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Growth and yield performance of organic beetroot as affected by eco-friendly weed management practices

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Abstract

A field experiment was conducted during the rabi seasons of 2022-2023 and 2023-2024 at the AICRP on Weed Management block, College Farm, PJTSAU, Rajendranagar, Hyderabad, to assess the effect of eco-friendly weed management practices on growth parameters and root yield of organic beetroot (*Beta vulgaris* L.) grown 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, replicated thrice. Growth parameters such as leaf length, leaf width, and number of leaves were recorded at different growth stages, along with root yield at harvest. Significant differences were observed among treatments for leaf length and leaf width at all stages, while leaf number showed significant variation only at 30 DAS. Poly mulch combined with intra-row hand weeding at 30 DAS consistently recorded the highest leaf length, leaf width, and root yield (24.11 and 25.99 t ha⁻¹ during 2022-2023 and 2023-2024, respectively), which was statistically comparable with rice straw mulch at 5 t ha⁻¹ followed by hand weeding and chemical weed control. The unweeded control recorded the lowest growth and yield in both years. Improved crop performance under mulching treatments was attributed to effective weed suppression during the critical growth period, enhanced moisture conservation, and improved nutrient availability. The study concludes that integration of organic mulching with timely hand weeding is a sustainable and effective alternative to chemical weed control for improving growth and productivity of organic beetroot.

Keywords: Organic beetroot, eco-friendly weed management, mulching, hand weeding, leaf growth parameters, root yield, organic farming

Introduction

Demand for organically grown vegetables is increasing in urban areas. Organic vegetable producers rank weeds as one of the most troublesome, time-consuming and costly production problems. Hence, there is a need to develop effective non-chemical weed management strategies for organic vegetables.

Organic farming is practiced in 187 countries, with at least 3.1 million farmers operating 72.3 million hectares of farmland organically (Willer *et al.*, 2021)^[9]. India had 1.4 million organic food producers during 2020, which was more than the combined number of organic food producers in the world's other nine largest countries. Organic farming is typically seen to be more sustainable than conventional farming, yet it comes with its own set of problems and opportunities.

Despite having a relatively small amount of organic land under cultivation, India is the country with the highest number of organic farmers, with over 1.9 million farmers as of March 2020, or 1.3% of 146 million agricultural land holders. The country implemented an organic farming policy in 2005, and the 2.66 million hectares covered by organic farming account for approximately 2% of the 140.1 million hectares of net sown area in India (APEDA, 2021)^[3].

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)^[5, 2]. Beetroot 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) ^[1].

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/m⁻³, available nitrogen 255 kg/ha, available phosphorus 18.1 kg/ha and available potassium 615 kg/ha. The treatments comprised 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).

Leaf length (cm)

With the help of a scale, the leaf length of ten leaves of five randomly selected tagged plants from each treatment in each replication was measured and average leaf width was measured in centimetres at 30 and 60 DAS.

Leaf width (cm)

With the help of a scale, the leaf width of ten leaves of five randomly selected tagged plants from each treatment in each replication was measured and average leaf width was measured in centimetres at 30 and 60 DAS.

Number of leaves

Five randomly selected tagged plants from each plot had their number of leaves measured. The average number of leaves from those five plants was recorded as the mean number of leaves.

Root Yield (t ha⁻¹)

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 by 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) ^[4]. Whenever the treatment differences were found significant (*F* test), critical differences were worked out at five per cent 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

Leaf length (cm)

The data on leaf length recorded at 30 DAS, 60 DAS and at

harvest during 2022-2023 and 2023-2024 revealed significant differences among the weed management treatments Table 4.32. In general, leaf length increased progressively from 30 DAS to harvest in all treatments during both years.

During 2022-2023, leaf length at 30 DAS ranged from 7.85 cm in the unweeded control (T₈) to 15.59 cm under poly mulch combined with intra-row hand weeding at 30 DAS (T₃). At 60 DAS, the maximum leaf length (20.03 cm) was again recorded in T₃, which was statistically on par with rice straw mulch @ 5 t ha⁻¹ followed by intra-row hand weeding (T₄) and chemical weed control with pendimethalin followed by hand weeding (T₉). At harvest, T₃ maintained its superiority by recording the highest leaf length (20.91 cm), followed closely by T₄ (20.53 cm) and T₉ (20.20 cm). The lowest leaf length at all stages was consistently observed in the unweeded control (T₈).

