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Mulch Based Soil Moisture Conservation and Weed Management Strategies for enhancing Flower Yield of Crossandra (Crossandra infundibuliformis) under Semi-Arid conditions

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Abstract
A field experiment was conducted during 2024–2025 at Sri Krishnadevaraya College of Horticultural Sciences, Ananthapuramu, Andhra Pradesh, India, to evaluate the effects of different mulching materials on growth, flowering, yield, quality, weed management, water use efficiency and economics of Crossandra (Crossandra infundibuliformis). The study was laid out in a Randomized Block Design with seven treatments and four replications, including straw mulch, compost mulch, polyethylene mulch, biodegradable mulch and an un-mulched control. Results indicated that mulching significantly improved plant growth, flowering behaviour, yield and quality compared to the control. Polyethylene mulch recorded the highest plant height, number of branches, leaf area index, chlorophyll content and dry matter production. It also resulted in earlier flowering, longer flowering duration and the highest flower yield. Superior flower quality, including greater flower size, weight, vase life and anthocyanin content, was also observed under polyethylene mulch. Additionally, this treatment effectively reduced weed density, improved soil moisture retention and enhanced water use efficiency. Economic analysis showed that polyethylene mulch produced the highest net returns and benefit–cost ratio, followed by straw and compost mulches. The findings suggest that polyethylene mulch is the most effective practice for improving growth, yield, flower quality and profitability of Crossandra under semi-arid conditions, though biodegradable mulches may be considered for sustainable production.

Keywords: *Crossandra infundibuliformis, mulching, polyethylene, flower yield, anthocyanin, water use efficiency, economics*

1. Introduction

Crossandra infundibuliformis (L.) Nees, commonly known as Firecracker flower or Kanakambaram, is a popular ornamental and loose flower crop cultivated widely across southern India for garland making and aesthetic decoration. It belongs to the family Acanthaceae and is valued for its vibrant orange flowers, long blooming period and ability to thrive under tropical and semi-arid conditions. The crop has gained significant economic importance in recent years owing to its consistent market demand and suitability for year-round cultivation [22].However, productivity and flower quality of *Crossandra* are often limited by soil moisture stress, nutrient depletion and weed competition, particularly under the dry climatic conditions of southern Andhra Pradesh. Efficient soil moisture and temperature management therefore become critical for enhancing the growth, yield and profitability of this crop.

Mulching is one of the most effective agronomic practices for improving soil hydrothermal conditions, conserving soil moisture, suppressing weed growth, enhancing nutrient availability and improving crop yield and quality. Mulch materials, whether organic or synthetic, serve as a protective layer that minimises evaporation, moderates soil temperature and reduces weed competition, thereby improving overall crop performance [7]. Among various mulch types, polyethylene mulch has been extensively reported to improve microclimatic conditions around the root zone, leading to better vegetative growth, flower yield and quality in several ornamental crops such as marigold, chrysanthemum and gerbera [11,20]. Organic mulches such as straw and compost, on the other hand, improve soil fertility, microbial activity and long-term soil health, though their effects on flower yield and water use efficiency may vary depending on thickness and decomposition rate [2,4].

In *Crossandra*, information on the comparative efficiency of different mulching materials, especially under semi-arid conditions,

2. Materials and Methods

The field experiment was conducted during 2024–2025 at the College Farm, Department of Floriculture and Landscape Architecture, Sri Krishnadevaraya College of Horticultural Sciences, Ananthapuramu, Andhra Pradesh, India (14°41 N latitude, 77°36 E longitude, 350 m above mean sea level). The region is characterised by a semi-arid tropical climate with hot, dry summers and mild winters, receiving an average annual rainfall of about 550–600 mm, predominantly from the southwest monsoon. The mean maximum temperature during the experimental period ranged from 30°C to 39°C, while the minimum temperature varied between 18°C and 25°C *AICRP2023*. The experimental soil was sandy loam in texture, slightly alkaline in reaction (pH 7.6), with an electrical conductivity of 0.17 dS m^{-1}, low in organic carbon (0.33%) and medium in available nitrogen (283 kg ha^{-1}), phosphorus (29.1 kg ha^{-1}) and potassium (297 kg ha^{-1}), indicating moderate fertility and non-saline conditions suitable for floricultural crops.

