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RESEARCH ARTICLE

Enriched retted coir pith compost - A potential organic amendment for yield and quality improvement in *Amaranthus tricolor*

Ameya Satheesh[1], Sheeja K Raj[2*], Jacob D[3], Shalini Pillai P[1] & K N Anith[4]

[1]Department of Agronomy, College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram 695 522, Kerala, India
[2]Department of Organic Agriculture, College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram 695 522, Kerala, India
[3]OFR Centre, Onattukara Regional Agricultural Research Station, Kayamkulam, Kerala Agricultural University, Thiruvananthapuram 690 502, Kerala, India
[4]Department of Microbiology, College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram 695 522, Kerala, India

*Correspondence email - sheeja.raj@kau.in

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Abstract

Raw coir pith, due to its high carbon-to-nitrogen (C:N) ratio (>100:1) and high lignin, cellulose and polyphenol content, is unsuitable for direct application in crop production because of nutrient immobilization and phytotoxic effects. Composting converts raw coir pith into a stable, nutrient-rich organic amendment. This study evaluated the effect of enriched retted coir pith compost (ERCC), in combination with the recommended dose of fertilizers (RDF), on the growth, yield and quality of *Amaranthus tricolor*. A factorial experiment was conducted with two factors: RDF at three levels (100 %, 75 % and 50 %) and ERCC at three rates (18.5, 12.5 and 6.25 t ha^{-1}), along with a control using farm yard manure (FYM) at 25 t ha^{-1}. Application of 18.5 t ha^{-1} ERCC with 75 % RDF significantly enhanced plant growth and yield, resulting in a 62 % yield increase compared to the control. The lowest oxalate content (8.4 mg 100^{-1} g dry weight) was observed with 6.25 t ha^{-1} ERCC combined with 100 % or 50 % RDF, while the lowest nitrate content (1065 mg kg^{-1} dry weight) was recorded with 12.5 t ha^{-1} ERCC and 50 % RDF. The control recorded the highest oxalate (20.3 mg 100^{-1} g dry weight) and nitrate (3435 mg kg^{-1} dry weight) contents. Notably, the treatment with 18.5 t ha^{-1} ERCC and 75 % RDF also reduced oxalate and nitrate levels (14.75 mg 100^{-1} g and 1290 mg kg^{-1} dry weight, respectively). The study highlighted the benefits of ERCC as a

Introduction

Amaranthus a short duration, herbaceous annual plant belonging to the Amaranthaceae family, widely distributed across the globe (1). Its leaves are known for their low saturated fat content and absence of cholesterol, making them a viable alternative to animal protein in the human diet. They contain 13-18 % protein, which is higher than that of wheat (14 %) and corn (10.3 %) (2). In addition, *Amaranthus* leaves are rich in dietary minerals such as calcium (Ca), potassium (K), copper (Cu), magnesium (Mg), phosphorus (P), iron (Fe) and zinc (Zn), as well as vitamins like β-carotene, vitamin B6, vitamin C, riboflavin and folate (3).

Organic amendments, derived from plant or animal sources, are rich in organic matter and are added to the soil to enhance its soil physical and chemical properties, improve soil health and promote plant growth (4, 5). Benefits of organic amendments include improved soil structure, increased water holding capacity, enhanced soil microbial activity, better nutrient availability, carbon sequestration, reduced soil compaction, decreased reliance on chemical fertilizers (6). Common organic amendments include composts, manures, green manures and biochar.

Coir pith, a byproduct of the coir industry, has a high-water retention capacity (500-600 %) and significant potassium content, making it a potential substitute for sphagnum peat (7). Its low bulk density and high specific surface area result in a high cation exchange capacity (CEC) which enhances nutrient retention. However, raw coir pith has limitations due to high C:N ratio (100:1), lignin, cellulose and polyphenol content, which can lead to nutrient immobilization and phytotoxic effects (8). The presence of polyphenols restricts N release by forming complexes with organic compounds (9, 10). Consequently, coir pith is unsuitable as a direct soil amendment.

Composting is the viable option to reduce the ill effects of raw coir pith. Composting coir pith significantly reduces its lignin and polyphenol content while increasing its levels of N, P and K (11). Coir pith compost has been shown to improve soil structure, texture, water-holding capacity, hydraulic conductivity and overall nutrient status. Due to its high organic matter content, it enhances soil organic carbon levels and promotes microbial activity. These properties contribute to improved crop growth and yield.

When enriched, coir pith compost has demonstrated positive effects on plant development. For example, it improved seedling growth in *Amaranthus* (12) and when combined with bone meal powder and panchagavya, it enhanced the leaf area index (LAI) and dry matter production (DMP) in barnyard millet (13). A combination of 75 % recommended dose of fertilizers (RDF), coir pith compost, 1.25 % mushroom spawn and 5 % poultry manure increased LAI and the number of branches per plant in onion and cassava (14).

