observations by showing that locally available rice straw, when integrated with hand weeding, produced yield statistically comparable to polythene mulch in both seasons.

The very low yield under *T*₈ emphasizes the magnitude of weed interference when no weed-control intervention is imposed. This is consistent with the broader weed-management literature, which emphasizes that crop competition, mulching, cultivation and hand weeding can act cumulatively and that integrated strategies are often more dependable than isolated measures (Bond *et al.*, 2001; Liebman *et al.*, 2009; Chauhan, 2020) [2, 3, 4].

3.2 Soil pH

Soil pH was not significantly influenced by the weed-management treatments in either season (Table 2). In 2022–23, pH ranged from 7.67 to 8.06, with the lowest value under *T*₃ and the highest under *T*₈. In 2023–24, pH ranged from 7.53 to 8.01, with *T*₃ recording the low

est value and T₅ the highest. The absence of a significant treatment effect indicates that the evaluated weed-management practices did not materially alter soil reaction over the period represented by the experiment. The relatively stable pH is also consistent with the observation

that soil pH responses to organic management and amendments can depend strongly on initial soil condition, amendment chemistry and duration of management (Suja *et al.*, 2017; Urrea *et al.*, 2019) [16, 17].

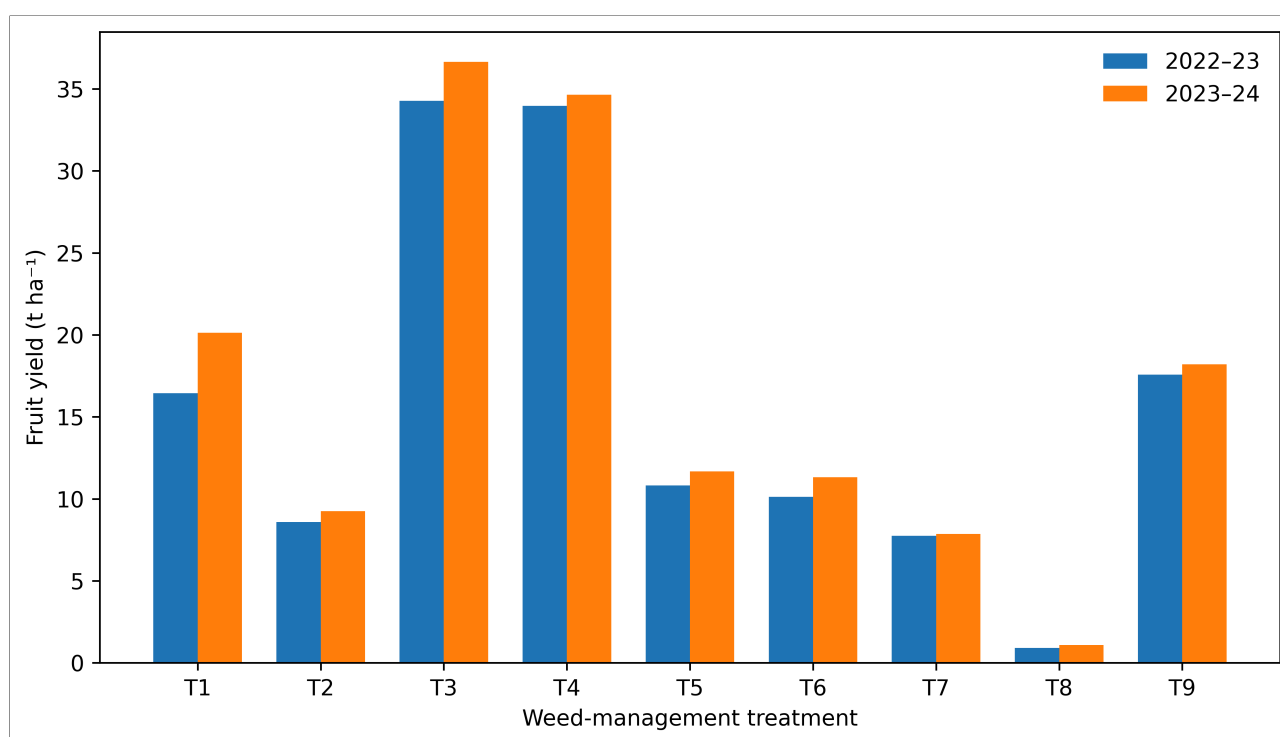


Figure 1. Fruit yield of watermelon as influenced by eco-friendly weed-management practices.

3.3 Soil electrical conductivity

Soil EC was significantly affected by weed-management practices in both seasons. In 2022-23, EC ranged from 0.25 to 0.70 dS m⁻¹. The highest EC was recorded under T₃ (0.70 dS m⁻¹), whereas T₈ recorded the lowest value (0.25 dS m⁻¹). In 2023-24, EC ranged from 0.19 to 0.91 dS m⁻¹, with T₃ again recording the highest value and T₈ the lowest. The higher EC under mulch treatments may reflect differences in nutrient cycling, residue decomposition and retention of soluble ions in the surface soil. However, EC is influenced by several interacting factors, and the present experiment did not measure individual soluble ions; therefore, the mechanism should be interpreted cautiously rather than attributed solely to decomposition.