A similar trend was observed during 2023-2024. At 30 DAS, leaf length varied from 7.81 cm (T₈) to 15.38 cm (T₃). At 60 DAS, T₃ recorded the maximum leaf length (20.27 cm), which was statistically comparable with T₄ (20.25 cm) and T₉ (19.61 cm). At harvest, the highest leaf length (20.46 cm) was observed under T₃, followed by T₄ (19.91 cm) and T₉ (19.77 cm). Treatments involving rice husk mulch (T₂), intercropping with green leaf vegetable (T₆) and tamarind leaf aqueous extract (T₇) recorded comparatively lower leaf length values.

Overall, the results clearly indicate that effective weed management through poly mulch combined with intra-row hand weeding (T₃), rice straw mulch with hand weeding (T₄) and chemical weed control (T₉) significantly enhanced leaf length at all growth stages, whereas poor weed control in the unweeded control (T₈) resulted in the lowest leaf length during both years. Similar results were found by Shafeek *et al.* (2019) ^[7] and Tsialtas and Maslaris. (2007) ^[8].

Leaf width (cm)

The data on leaf width recorded at 30 DAS, 60 DAS and at harvest during 2022-2023 and 2023-2024 showed significant variation among the weed management treatments (Table 4.33). In general, leaf width increased progressively from 30 DAS to harvest in all treatments during both years.

During 2022-2023, leaf width at 30 DAS ranged from 3.89 cm in the unweeded control (T₈) to 8.80 cm under poly mulch combined with intra-row hand weeding at 30 DAS (T₃). At 60 DAS, the maximum leaf width (10.43 cm) was recorded in T₃, which was statistically on par with rice straw mulch @ 5 t ha⁻¹ followed by intra-row hand weeding (T₄) (10.33 cm) and chemical weed control with pendimethalin followed by hand weeding (T₉) (9.57 cm). At harvest, T₃ recorded the highest leaf width (11.33 cm), followed by T₄ (11.03 cm) and T₉ (9.97 cm). The lowest leaf width at all stages was consistently observed in the unweeded control (T₈).

A similar trend was observed during 2023-2024. At 30 DAS, leaf width varied from 3.88 cm (T₈) to 7.90 cm (T₃). At 60 DAS, T₃ recorded the maximum leaf width (11.07 cm), which was statistically comparable with T₄ (10.67 cm) and T₉ (9.83 cm). At harvest, the highest leaf width (11.27 cm) was again observed under T₃, followed by T₄ (10.87 cm) and T₉ (10.03 cm). Treatments involving rice husk mulch (T₂), intercropping with green leaf vegetable (T₆) and tamarind leaf aqueous extract (T₇) recorded comparatively lower leaf width values. Similar results were found by Shafeek *et al.* (2019) ^[7]; Tsialtas and Maslaris, (2007) ^[8].

Leaf number

Leaf number recorded at 30 DAS, 60 DAS and at harvest during

both years showed significant differences at 30 DAS, while differences at later stages were non-significant (Table 4.35).

During 2022-2023, at 30 DAS, the highest leaf number was recorded in poly mulch + intra-row hand weeding (T_3) (11.20 leaves plant⁻¹), which was on par with rice straw mulch + hand weeding (T_4) and chemical weed control (T_9). The lowest leaf number was observed in the unweeded control (T_8) (7.40 leaves plant⁻¹). At 60 DAS and harvest, numerical differences were observed among treatments, but they were statistically non-significant.

During 2023-2024, a similar trend was recorded. At 30 DAS, T_3 and T_4 recorded the maximum leaf number (11.40 and 11.33 leaves plant⁻¹, respectively), while T_8 recorded the minimum (7.60 leaves plant⁻¹). Differences at 60 DAS and harvest were again non-significant.

Overall, the results suggest that efficient weed management enhanced early vegetative growth, as reflected by a higher number of leaves at 30 DAS, while leaf number at later stages was less sensitive to weed management practices (Tsialtas and Maslaris, 2007)^[8] and (Kumar *et al.*, 2013)^[5].

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 (Figure 1).