The integrated use of organic and inorganic fertilizers has been shown to improve fertilizer use efficiency, reduce nutrient losses and enhance crop productivity. It also improves soil structure and serves as a long-term nutrient reservoir (15, 16). In grain *Amaranthus*, optimum growth, yield and economic returns were achieved with 60 N kg ha^{-1}, comprising 75 % N from chemical fertilizer and 25 % from bio-compost (17). Similarly, the application of pseudostem compost (750 kg ha^{-1}) with 75 % RDF significantly improved *Amaranthus* yield (18). Similarly, the application of enriched pseudostem compost at 750 kg ha^{-1} combined with 75 % of the RDF (90:45:67.5 kg N, P_2O_5 and K_2O ha^{-1}) had a significant impact on *Amaranthus* yield (18). The use of 50 % RDF along with vermicompost, *Azotobacter* and phosphate-solubilizing bacteria also resulted in higher yields (19). Another study reported improved growth and yield in grain amaranth with the application of 75 % NPK and bio-compost (20).

In this context, the present study investigates the effects of graded levels of RDF and different application rates of enriched retted coir pith compost (ERCC) on the growth, yield and quality of *Amaranthus tricolor*.

Materials and Methods

A field experiment was conducted at the research field of Instructional Farm, College of Agriculture, Vellayani, located at 8° 25′43″ N latitude, 76°59′98″ E longitude and 29 m above mean sea level (MSL) during the summer season of 2023-24 (February 2024-April 2024). The experiment was laid out in randomized block design with two factors. The first factor included three levels of RDF:100 % RDF (100:50:50 NPK kg ha^{-1}), 75 % RDF and 50 % RDF. Second factor consisted of three levels of ERCC compost-18.5 t ha^{-1}, 12.5 t ha^{-1} and 6.25 t ha^{-1}-along with a control treatment using farm yard manure (FYM) at 25 t ha^{-1}. The ERCC used in the study was prepared through aerobic composting. The composting site was covered with a roof to protect it from direct sunlight and rain. The ERCC was made by mixing 90 kg retted coir pith, 5 kg poultry manure, 5 kg FYM, 500 g rock phosphate, 500 g lime and 100 g of talc-based formulation of *Trichoderma asperellum*. The mixture was heaped and maintained under moist aerobic conditions by sprinkling water and turning the heap once every seven days. The compost matured in 35 days. The final ERCC contained 15.80 % C, 0.877 % N, 0.35 % P, 1.147 % K, 10.6 mg kg^{-1} Fe, 0.406 mg kg^{-1} Mn, 10.2 mg kg^{-1} Zn, 0.150 mg kg^{-1}Cu, with a C:N ratio of 18:1. The lignin, cellulose and phenol contents were 4.76 %, 8.76 % and 2.76 mg g^{-1}, respectively-significantly lower than those in raw retted coir pith.

The ERCC was applied as per the treatments prior to transplanting *Amaranthus* seedings. Half of the N and full dose of P and K were applied as a basal dose. The remaining half of the N was applied 15 days after transplanting (DAT) (21). Nutrients were supplied through urea (for N), rock phosphate (for P_2O_5) and muriate of potash (for K_2O).

The soil of the experimental field was sandy loam in texture, strongly acidic in reaction (pH 4.83), with low electrical conductivity (EC) of 0.1 dS m^{-1}. It was low in organic carbon (0.48 %) and available N (283.3 kg ha^{-1}), but high in available P (43.0 kg ha^{-1}) and K (251 kg ha^{-1}). A hot climate prevailed during the cropping period. Weather data, including mean maximum and minimum temperatures, relative humidity, rainfall and sunshine hours, were recorded from the Class B Agrometeorological Observatory at the College of Agriculture, Vellayani.

During the experimental period, the mean maximum temperature ranged from 33.2 °C to 34.4 °C and the mean minimum temperature ranged from 21.4 °C to 25.8 °C. The mean maximum relative humidity varied between 84 % and 86.6 %, while the mean minimum relative humidity ranged from 64.5 % to 74.4 %. The total rainfall received during the crop period was 112.3 mm and the mean sunshine hours during the period was 8.6 hr.

The *Amaranthus* variety used for the study was 'Arun' which was released from Kerala Agricultural University has a yield potential of 20 t ha^{-1} (22) Seedlings were initially raised in a nursery, where seeds were sown at a rate of 1.5 kg ha^{-1}. The nursery area was manured with ERCC at a rate of 10 kg m^{-1}. Twenty-day-old seedlings were transplanted into the main field at a spacing of 25 cm × 15 cm. The gross plot size was 3 m × 3 m. The experiment included 12 treatments; each replicated three times. A total of 240 plants were maintained per treatment.

Observations on plant height, number of branches and number of leaves per plant were recorded from tagged plants at 15-day intervals, specifically at 15 days after transplanting (15 DAT) and 30 DAT. For the determination of DMP per plant, root volume and root dry weight, three plants were randomly uprooted from outside the net plot area to avoid disturbing the experimental plots. The water replacement technique was adopted to determine the root volume (23). The leaf area of *Amaranthus* was calculated using the formula (24):

Leaf area = L × B × constant (Eqn. 1)

Where L = Length of the leaf in cm

B = Breadth of the leaf in cm

The leaf area index was then calculated using the formula (25):

Leaf area index = leaf area/ ground area (Eqn. 2)

Amaranthus was harvested by cutting the plants at 10 cm above ground level to ensure a higher leaf yield. The yield from the net plot area was recorded and expressed in kg ha^{-1}. The antinutritional factors, specifically oxalate and nitrate contents of the *Amaranthus* leaves, were determined at the time of harvest using standard procedures (26, 27). The cost of cultivation and gross return were calculated based on the total cost of inputs and the market price of the harvested produce. Data were statistically analysed using Grapes Agri 1, an opensource R package for agricultural research data analysis (28). When treatment effects were found to be significant, mean comparisons were conducted using the critical difference at a 5 % probability level.