The experiment was laid out in a Randomised Block Design (RBD) with seven treatments and four replications. Each plot measured 5.0 m $\times$ 5.0 m, with plant spacing maintained at 45 cm $\times$ 30 cm. The seven treatments were: T_1: Control (no mulch), T_2: Straw mulch (5 cm thickness), T_3: Straw mulch (10 cm thickness), T_4: Compost mulch (5 cm thickness), T_5: Compost mulch (10 cm thickness), T_6: Polyethylene mulch (black, 50 µ thickness) and T_7: Biodegradable mulch (5 cm thickness). Healthy and uniform suckers of *Crossandra infundibuliformis* cv. Arka Shreeya were used for planting. In polyethylene and biodegradable mulch treatments, sheets were spread over the prepared beds before transplanting and holes were punched at the designated spacing for planting.

Uniform cultural and management practices were adopted across all treatments. A basal fertiliser dose of 75:50:50 kg N:P_2O_5:K_2O ha^{-1} was applied, with nitrogen applied in two equal splits at 30 and 60 days after planting. Irrigation was scheduled based on soil moisture status using the surface irrigation method and intercultural operations were carried out manually as needed. Standard pest and disease management practices recommended for Crossandra were followed to maintain a healthy crop [6].

Observations were recorded from five randomly selected plants per treatment on various growth, flowering, yield, quality, weed and water-use parameters. Growth parameters included plant height (cm), number of branches per plant, leaf area index (LAI), chlorophyll content (SPAD) and dry matter production (g $plant^{-1}$). Flowering attributes such as days to first flowering, days to peak flowering, flowering duration and number of pickings were recorded. Yield was determined by summing the cumulative flower harvests and expressed in kilograms per hectare. Quality parameters included flower length (cm), flower diameter (cm), weight of 100 flowers (g), vase life (days) and anthocyanin content (mg g^{-1} FW), the latter determined using the pH differential method [5].

Weed observations included weed density (no. m^{-2}), fresh and dry weight (g m^{-2}) and weed control efficiency (%), recorded at 45 and 90 days after planting. Soil moisture (%) was measured gravimetrically at 0–15 cm depth at regular intervals to monitor moisture retention under different mulches. Water productivity and water use efficiency (WUE) were calculated as the ratio of flower yield to total water applied (kg ha^{-1} mm^{-1}). Economic evaluation of each treatment was carried out based on total cost of cultivation, gross returns, net returns and benefit–cost (B:C) ratio computed from the prevailing local market prices.

All recorded data were subjected to statistical analysis using the Analysis of Variance (ANOVA) method [19]. Significance of treatment effects was tested at a 5% probability level ($p \leq 0.05$) and mean comparisons were made using the Least Significant Difference (LSD) test. Data analysis was performed using OPSTAT software [3].

3. RESULTS

Significant variations were observed among the different mulching treatments with respect to growth, flowering, yield, quality, weed management, water use efficiency and economics of *Crossandra infundibuliformis*. Among all the treatments, plants mulched with polyethylene (T_6) (Table 1) recorded the maximum plant height (40.50 cm), number of branches per plant (5.63), leaf area index (1.85), chlorophyll content (38.21 SPAD) and dry matter production (184.09 g $plant^{-1}$). This was followed by compost mulch at 10 cm thickness (T_5) and straw mulch at 10 cm thickness (T_3), while the control (T_1) recorded the lowest growth values. The superior performance of polyethylene mulch may be attributed to better soil moisture conservation and favourable microclimatic conditions that enhanced photosynthetic activity and vegetative growth.