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 (T_3) (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 (T_4) (23.59 t ha⁻¹) and chemical weed control with pendimethalin followed by hand weeding at 30 DAS (T_9) (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 (T_1) (16.95 t ha⁻¹), hoeing twice at 15 and 30 DAS (T_5) (13.88 t ha⁻¹) and intercropping with green leaf vegetable followed by hand weeding at 30 DAS (T_6) (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 (T_7) (3.20 t ha⁻¹) and unweeded control (T_8) (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 (T_3) again recorded the highest tuber yield (25.99 t ha⁻¹), which was statistically comparable with T_4 and T_9 , 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 (T_1) (18.51 t ha⁻¹) and intercropping with green leaf vegetable *fb* hand weeding (T_6) (14.23 t ha⁻¹) recorded moderate yields, while hoeing twice (T_5) showed comparatively lower yield (8.06 t ha⁻¹), possibly due to regrowth of weeds between hoeing operations. The tamarind leaf aqueous extract treatment (T_7) 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 (T_8) 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 in accordance with Majhi *et al.* (2024)^[6] and Yordanova and Gerasimova (2016)^[10].

Table 1: Leaf length (cm) of organic beetroot as influenced by eco-friendly weed management practices

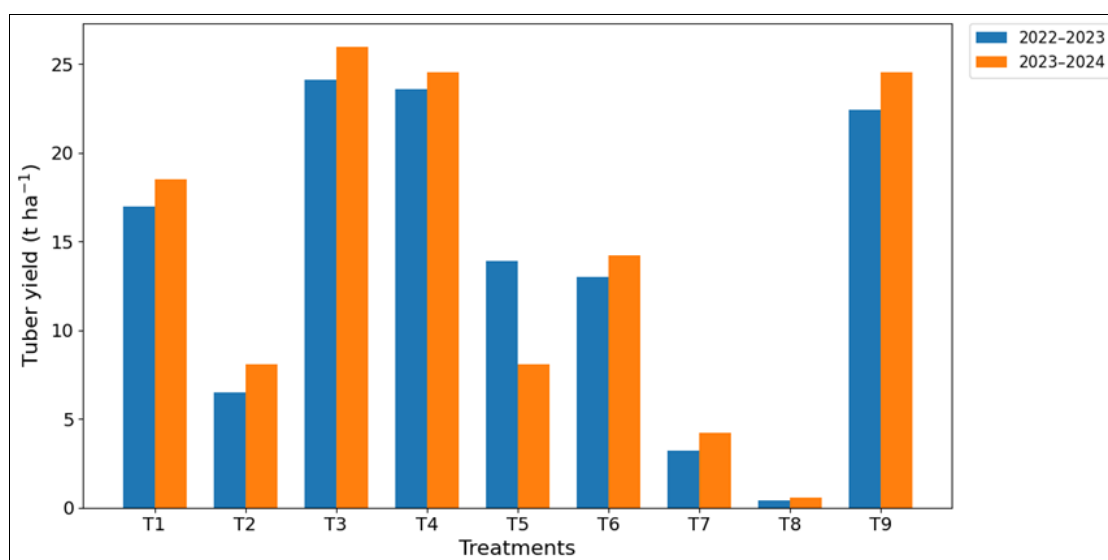
Treatment		2022-2023			2023-2024		
		30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest
T_1	Groundnut shell mulch 5 t ha ⁻¹	14.32	17.84	18.73	14.4	18.31	18.44
T_2	Rice husk mulch 3 t ha ⁻¹	11.26	15.21	16.07	11.44	15.57	15.93
T_3	Poly mulch + intra row hand weeding (HW) at 30 DAS	15.59	20.03	20.91	15.38	20.27	20.46
T_4	Rice straw mulch 5 t ha ⁻¹ <i>fb</i> intra row HW at 30 DAS	15.08	19.98	20.53	14.78	20.25	19.91
T_5	Hoeing twice at 15 & 30 DAS	12.84	17.43	18	12.56	17.38	17.78
T_6	Intercrop green leaf vegetable <i>fb</i> HW at 30 DAS	12.38	15.92	16.88	12.53	15.95	16.24
T_7	Tamarind leaf aqueous extract @ 10% at 3 and 20 DAT <i>fb</i> HW at 30 DAS	8.05	13.28	14.15	8.08	13.59	13.73
T_8	Unweeded control	7.85	12.47	13.29	7.81	12.74	13.03
T_9	Chemical weed control-pendimethalin 30% EC @ 1.0 kg a.i ha ⁻¹ <i>fb</i> HW at 30 DAS	15.04	19.38	20.2	14.73	19.61	19.77
SE (m) ±		0.88	0.99	0.94	0.70	1.03	1.03
CD ($p = 0.05$)		2.64	2.96	2.83	2.10	3.08	3.08