Effect of graded levels of RDF and ERCC on growth parameters

Interaction effect between graded levels of RDF and different application rates of ERCC had a significant effect on growth characters, as presented in Table 1. At 30 days after transplanting (DAT), the treatment d_2c_2 (75 % RDF along with 18.5 t ha^{-1} ERCC) resulted in taller plants and was statistically on par with treatments d_3c_2, d_3c_3 and d_2c_3. At 15 DAT, d_2c_2 also recorded a greater number of branches per plant, comparable to d_3c_1, d_3c_3 and d_3c_4. However, at 30 DAT d_3c_3 produced greater number of branches per plants which was on par with d_2c_1, d_3c_4 and d_2c_2. The number of leaves per plant was also higher in d_2c_2 at both 15 DAT and 30 DAT. At 15 DAT, it was on par with d_1c_3, d_2c_1, d_3c_1, d_3c_2 and d_3c_3, while at 30 DAT, it was on par with d_2c_1. Better expression of growth attributes in these treatments may be attributed to the synergistic effects of organic and inorganic nutrients sources. In general, treatments involving ERCC showed better growth performances than those with farm yard manure (FYM). The addition of ERCC improved water holding capacity, aeration, porosity and reduced bulk density (7). These improvements in soil structure and nutrient retention capacity helped minimize nutrient loss and ensured a steady nutrient release throughout the crop growth period. Among all treatments, the application of 18.5 t ha^{-1} ERCC combined with 75 % RDF (d_2c_2) consistently resulted in superior growth attributes (Table 1). This effect may be due to the moderate use of inorganic fertilizers, which helps prevent nutrient imbalances, increases nutrient availability and minimizes the risk of salt or mineral toxicity. Similar findings were reported in spinach, where 75 % RDF produced taller plants compared to 50 % and 30 % RDF (29). Corresponding results in onion and cassava also showed greater number of leaves and taller plants when 75 % RDF was applied along with a compost mixture of coir pith, mushroom spawn and poultry manure (14).

Effect of levels of RDF and ERCC on leaf area index and dry matter production

LAI was significantly influenced by the interaction between different levels of RDF and varying application rates of ERCC, as shown in Fig. 1. Leaf area index is the key indicators of plant's photosynthetic capacity, representing the ratio of leaf area to ground area. It plays a crucial role in determining how efficiently a plant converts available resources-such as light, water and nutrients-into biomass, thereby directly affecting crop productivity. The treatment d_3c_3 (ERCC at 12.5 t ha^{-1} with 50 % RDF) resulted in higher LAI at both 15 DAT and 30 DAT. At 15 DAT, this treatment was statistically on par with d_3c_2, d_3c_1 and d_2c_2, while at 30 DAT, it was comparable with d_2c_2. The higher LAI observed in these treatments may be attributed to the greater number of leaves per plant (Table 1) and larger leaf surface area. Increased leaf production and size are likely due to better nutrient availability and uptake, resulting in improved canopy development. The plants grown in nutrient rich media typically exhibit higher LAI compared to those in nutrient poor conditions (29, 30). Moreover, balanced nutrient supply is known to enhance the leaf area and photosynthetic efficiency (31). In spinach, application of coir pith compost at 10 t ha^{-1}along with 75 % N from inorganic sources increased both leaf length and width (32).

The interaction between RDF levels and ERCC application rates also had a significant effect on DMP at both 15 DAT and 30 DAT, as illustrated in Fig. 2. At 15 DAT, the treatment d_2c_1 recorded higher DMP, which was statistically on par with d_2c_2. However, at 30 DAT, the treatment, d_2c_2 resulted in the highest DMP, followed by d_1c_1. The increased DMP in these treatments can be attributed to higher LAI (Fig. 1) and the overall better expression of growth attributes**.** Previous studies have shown a direct relationship between LAI and DMP (33). As LAI increases, interception of solar radiation also increases, enhancing photosynthesis and ultimately leading to greater dry matter accumulation per plant over time. Similarly, in grain amaranth, the combined application of 75 % RDF and 25 % bio-compost resulted in significantly higher DMP (34).

Effect of levels of RDF and ERCC on root dry weight and root volume of *Amaranthus*

The interaction between different levels of RDF and enriched retted coir pith had a significant effect on root dry weight at 15 DAT and 30 DAT and on root volume at 15 DAT, as presented in Table 2. At 15 DAT, the treatment d_1c_4, resulted in higher root dry weight which was statistically on par with d_1c_3 and d_2c_1. At 30 DAT, d_3c_3 resulted in the highest root dry weight (0.840) which was on par with d_3c_4 and d_3c_1. For root volume at 15 DAT, d_1c_4 showed higher root volume, comparable to d_1c_3 and d_2c_1. Root growth in crops is significantly influenced by environmental factors and nutrient availability (35). The higher root dry weight and root volume observed in these treatments may be attributed to improved root development, supported by better nutrient availability and favourable environmental conditions—such as optimal soil temperature, adequate moisture content and improved physical, chemical and biological soil properties (36).