Flowering parameters were also significantly influenced by different mulches. Polyethylene mulch (T_6) (Table 2) resulted in the earliest flowering (45.02 days to first flowering and 62.42 days to peak flowering) along with the longest flowering duration (57.02 days) and highest number of pickings (25.91), while the control took the longest time for flowering (54.33 days to first flowering) and showed the shortest flowering duration (42.55 days). The enhancement in flowering under polyethylene mulch might be due to the favourable soil temperature and moisture conditions, which accelerate physiological and biochemical processes related to flower initiation and development. A similar trend was noticed for flower yield, where polyethylene mulch (T_6) (Table 3) produced the highest flower yield (5015.04 kg ha^{-1}), followed by straw mulch (10 cm) (4349.34 kg ha^{-1}) and compost mulch (10 cm) (4080.75 kg ha^{-1}), while the control recorded the lowest yield (3072.44 kg ha^{-1}). The increase in yield under mulched conditions could be attributed to enhanced vegetative growth, prolonged flowering and efficient utilization of soil moisture and nutrients.

Regarding flower quality, polyethylene mulch (T_6) produced flowers of superior quality with maximum flower length (4.45 cm), flower diameter (4.45 cm), flower weight (32.87 g per 100 flowers), vase life (12.40 days) and anthocyanin content (0.72 mg g^{-1} FW), followed by straw mulch (10 cm) and compost mulch (10 cm). The improvement in quality parameters might be due to the favourable soil environment that facilitated better nutrient uptake and pigment synthesis.

Mulching also had a significant effect on weed dynamics. The lowest weed density (30.01 no. m^{-2}), fresh weight (146.71 g m^{-2}) and dry weight (96.74 g m^{-2}) were recorded under polyethylene mulch (T_6) (Table 4), resulting in a 73.91% reduction in weed density and 71.91% weed control efficiency over the control, followed by straw mulch (10 cm) and compost mulch (10 cm). The control plot exhibited the highest weed infestation, indicating the effectiveness of opaque mulching materials in suppressing weed growth.

Soil moisture content and irrigation efficiency were greatly improved by mulching. Polyethylene mulch (T_6) (Table 5) maintained the highest soil moisture (23.56%), longest irrigation interval (4.91 days), least total water applied (250.40 mm) and maximum water productivity and water use efficiency (20.06 kg ha^{-1} mm^{-1}). The control treatment recorded the lowest soil moisture and efficiency values. These results indicate that mulching minimises evaporative losses and enhances water use efficiency by maintaining favourable soil moisture conditions.

Economic analysis revealed that polyethylene mulch (T_6) (Table 6) achieved the highest net returns (₹ 156,175 ha^{-1}) with a benefit–cost ratio of 3.25, followed by straw mulch (10 cm) (₹ 138,705 ha^{-1}; B:C ratio 3.43) and compost mulch (10 cm) (₹ 122,600 ha^{-1}; B:C ratio 3.01). Although the cost of polyethylene mulch was relatively higher, the greater yield and quality compensated for the increased expenditure. The lowest net returns (₹ 88,240 ha^{-1}) and B:C ratio (2.76) were observed in the control. In general, polyethylene mulch (T_6) was shown to be the most effective treatment, significantly improving growth, flowering, yield, flower quality, weed suppression, water conservation and economic returns, followed by straw mulch (10 cm) and compost mulch (10 cm). The unmulched control consistently recorded the lowest values for all parameters.

4. Discussions

Significant and consistent variations in morpho-physiological and yield-related parameters were observed across different mulching treatments in *Crossandra infundibuliformis* (L.) Nees, unequivocally demonstrating that both the type and thickness of mulch material exert a profound and decisive influence on vegetative growth dynamics, phenological advancement, floral yield and overall agronomic performance of the crop. The markedly superior vegetative growth indices encompassing plant height, number of branches per plant, leaf area index and total dry matter accumulation recorded under black polyethylene mulch (Fig. 1) may be ascribed to its unique capacity to conserve soil moisture by substantially curtailing evaporative losses from the soil surface, maintain near optimal rhizosphere temperature and enhance root zone aeration, thereby collectively creating a thermodynamically and hydrologically favourable micro-environment that is conducive to sustained photosynthetic activity and accelerated biomass accumulation. The physiologically enriched root zone environment under polyethylene mulch facilitates enhanced mineral nutrient solubilisation, uptake and translocation, ultimately augmenting the metabolic efficiency of the crop canopy. Comparable physiological improvements in *Crossandra* have been substantiated by [22], who conclusively demonstrated that optimised micro-environmental conditions, particularly with respect to soil moisture and temperature regimes, significantly enhance chlorophyll biosynthesis, net assimilation rate and consequent vegetative vigour. In consonance with these findings, [7] reported that the judicious integration of nitrogen management with nano-urea applications synergistically improved plant height, lateral branching intensity and leaf area development in *Crossandra infundibuliformis* cv. Lakshmi, while [6] further corroborated that improved nutrient and irrigation management directly translates into measurable gains in vegetative parameters of this ornamental species. These findings are further substantiated by investigations in other floricultural and horticultural crops, wherein [10] and [14] conclusively established that polyethylene mulch significantly promotes photosynthetic efficiency, carbon assimilation and dry matter partitioning compared to unmulched or organically mulched controls, primarily through its superior reflectance characteristics and impermeability to water vapour.