3.4 Cation exchange capacity

CEC differed significantly among treatments in both seasons. During 2022-23, CEC ranged from 30.00 to 38.48 cmol(p⁺) kg⁻¹, whereas in 2023-24 it ranged from 30.49 to 39.06 cmol(p⁺) kg⁻¹. T₄ (rice-straw mulch + hand weeding) recorded the highest CEC in both seasons

(38.48 and 39.06 cmol(p⁺) kg⁻¹, respectively). T₁ and T₆ also recorded comparatively high CEC values. The unweeded control recorded the lowest CEC in 2022-23 and a low value in 2023-24. T₉ and T₃ were intermediate.

The relatively higher CEC associated with rice-straw mulch is biologically plausible because repeated organic-residue inputs can contribute organic matter and functional exchange sites. Organic-residue inputs can contribute to the stabilization and accumulation of soil organic matter, which may subsequently influence nutrient-retention characteristics and soil exchange capacity (Six *et al.*, 2002) [18]. Organic inputs have been associated with changes in soil carbon pools and nutrient-retention characteristics, although the magnitude and direction of response depend on soil texture, amendment quality and management duration (Reganold *et al.*, 2010; Urrea *et al.*, 2019; Crystal-Ornelas *et al.*, 2021) [12, 17, 11]. Importantly, the present experiment measured CEC but did not quantify soil organic carbon after treatment, so the proposed relationship between rice-straw addition and CEC should be regarded as a plausible interpretation rather than a directly demonstrated causal pathway.

Table 1. Fruit yield of watermelon as influenced by weed-management practices.

Treatment	Description	2022-23 (t ha ⁻¹)	2023-24 (t ha ⁻¹)
T ₁	Groundnut-shell mulch @ 5 t ha ⁻¹	16.44	20.13
T ₂	Rice-husk mulch @ 3 t ha ⁻¹	8.59	9.25
T ₃	Polythene mulch + intra-row hand weeding at 30 DAS	34.27	36.64
T ₄	Rice-straw mulch @ 5 t ha ⁻¹ followed by intra-row hand weeding at 30 DAS	33.97	34.64
T ₅	Hoeing twice at 15 and 30 DAS	10.82	11.67
T ₆	Fenugreek green-leaf vegetable intercrop followed by hand weeding at 30 DAS	10.12	11.32
T ₇	Tamarind-leaf aqueous extract @ 10% at 3 and 20 DAT followed by hand weeding at 30 DAS	7.75	7.86

(continued on next page)

Treatment	Description	2022–23 (t ha ⁻¹)	2023–24 (t ha ⁻¹)
T ₈	Unweeded control	0.91	1.09
T ₉	Pendimethalin 30% EC @ 1.0 kg a.i. ha ⁻¹ followed by hand weeding at 30 DAS; chemical comparison	17.57	18.21

SE(m) ±: 0.99 and 1.07; CD (*P* = 0.05): 2.96 and 3.21 for 2022–23 and 2023–24, respectively.

Table 2. Soil chemical properties of watermelon as influenced by weed-management practices.

Treatment	pH 2022–23	pH 2023–24	EC 2022–23	EC 2023–24	CEC 2022–23	CEC 2023–24
T ₁	7.94	7.85	0.40	0.40	37.33	35.45
T ₂	7.85	7.79	0.42	0.40	33.92	32.30
T ₃	7.67	7.53	0.70	0.91	34.14	32.26
T ₄	7.75	7.78	0.46	0.47	38.48	39.06
T ₅	7.87	8.01	0.35	0.29	34.15	30.49
T ₆	7.72	7.89	0.46	0.40	36.73	36.07
T ₇	7.98	7.78	0.53	0.50	33.92	32.20
T ₈	8.06	7.92	0.25	0.19	30.00	30.71
T ₉	7.89	7.78	0.56	0.51	34.36	34.89

SE(m) ±: pH 0.16 and 0.10; EC 0.01 and 0.01; CEC 1.51 and 1.27. CD (*P* = 0.05): pH NS; EC 0.02 and 0.03; CEC 4.54 and 3.81 for 2022–23 and 2023–24, respectively.

4. Conclusion

The two-year field experiment demonstrated that weed-management practices strongly influenced watermelon fruit yield and selected soil chemical properties. Polythene mulch combined with intra-row hand weeding at 30 DAS produced the highest fruit yield in both seasons, but its yield was statistically at par with rice-straw mulch at 5 t ha⁻¹ followed by hand weeding. Rice-straw mulch also recorded the highest CEC in both seasons, whereas soil pH remained statistically unchanged. EC was significantly affected by treatment, with the highest values under Polythene mulch plus hand weeding. The unweeded control resulted in very low fruit yield in both seasons, emphasizing the importance of effective weed suppression during watermelon production. Under conditions where synthetic herbicides are restricted, rice-straw mulch integrated with timely hand weeding provides a residue-based weed-management option that combines effective weed suppression with the potential to maintain soil chemical fertility.

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