Effect of different levels of RDF and ERCC on yield of *Amaranthus*

The yield of *Amaranthus* was significantly influenced by the

Table 1. Effect of different levels of recommended dose of fertilizers and the application of enriched retted coir pith compost on growth parameters of *Amaranthus*

Treatments	Plant height cm		Number of branches per plant		Number of leaves per plant	
	15 DAT	30 DAT	15 DAT	30 DAT	15 DAT	30 DAT
d_1c_1:100 % RDF × 25 t FYM (control)	29.6	68.0	6.0	10.0	38.0	87.9
d_1c_2:100 % RDF × 18.5 t ERCC	36.9	63.5	7.0	8.5	34.0	68.7
d_1c_3: 100 % RDF ×12.5 t ERCC	35.0	75.8	8.0	9.8	49.3	92.4
d_1c_4: 100 % RDF × 6.25 t ERCC	29.7	61.4	5.7	9.8	26.7	86.1
d_2c_1: 75 % RDF × 25 t FYM	42.5	67.9	9.3	11.5	51.3	123.6
d_2c_2: 75 % RDF × 18.5 t ERCC	45.5	83.3	9.7	10.7	53.0	131.6
d_3c_3: 75 % RDF × 12.5 t ERCC	40.0	71.1	8.7	8.7	40.7	86.1
d_4c_4: 75 % RDF × 6.25 t ERCC	37.4	59.2	8.0	7.7	34.0	59.6
d_3c_1: 50 % RDF ×25 t FYM	38.6	72.5	7.0	8.8	48.0	84.3
d_3c_2: 50 % RDF × 18.5 t ERCC	42.1	78.3	8.3	8.8	49.0	79.8
d_3c_3: 50 % RDF × 12.5 t ERCC	44.2	77.3	8.5	11.8	47.0	117.4
d_3c_4: 50 % RDF × 6.25 t ERCC	39.1	70.7	8.0	10.8	44.0	106.3
SEm (±)	2.2	4.4	0.4	0.4	2.8	2.9
CD (P = 0.05)	NS	9.23	1.31	1.22	8.13	8.59

RDF: recommended dose of fertilizers; NS: not significant; DAT: days after transplanting; FYM: farm yard manure; ERCC: enriched retted coir pith compost.

Table 2. Effect of different levels of RDF and the application of enriched retted coir pith compost on root dry weight and root volume of *Amaranthus* at 15 and 30 DAT

Treatments	Root dry weight g		Root volume cm^3	
	15 DAT	30 DAT	15 DAT	30 DAT
d_1c_1:100 % RDF × 25 t FYM (control)	0.260	0.410	13.06	252.2
d_1c_2:100 % RDF × 18.5 t ERCC	0.237	0.417	11.89	201.0
d_1c_3: 100 % RDF ×12.5 t ERCC	0.397	0.500	19.93	201.0
d_1c_4: 100 % RDF × 6.25 t ERCC	0.400	0.590	20.10	250.7
d_2c_1: 75 % RDF × 25 t FYM	0.393	0.453	19.76	264.3
d_2c_2: 75 % RDF × 18.5 t ERCC	0.303	0.783	15.24	291.9
d_3c_3: 75 % RDF × 12.5 t ERCC	0.283	0.530	14.24	251.2
d_4c_4: 75 % RDF × 6.25 t ERCC	0.250	0.430	12.56	250.7
d_3c_1: 50 % RDF ×25 t FYM	0.227	0.740	11.39	201.4
d_3c_2: 50 % RDF × 18.5 t ERCC	0.177	0.480	8.88	244.1
d_3c_3: 50 % RDF × 12.5 t ERCC	0.210	0.840	10.55	251.7
d_3c_4: 50 % RDF × 6.25 t ERCC	0,263	0.760	12.90	251.7
SEm (±)	0.016	0.018	0.54	0.5
CD ($P = 0.05$)	0.0470	0.0540	1.583	NS

DAT: days after transplanting; RDF: recommended dose of fertilizers; FYM: farm yard manure; ERCC: enriched retted coir pith compost.