The significant advancement in flowering phenology under polyethylene mulch, as evidenced by appreciably earlier days to first flower bud initiation, first flower opening and a notably extended total flowering duration, may be mechanistically attributed to the stable and optimal soil moisture and temperature conditions that collectively favour the complex cascade of physiological and biochemical processes governing floral induction and anthesis in *Crossandra*. Adequate soil moisture availability during critical developmental phases ensures uninterrupted turgor-driven cell expansion and sustained phytohormone biosynthesis, which are prerequisites for timely floral transition. These observations are in close agreement with the findings of [22], who unambiguously emphasised that environmentally optimised conditions, particularly moderated soil temperature and consistent moisture availability, significantly accelerate the flowering phenology in *Crossandra*. The genotypic sensitivity of flowering parameters to prevailing agro-environmental and edaphic conditions was further elucidated by [15], who documented significant variability in days to flowering, flowering duration and associated phenological traits among diverse *Crossandra infundibuliformis* genotypes under Konkan agro-climatic conditions, underscoring the pivotal role of micro-environmental modulation in determining flowering outcomes. Analogous responses have been systematically documented in other ornamental species by [11] and [17], where mulching treatments were shown to improve floral initiation, advance first bloom and meaningfully extend the productive blooming period. Furthermore, [4] and [9] collectively reported that mulched plots exhibited a significantly higher number of flower pickings per plant per season, which was attributed to enhanced efficiency of nutrient and water utilisation under favourable soil physical conditions created by mulching.

The recorded superiority in flower yield and the concomitant enhancement of qualitative attributes encompassing spike length, floret diameter, individual flower weight, post-harvest vase life and anthocyanin pigment concentration (Fig. 2) under polyethylene mulch may be mechanistically explained by the maintenance of favourable rhizosphere physicochemical conditions that optimise nutrient solubility and active absorption by root systems, thereby ensuring an uninterrupted supply of assimilates and structural precursors required for floral development and pigment biosynthesis. The biosynthesis of anthocyanins, which are flavonoid-class secondary metabolites and major determinants of flower colour intensity and post-harvest ornamental value, is particularly sensitive to fluctuations in temperature and oxidative stress, both of which are effectively moderated by polyethylene mulching.

Table 1. Effect of mulching on growth parameters of *Crossandra infundibuliformis*

Treatments	**Plant height (cm)**	**Branches plant^{-1}**	**LAI**	**Chlorophyll (SPAD)**	**DMP (g plant^{-1})**
T_1 : Control	28.54	3.25	1.05	32.04	109.84
T_2 : Straw mulch (5 cm)	31.03	3.83	1.20	33.53	124.97
T_3 : Straw mulch (10 cm)	35.52	4.69	1.45	35.89	159.13
T_4 : Compost mulch (5 cm)	33.07	4.27	1.30	34.56	139.52
T_5 : Compost mulch (10 cm)	36.25	4.85	1.50	36.03	152.87
T_6 : Polyethylene mulch	40.50	5.63	1.85	38.21	184.09
T_7 : Biodegradable mulch	34.04	4.41	1.35	35.01	149.24
CD (P = 0.05)	4.45	1.07	3.56	5.34	3.79
S Ed	2.04	0.49	1.63	2.45	1.74

Table 2. Effect of different mulching materials on flowering and yield parameters of *Crossandra infundibuliformis*