Table 2: Leaf width (cm) of organic beetroot as influenced by eco-friendly weed management practices

Treatment		2022-2023			2023-2024		
		30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest
T ₁	Groundnut shell mulch 5 t ha ⁻¹	7.12	9.47	9.73	7.8	9.53	9.67
T ₂	Rice husk mulch 3 t ha ⁻¹	4.51	8.97	8.7	4.68	8.43	8.63
T ₃	Poly mulch + intra row hand weeding (HW) at 30 DAS	8.8	10.43	11.33	7.9	11.07	11.27
T ₄	Rice straw mulch 5 t ha ⁻¹ fb intra row HW at 30 DAS	8.1	10.33	11.03	7.88	10.67	10.87
T ₅	Hoeing twice at 15 & 30 DAS	7.83	9.40	9.67	7.25	9.43	9.63
T ₆	Intercrop green leaf vegetable fb HW at 30 DAS	6.96	9.10	9.47	6.76	9.33	9.53
T ₇	Tamarind leaf aqueous extract @ 10% at 3 and 20 DAT fb HW at 30 DAS	4.43	7.97	8.57	4.5	8.43	8.63
T ₈	Unweeded control	3.89	5.00	5.37	3.88	5.1	5.3
T ₉	Chemical weed control- pendimethalin 30% EC @ 0.525 kg a.i ha ⁻¹ fb HW at 30 DAS	7.83	9.57	9.97	7.83	9.83	10.03
SE (m) ±		0.43	0.54	0.59	0.43	0.62	0.59
CD (p = 0.05)		1.29	1.61	1.78	1.29	1.87	1.77

Table 3: Leaf number of organic beetroot as influenced by eco-friendly weed management

Treatment		2022-2023			2023-2024		
		30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest
T ₁	Groundnut shell mulch 5 t ha ⁻¹	10.27	10.33	9.33	10.47	10.53	9.53
T ₂	Rice husk mulch 3 t ha ⁻¹	8.93	8.6	7.6	9.13	8.8	7.8
T ₃	Poly mulch + intra row hand weeding (HW) at 30 DAS	11.2	11.13	10.13	11.4	11.33	10.33
T ₄	Rice straw mulch 5 t ha ⁻¹ fb intra row HW at 30 DAS	11.13	10.93	9.93	11.33	11.07	10.07
T ₅	Hoeing twice at 15 & 30 DAS	10.13	10.2	9.2	10.33	10.4	9.33
T ₆	Intercrop green leaf vegetable fb HW at 30 DAS	9.87	9.73	8.73	10.13	9.93	8.8
T ₇	Tamarind leaf aqueous extract @ 10% at 3 and 20 DAT fb HW at 30 DAS	8.73	8.6	7.6	8.93	8.8	7.8
T ₈	Unweeded control	7.4	7.93	6.93	7.6	8.13	7.27
T ₉	Chemical weed control- pendimethalin 30% EC @ 1.0 kg a.i ha ⁻¹ fb HW at 30 DAS	11.13	10.6	9.6	11.33	10.73	9.73
SE (m) ±		0.57	0.39	0.52	0.61	0.38	0.41
CD (p = 0.05)		1.71	NS	NS	1.81	NS	NS

**Fig 1:** Yield (t ha⁻¹) of organic beetroot as influenced by eco-friendly weed management practices

Conclusion

The study demonstrated that eco-friendly weed management practices significantly influenced growth parameters and root yield of organic beetroot during both years of experimentation. Among the treatments, poly mulch combined with intra-row hand weeding at 30 DAS consistently recorded the highest leaf length, leaf width, and root yield, followed by rice straw mulch at 5 t ha⁻¹ integrated with hand weeding and chemical weed control. Effective weed suppression under these treatments reduced crop-weed competition and improved nutrient availability, moisture conservation, and light interception, resulting in enhanced vegetative growth and yield.

Leaf number was significantly affected by weed management practices at the early growth stage, highlighting the importance

of timely weed control, whereas differences at later stages were non-significant. Moderate performance was observed under organic mulches, intercropping, and mechanical weeding, while botanical extract alone and unweeded control resulted in poor growth and severe yield losses due to ineffective weed suppression.

Overall, integration of organic mulching with timely hand weeding proved to be an effective and sustainable alternative to chemical weed control for improving growth and productivity of organic beetroot.

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