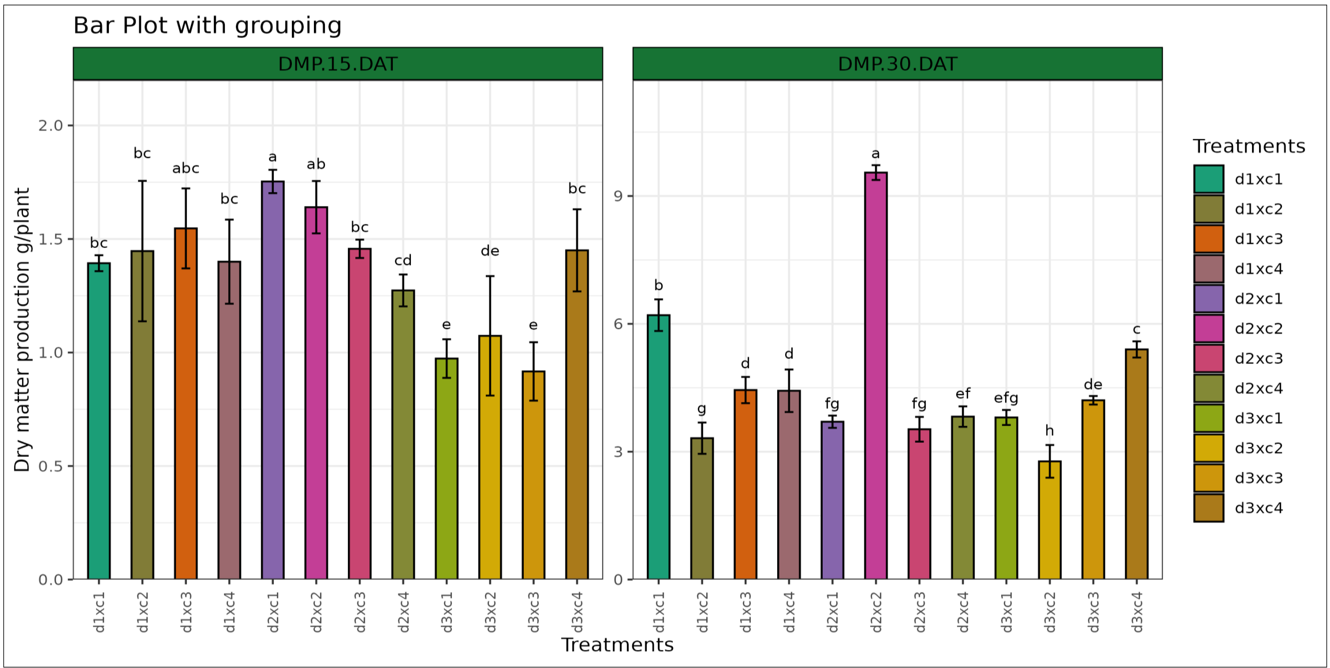

Fig. 1. Effect of different levels of RDF and the application of enriched retted coir pith compost on dry matter production at 15 and 30 DAT.

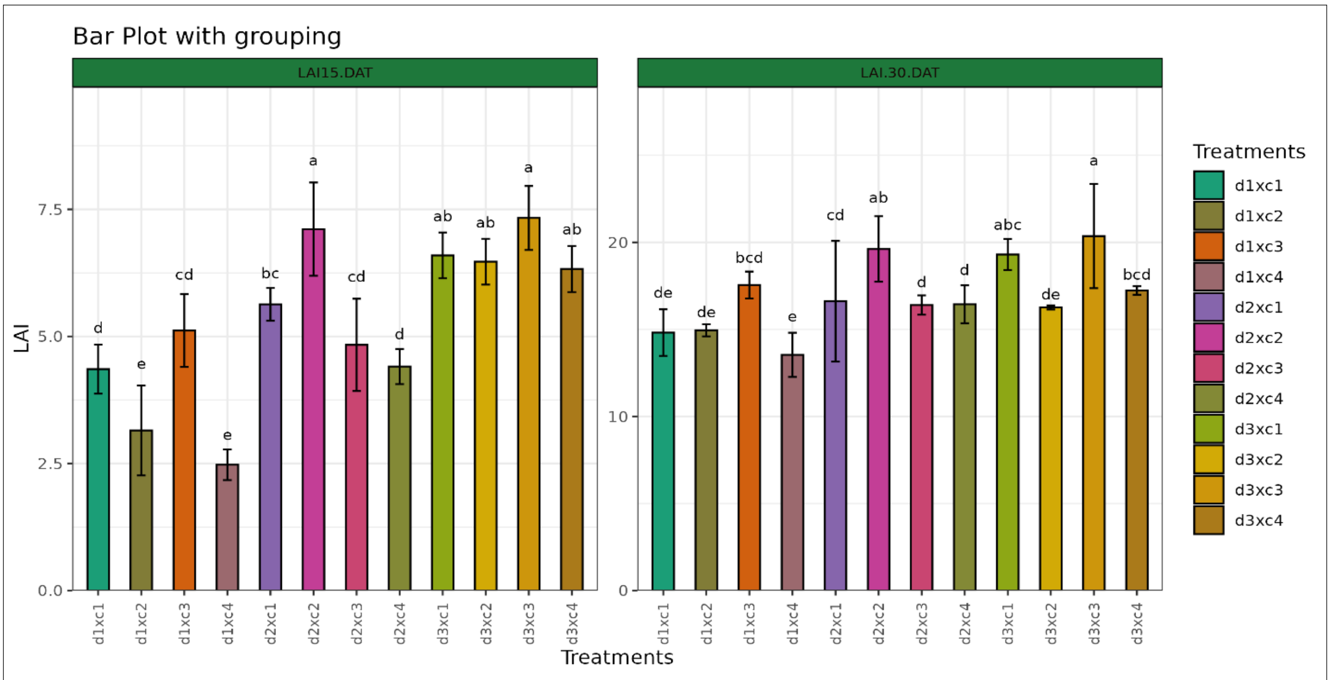

Fig. 2. Effect of different levels of RDF and the application of enriched retted coir pith compost on leaf area index of *Amaranthus* at 15 and 30 DAT.