Treatments	**Days to first flowering**	**Days to peak flowering**	**Flowering duration (days)**	**No. of pickings**	**Flower yield (kg ha^{-1})**
T_1 : Control	54.33	71.06	42.55	18.87	3072.44
T_2 : Straw mulch (5 cm)	51.05	68.25	47.78	20.63	3631.56
T_3 : Straw mulch (10 cm)	48.42	65.58	52.42	23.54	4349.34
T_4 : Compost mulch (5 cm)	50.17	67.33	48.65	21.87	3930.64
T_5 : Compost mulch (10 cm)	47.98	64.90	53.00	22.08	4080.75
T_6 : Polyethylene mulch	45.02	62.42	57.02	25.91	5015.04
T_7 : Biodegradable mulch	49.25	66.16	50.93	21.27	3886.72
CD (P = 0.05)	4.45	1.07	3.56	1.42	522.06
S Ed	2.04	0.49	1.63	0.66	251.38

Analogous enhancement in flower yield and qualitative traits of *Crossandra* was systematically documented by [22] and [6], who established that improved physiological efficiency, particularly in terms of source–sink dynamics and nutrient use efficiency, constitutes the primary driver of superior floral attributes and marketable yield. Parallel findings in other ornamental crops were presented by [2], [20] and [21], all of whom attributed significantly enhanced flower pigmentation intensity, improved vase life and superior structural floral traits to the thermally and hydrologically stable root zone microclimate sustained by effective mulching practices.

Weed suppression efficiency was most pronounced and statistically significant under polyethylene mulch, a phenomenon primarily attributable to its physical opacity and light-impermeable nature, which effectively eliminates the photosynthetically active radiation (PAR) prerequisite for weed seed germination and early seedling establishment, thereby disrupting the weed life cycle at its most vulnerable stage. The physical barrier created by the mulch film also prevents the mechanical emergence of germinated weed seedlings from the soil surface, further reinforcing the herbicidal effect without chemical inputs. Comparable and well-documented weed-suppressive effects of polyethylene mulch have been reported in other horticultural production systems by [14] and [8], who provided quantitative data confirming significant reductions in weed density, weed biomass and weed species diversity under plastic mulched plots. Meanwhile, [4] and [2] reported that organic mulching materials such as paddy straw and compost, whilst offering moderately effective weed suppression through physical exclusion of light, simultaneously confer the added agronomic advantage of progressively enriching soil organic matter content, stimulating beneficial microbial communities and improving soil biological activity over successive crop seasons. These complementary mechanisms of

Table 3. Effect of different mulching materials on flower quality parameters of *Crossandra infundibuliformis*

Treatments	Flower length (cm)	Flower diameter (cm)	Weight of 100 flowers (g)	Vase life (days)	Anthocyanin content (mg g^{-1} FW)
T_1 : Control	3.82	3.82	28.42	7.17	0.48
T_2 : Straw mulch (5 cm)	4.01	4.01	29.73	8.27	0.54
T_3 : Straw mulch (10 cm)	4.30	4.30	31.25	10.10	0.62
T_4 : Compost mulch (5 cm)	4.08	4.08	30.16	9.10	0.57
T_5 : Compost mulch (10 cm)	4.22	4.22	31.04	10.50	0.62
T_6 : Polyethylene mulch	4.45	4.45	32.87	12.40	0.72
T_7 : Biodegradable mulch	4.15	4.15	30.42	9.23	0.60
CD (P = 0.05)	0.53	0.58	2.14	3.56	0.36
S Ed	0.24	0.26	0.98	1.63	0.16

Table 4. Effect of different mulching materials on weed parameters of *Crossandra infundibuliformis*

Treatments	Weed density (no. m^{-2})	Fresh weight (g m^{-2})	Dry weight (g m^{-2})	Weed density reduction (%)	Weed control efficiency (%)
T_1 : Control	115.02	539.33	361.31	0.00	0.00
T_2 : Straw Mulch (5 cm)	81.32	361.72	240.02	29.33	32.93
T_3 : Straw Mulch (10 cm)	50.01	245.01	159.74	56.52	53.72
T_4 : Compost Mulch (5 cm)	71.72	314.34	212.35	37.78	40.26
T_5 : Compost Mulch (10 cm)	59.04	274.32	176.01	48.73	51.28
T_6 : Polyethylene mulch	30.01	146.71	96.74	73.91	71.91
T_7 : Biodegradable mulch	43.72	217.78	147.01	62.07	43.95
CD (P = 0.05)	7.66	31.84	18.32	–	14.23
S Ed	3.52	14.61	8.41	–	6.53

weed management under mulching, by eliminating inter-specific competition for limiting resources including mineral nutrients, soil moisture and incident solar radiation, indirectly but substantially contribute to improved crop growth and productivity.

The significantly superior soil moisture retention capacity, appreciably extended irrigation intervals and markedly elevated water use efficiency (WUE) quantified under polyethylene mulch provide compelling empirical validation of the well-established principle that impermeable mulch films effectively intercept and arrest the upward capillary flux of soil water towards the evaporative surface, thereby substantially reducing non-productive evaporative losses from the soil–plant–atmosphere continuum. These observations are in strong concordance with the findings of [16], [14] and [13], who reported across independent experimental systems that mulching practices minimise evaporative water losses, maintain soil moisture at plant-available levels for extended periods and consequently optimise crop water productivity under conditions of limited and erratic precipitation. Similarly, [11] and [4] demonstrated that the thermal buffering capacity of mulch materials by modulating diurnal and seasonal soil surface temperature fluctuations significantly improves overall water productivity under semi-arid agro-climatic conditions characterised by high evapotranspiration demand. These findings are further corroborated by the investigations of [6] in *Crossandra*, who convincingly demonstrated that the conjunctive management of soil moisture conservation and enhanced nutrient availability constitutes the primary mechanism through which mulching improves floral yield, quality and overall crop performance of this commercially important ornamental.

The economic analysis of mulching treatments unambiguously revealed that polyethylene mulch achieved the highest gross returns, net returns per unit area and benefit-cost ratio (BCR), primarily driven by its capacity to deliver significantly enhanced marketable flower yield coupled with superior qualitative attributes that command premium market prices. These economic

Table 5. Effect of different mulching materials on soil moisture and water use efficiency of *Crossandra infundibuliformis*

Treatments	Soil moisture (0–15 cm) (%)	Irrigation interval (days)	Total water applied (mm)	Water productivity (kg mm^{-1})	Water use efficiency (kg ha^{-1} mm^{-1})
T_1 : Control	13.42	3.14	310.66	9.91	9.91
T_2 : Straw Mulch (5 cm)	16.64	3.63	290.45	12.53	12.53
T_3 : Straw Mulch (10 cm)	21.15	4.16	275.32	15.81	15.81
T_4 : Compost Mulch (5 cm)	17.67	3.87	285.68	13.79	13.79
T_5 : Compost Mulch (10 cm)	19.81	4.38	270.66	15.11	15.11
T_6 : Polyethylene mulch	23.56	4.91	250.40	20.06	20.06
T_7 : Biodegradable mulch	19.20	4.14	265.21	14.66	14.66
CD (P = 0.05)	1.16	0.37	1.59	1.28	1.28
S Ed	0.53	0.17	0.61	0.59	0.59

Table 6. Effect of different mulching materials on economics of *Crossandra infundibuliformis*

Treatments	Total cost (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C Ratio
T_1 : Control	50,000.00	163,395.00	88,240.00	2.76
T_2 : Straw Mulch (5 cm)	55,000.00	195,705.00	108,395.00	2.97
T_3 : Straw Mulch (10 cm)	57,000.00	176,850.00	138,705.00	3.43
T_4 : Compost Mulch (5 cm)	57,500.00	183,600.00	119,350.00	3.08
T_5 : Compost Mulch (10 cm)	61,000.00	225,675.00	122,600.00	3.01
T_6 : Polyethylene mulch	69,500.00	174,870.00	156,175.00	3.25
T_7 : Biodegradable mulch	85,000.00	138,240.00	89,870.00	2.06