interaction between RDF and ERCC, as shown in Fig. 3. The treatment d_2c_2 (75 % RDF combined with 18.5 t ha^{-1} ERCC) resulted in higher yield, with a 62 % increase over d_1c_1. The higher yield observed in $d_2c_2$can be attributed to the greater number of leaves and branches, DMP and taller plants (Fig. 2 and Table 1). This yield improvement may also be due to the beneficial effects of ERCC on soil properties, including enhanced structure, water holding capacity, porosity, reduced bulk density and improved nutrient retention. Incorporation of organic manures like ERCC has been shown to enhance root architecture, root activity and the effective absorbing area, thereby improving nutrient uptake (37). A larger root volume facilitates better absorption of water and nutrients, directly contributing to improved plant growth and biomass. Higher LAI also contributed to higher yield in d_2c_2, as leaves are the economic part of *Amaranthus*. Experimental evidence from other crops supports this relationship; in rice higher DMP and LAI were linked to greater yields (38). Additionally, higher LAI can reduce evaporation loss of water from the soil due to better ground coverage (39). Similar findings were reported in onion and cassava, where the application of 75 % NPK along with a compost mixture resulted in higher yields compared to 100 % NPK alone (14). In *Amaranthus*, greater yield was achieved when fertilized with 50 % RDF (60:40:20 kg ha^{-1}), combined with 50 % of the recommended dose of vermicompost (2.5 t ha^{-1}) along with *Azotobacter* and phosphate solubilising bacteria (PSB) as seed treatment at 20 g kg^{-1} seed, compared to either 100 % RDF or 100 % vermicompost alone (19). Additionally, applying 75 % RDF along with 25 % through vermicompost and *Azotobacter* resulted in higher yields in *Amaranthus* var. Arun (40).

Effect of different levels of RDF and ERCC on economics of cultivation of *Amaranthus*

The interaction between levels of RDF and rates of ERCC application had a significant effect on gross return, net return and BCR, as presented in Table 3. The treatment d_2c_2 (75 % RDF combined with 18.5 t ha^{-1}ERCC) resulted in the highest gross return (₹231360 ha^{-1}) and net return (₹88328 ha^{-1}), followed by d_3c_2(50 % RDF with 18.5 t ha^{-1} ERCC which yielded a gross return of ₹216280 ha^{-1} and a net return of ₹75436 ha^{-1}. The B:C ratio was also the highest in d_2c_2 (1.62), followed by d_1c_3 (100 % RDF with 12.5 t ha^{-1} ERCC). The superior yield in d_2c_2 (Fig. 2) contributed to its higher economic returns. Previous studies have also demonstrated similar findings. For example, the highest net return (₹130800 ha^{-1}) and BCR were reported in *Amaranthus* when coir pith compost (50 g), rock phosphate (19 g), groundnut cake (30 g) and a microbial consortium (1 g) were applied (41). In bitter gourd, application of 50 % NPK along with 50 % poultry manure resulted in the highest net return and a BCR of 3.14 (42). Similarly, in black pepper, application of coir pith compost at 1.25 t ha^{-1} in black petter resulted in a net return of ₹42630 ha^{-1}, followed by the application of 2.5 t ha^{-1} (43).

Effect of graded levels of RDF and ERCC on antinutritional factors *Amaranthus*

The interaction between graded levels of RDF and the rate of ERCC application had a significant effect on nitrate and oxalate content of *Amaranthus* (Fig. 4 and 5). Among the treatments, the lowest nitrate content was observed in d_3c_3 (1065 mg kg^{-1}), which was statistically on par with all other treatments except d_1c_3 and d_1c_1. The highest nitrate content was noted in d_1c_1 (3435 mg kg^{-1}). This increase in nitrate content with higher N application aligns with established findings that nitrogenous fertilizers contribute to nitrate accumulation in vegetables. Nitrate accumulation is a complex process influenced by both external and internal factors, including the type of and amount of N fertilizers, growth conditions, temperature, light intensity, moisture stress and storage conditions (44, 45). The lower nitrate content in d_3c_3 may be attributed to enhanced nitrate reductase activity, which reduces nitrate accumulation. Higher nitrate reductase activity has been associated with reduced nitrate levels under both green house and open field conditions. Previous studies also suggest that the rate and method of N application, along with factors such as nutrient availability, moisture availability, solar radiation and photoperiod, significantly influence nitrate accumulation in leafy vegetables (46).

Oxalates in plants are formed through metabolic processes and exist in soluble and insoluble forms (47). In the present study, the control treatment (d_1c_1) (100 % RDF with FYM 25 t ha^{-1}) resulted in higher oxalate content, whereas lower values were observed in d_1c_4 and d_3c_4. Agronomic factors such as variety, N source, inorganic ion availability, season, soil condition and time of harvest all influence oxalate accumulation in plants (48). The application of N in the form of nitrate fertilizers has been shown to increase oxalate levels more than ammoniacal forms (49). The elevated oxalate content in d_1c_1 may be due to increased availability of nitrate ion in the soil resulting from the combined application of 25 t ha^{-1} FYM and 100 % RDF.

Conclusion

This study evaluated the impact of ERCC, applied in combination with varying levels of RDF on the growth, yield and quality of *Amaranthus*. Among the various treatments, the application of 18.5 t ha^{-1} ERCC with 75 % RDF (75:37.5:37.5 kg N:P:K ha^{-1}) (d_2c_2) produced the highest yield, achieving a 62 % increase over the

Table 3. Effect of different levels of RDF and the application of enriched retted coir pith compost on economics of *Amaranthus* cultivation

Treatments	Gross returns ₹ ha^{-1}	Cost of cultivation ₹ ha^{-1}	Net return ₹ ha^{-1}	B:C ratio
d_1c_1:100 % RDF × 25 t FYM (control)	142600	140525	2,075	1.01
d_1c_2:100 % RDF × 18.5 t ERCC	172960	145220	27,740	1.19
d_1c_3: 100 % RDF ×12.5 t ERCC	195300	124400	70,900	1.57
d_1c_4: 100 % RDF × 6.25 t ERCC	132100	102712	29,388	1.29
d_2c_1: 75 % RDF × 25 t FYM	196540	138337	58,203	1.42
d_2c_2: 75 % RDF × 18.5 t ERCC	231360	143032	88,328	1.62
d_3c_3: 75 % RDF × 12.5 t ERCC	177540	122212	55,328	1.45
d_4c_4: 75 % RDF × 6.25 t ERCC	157780	100525	57,255	1.57
d_3c_1: 50 % RDF ×25 t FYM	153820	135149	17,671	1.13
d_3c_2: 50 % RDF × 18.5 t ERCC	216280	140844	75,436	1.54
d_3c_3: 50 % RDF × 12.5 t ERCC	178020	120024	57,996	1.48
d_3c_4: 50 % RDF × 6.25 t ERCC	141980	94337	47,643	1.51

DAT: days after transplanting; RDF: recommended dose of fertilizers; FYM: farm yard manure; ERCC: enriched retted coir pith compost.

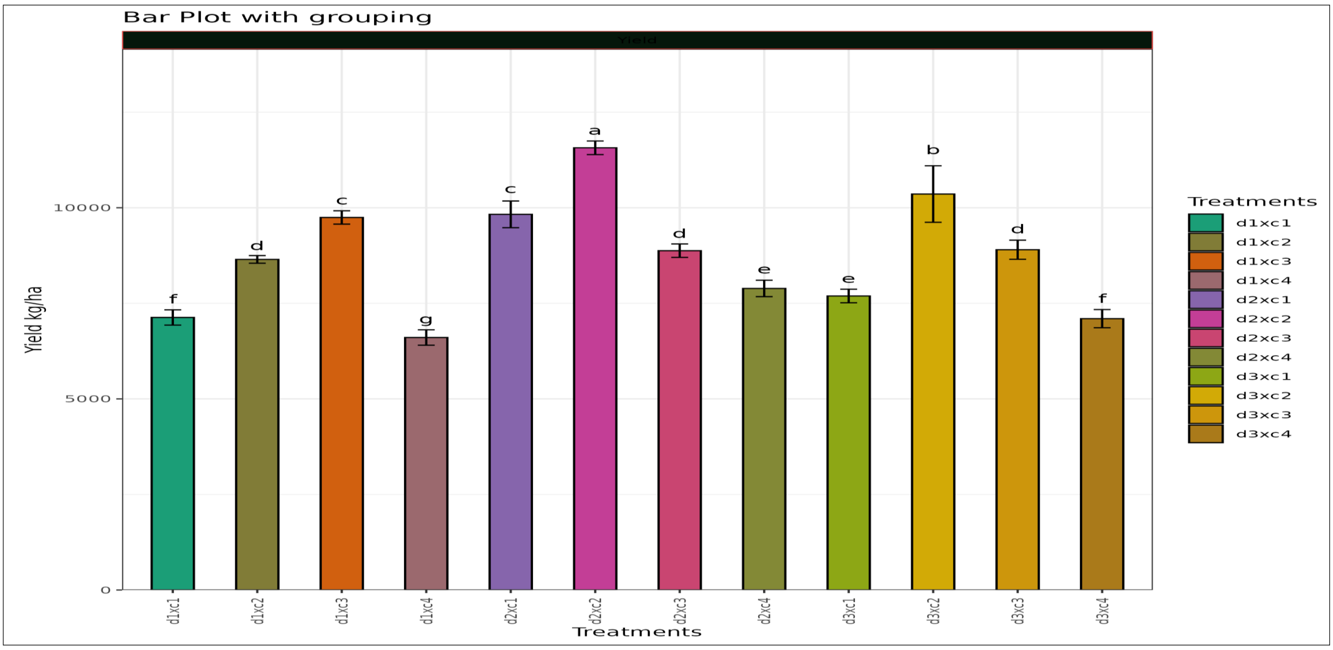

Fig. 3. Effect of different levels of RDF and the application of enriched retted coir pith compost on yield of *Amaranthus*.