outcomes are entirely consistent with the yield and economic variability data reported by [15] among diverse *Crossandra infundibuliformis* genotypes evaluated under varying agro-climatic conditions and are further reinforced by comparable economic benefit assessments of mulching documented by [20] and [17] across multiple ornamental and flower crop species. It is, however, imperative to contextualise these economic advantages within the broader framework of environmental sustainability, given the well-documented ecological concerns associated with the persistence and accumulative soil contamination potential of polyethylene mulch residues, as highlighted by [25] and [10]. Polyethylene films, being recalcitrant to biological degradation, progressively fragment into microplastic particles that persist in the soil matrix for extended periods, potentially disrupting soil structure, microbial ecology and long-term land productivity. In direct response to these sustainability imperatives, [13] and [21] have recently advocated for biodegradable mulching materials including polylactic acid (PLA) films and starch-based composites as ecologically responsible and agronomically viable alternatives, demonstrating comparable efficacy in terms of soil moisture conservation, crop yield enhancement and water use efficiency whilst simultaneously eliminating the environmental burden associated with residue management. Collectively and in the broader global context, the present findings are in strong agreement with those of [22], [6] and [15], collectively affirming that the growth, flowering phenology, yield and qualitative attributes of *Crossandra infundibuliformis* respond significantly and favourably to the improved soil moisture conservation and enhanced nutrient management regimes achieved through systematic mulching interventions. Polyethylene mulch emerged as the most agronomically and economically effective mulching material under the prevailing semi-arid agro-climatic conditions of Ananthapuramu, followed in performance by paddy straw and compost mulches. Nevertheless, from the perspective of long-term agricultural sustainability and environmental stewardship, future research endeavours should prioritise the systematic investigation and field-level validation of biodegradable and eco-friendly mulching materials in *Crossandra infundibuliformis* production systems, with the dual objective of ensuring ecological safety and sustaining high levels of crop productivity across agro-climatic regions.

Figure 1. Treatment plot Polyethylene mulch of Crossandra infundibuliformis

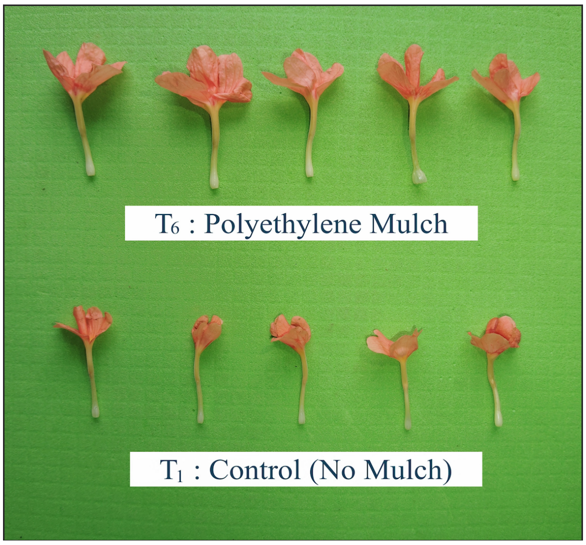

Figure 2. Effect of mulching on flower characteristics of Crossandra infundibuliformis

5. Conclusion

The study revealed that mulching significantly influenced the growth, flowering, yield, flower quality and economics of *Crossandra infundibuliformis* under the semi-arid conditions of Ananthapuramu. Among the treatments, black polyethylene mulch (50 μm) proved superior by recording the highest plant height, number of branches, flower yield, anthocyanin content and vase life, along with the lowest weed density and optimum soil moisture retention. These improvements are attributed to better soil temperature regulation, enhanced nutrient uptake and favourable root-zone conditions created by the mulch. Organic mulches such as dried leaves and coconut husk also enhanced crop performance compared to the unmulched control, highlighting their potential as sustainable alternatives.

Economically, polyethylene mulch provided the highest net returns and benefit–cost ratio owing to improved flower yield and quality traits. Hence, polyethylene mulch can be recommended for maximising productivity and profitability in *Crossandra* cultivation. However, for long-term sustainability and environmental safety, the use of biodegradable or organic mulching materials should be explored as viable alternatives to plastic mulch.

6. References

1. AICRP on Floriculture (2023). *Annual Report 2022–23*. ICAR-IIHR.
2. Bogunović, I., Pereira, P., & Rahman, M. M. (2023). Effects of different mulching materials on soil properties, crop yield and weed suppression in ornamental plant cultivation. *Journal of Environmental Management*, 345(2), 118623.
3. Chaudhary, R., & Kapoor, D. (2023). *OPSTAT: Statistical software for agricultural research*. CCSHAU.
4. Demo, P., Njeru, R. W., & Gachene, C. K. (2024). Impact of organic and synthetic mulching on soil temperature, weed suppression and flower yield. *Horticultural Science Reports*, 19(1), 45–56.
5. Giusti, M. M., & Wrolstad, R. E. (2001). Anthocyanins: Characterization and measurement with UV-visible spectroscopy. *Current Protocols in Food Analytical Chemistry*, F1.2.1–F1.2.13.
6. Gowtham, R., & Karuppaiah, P. (2024). Effect of nutrient and irrigation management on growth and flowering of *Crossandra infundibuliformis*. *Journal of Ornamental Horticulture*, 27(1), 45–52.
7. Gowtham, S., & Karuppaiah, P. (2024). Influence of nitrogen and nano urea on growth and yield of *Crossandra infundibuliformis*. *The Crop Research*, 59(3–4), 235–241.
8. Heidari, M., Hosseinzadeh, S. R., & Shakiba, M. R. (2023). Weed suppression and soil moisture retention under mulching. *Agricultural Research Journal*, 60(1), 89–98.
9. Hossain, M. A., Rahman, M. M., & Islam, M. N. (2022). Effect of mulching on ornamental plants. *Bangladesh Journal of Agricultural Research*, 47(4), 521–532.
10. Huang, X., Li, Y., & Chen, Z. (2024). Biodegradable vs polyethylene mulches. *Scientia Horticulturae*, 328, 111614.
11. Iacuzzi, N., Pérez, A., & Moriconi, M. (2024). Role of mulching in ornamental plants. *Horticulture International Journal*, 12(2), 55–63.
12. Jackson, M. L. (1973). *Soil Chemical Analysis*. Prentice Hall of India.
13. Jin, Y., Zhang, H., & Li, L. (2024). Biodegradable mulches in floriculture. *Agronomy*, 14(5), 1042.
14. Li, Q., Zhang, Y., & Wang, J. (2025). Effects of

mulch type on yield. *Journal of Applied Horticulture*, 27(1), 18–28.

15. Madhuma, S. K., et al. (2025). Genotypic variability in *Crossandra*. *International Journal of Biochemistry Research*, 9(9S), 82–91.
16. Mansoor, S., Ahmed, M., & Hassan, I. (2022). Mulching and irrigation management. *Irrigation Science*, 40(3), 459–470.
17. McIntosh, C. A., Jensen, T., & Li, K. (2023). Plastic mulching impacts. *Horticultural Plant Journal*, 9(4), 512–521.
18. Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L. A. (1954). Estimation of available phosphorus in soils. USDA Circular 939.
19. Panse, V. G., & Sukhatme, P. V. (1985). *Statistical Methods for Agricultural Workers*. ICAR.
20. Park, J., Kim, S., & Han, D. (2025). Evaluation of mulching materials. *Floricultural Research*, 12(1), 33–45.
21. Shcherbatyuk, D. M., Ivanova, T. Y., & Volkov, E. A. (2024). Mulches in ornamental horticulture. *Plants*, 13(2), 275.
22. Srinivasulu, G. B., et al. (2024). Growth regulators in *Crossandra*. *International Journal of Biochemistry Research*, 8(2S), 115–123.
23. Subbiah, B. V., & Asija, G. L. (1956). Estimation of available nitrogen. *Current Science*, 25, 259–260.
24. Walkley, A., & Black, I. A. (1934). Soil organic matter determination. *Soil Science*, 37, 29–38.
25. Xie, T., Liu, Z., & Zhou, W. (2025). Environmental implications of polyethylene mulch. *Journal of Cleaner Production*, 456, 143029.