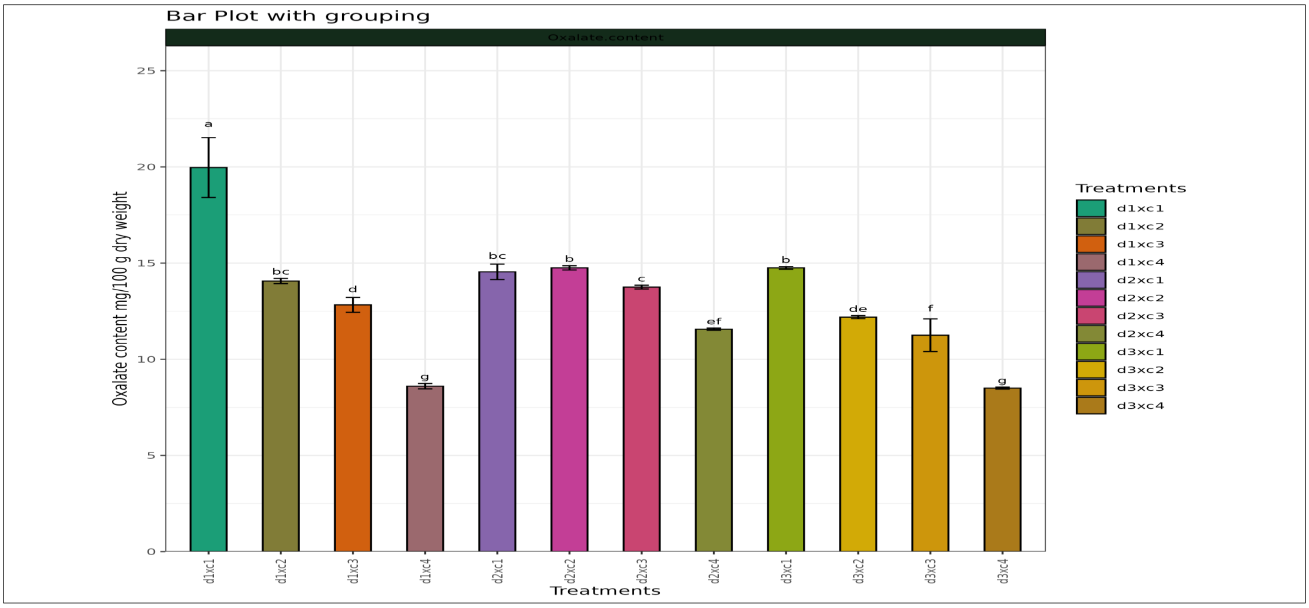

Fig. 4. Effect of different levels of RDF and the application of enriched retted coir pith compost on oxalate content of *Amaranthus*.

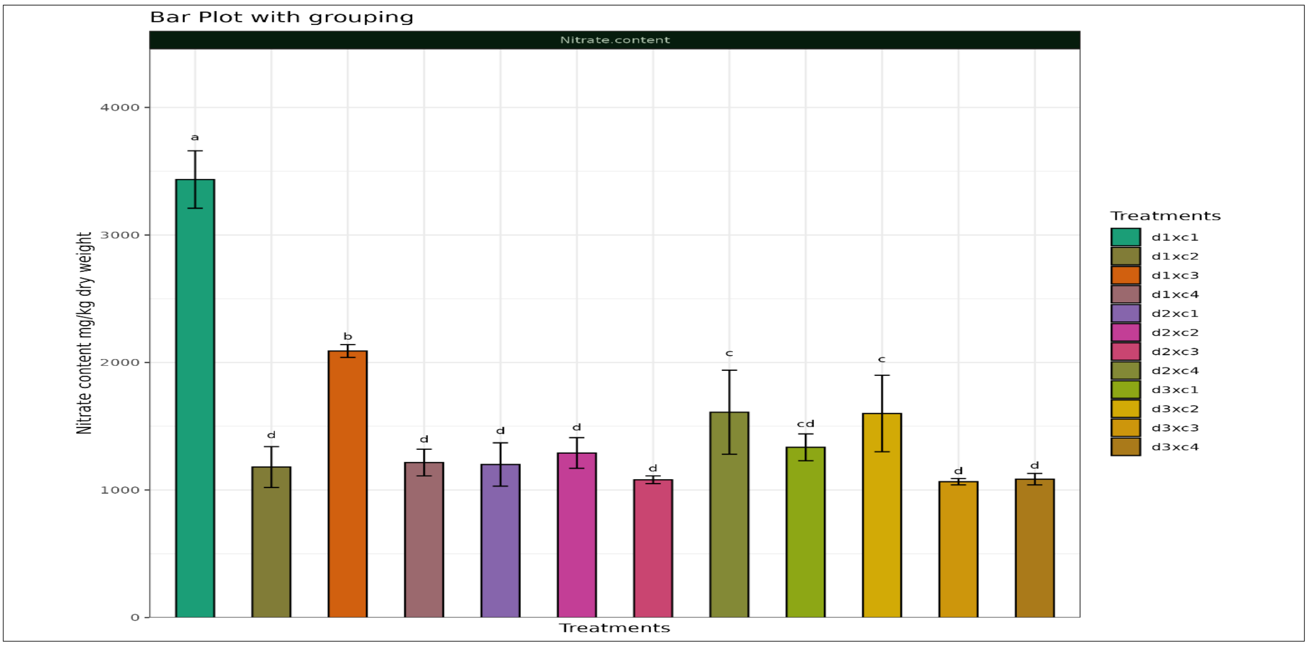

Fig. 5. Effect of different levels of RDF and the application of enriched retted coir pith compost on nitrate content of *Amaranthus*.

control treatment (25 t ha^{-1} FYM with 100 % RDF). Although the nitrate and oxalate levels in treatment d_2c_2 were slightly higher than those observed in treatments d_3c_3, d_1c_4 and d_3c_4, they were still significantly lower than the levels found in the control (d_1c_1) and remained well within acceptable safety limit. Based on superior yield, favourable economic returns and acceptable quality parameters, the d_2c_2 treatment [application of 18.5 t ha^{-1} ERCC with 75 % RDF (75:37.5:37.5 kg N:P:K ha^{-1})] is recommended as an effective and sustainable nutrient management strategy for *Amaranthus* cultivation. Future research should explore long-term field performance of ERCC with reduced RDF across varied agro-climatic conditions, focusing on soil health, nutrient cycling, food safety and the economic feasibility for smallholder adoption.

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Authors' contributions

SK conceptualized and designed the research paper. AS drafted the manuscript. Proper guidance was provided by DJ, SP and KN. All authors helped in the drafting and correction of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

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