

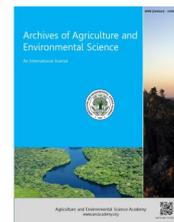


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ORIGINAL RESEARCH ARTICLE

Effects of integrated nutrient management on agronomical attributes of tomato (*Lycopersicon esculentum* L.) under field conditions

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ABSTRACT

In this investigation the effects of different integrated nutrient management on agronomical attributes of tomato (*Lycopersicon esculentum* L. cv. F₁ Hybrid Arka Rakshak) under field conditions were investigated. Ten nutrients treatments viz., without nutrient (control) (T₁), recommended dose of fertilizer (RDF) (T₂), agro residue vermicompost (ARV) @ 5 t ha⁻¹ (T₃), sugarcane pressmud compost (SPC) @ 5 t ha⁻¹ (T₄), cattle dung compost (CDC) @ 12.5 t ha⁻¹ (T₅), sewage sludge (SS) @ 2 t ha⁻¹ (T₆), T₇ (50 % RDF + ARV @ 5 t ha⁻¹), T₈ (50 % RDF + SPC @ 5 t ha⁻¹), T₉ (50 % RDF + CDC @ 12.5 t ha⁻¹) and T₁₀ (50% RDF + SS @ 2 t ha⁻¹) were used for the cultivation of *L. esculentum*. The results showed that different treatments showed significant (P<0.05/P<0.01) change in EC, OC, TKN, PO₄³⁻, Na⁺, K⁺, Ca²⁺, Mg²⁺, Cd, Cr, Cu, Fe, Mn and Zn of the soil. Among various treatments the most plant height, root length, dry weight, chlorophyll content, LAI, number of flowers/plant, fruits/plant, crop yield/plant, and biochemical ingredient like crude protein, dietary fiber, total carbohydrates and total sugar of *L. esculentum* was recorded with 50% RDF + ARV @ 5 t ha⁻¹. The agronomical performance of *L. esculentum* was recorded in the order of T₇ > T₁₀ > T₉ > T₈ > T₃ > T₆ > T₅ > T₄ > T₂ > T₁ treatments. Thus, sole ARV and 50% RDF along with ARV @ 5 t ha⁻¹ can be used to achieve the maximum crop yield of *L. esculentum*.

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INTRODUCTION

The use of integrated nutrient management concerned to the protection of soil productiveness and to provide these nutrients to the cultivated plants at an most favorable level for sustaining the desired yield through optimization of the benefits from all probable sources of organic, inorganic and biological ingredients in an integrated way (Prabhakar *et al.*, 2007; Sujatha *et al.*, 2008; Tetarwal *et al.*, 2011). Soil's potential to generate agricultural crops is principally determined by the environment that the soil provides for root growth. Roots absorb air, water, nutrients, and plenty space in which they develop (Shanwad *et al.*, 2010). Soil properties, such as the capability to hold up water, acidity, depth, and density determine how well roots development. Alteration in these soil characteristics unswervingly affects the health of the plant. For example, bulk density, a determination of the compactness of a soil, affects agricultural

productivity (Praharaj and Rajendran, 2007; Spurti *et al.*, 2015).

Organic fertilizers hold comparatively low concentrations of nutrients in contrast to chemical one, but they perform significant functions which the chemical fertilizers do not do (Jeyajothi and Nalliah, 2015). The addition of organic fertilizers and their appropriate administration can be decreased the need for chemical fertilizers thus allowing the small farmers to save in the part the price of manufacture. Additionally, the discharge of inorganic fertilizers compared to organic one is higher. As a result, available nutrients are utilized and lost rapidly by different means. Alternatively, organic fertilizers were decomposed gradually and nutrients are accessible for longer period of time which helps to preserve soil nutrient status (Praharaj and Rajendran, 2007; Tetarwal *et al.*, 2011).

The growth of crop plants is the result of a complex

process whereby the crop plants synthesizes sun power, carbon dioxide, water, and nutrients from the soil. In all, between 21 and 24 elements are necessary for plant growth (Kalhapure *et al.*, 2013). The primary nutrients for plant growth are nitrogen, phosphorus, and potassium (NPK). Whilst inadequate, these primary nutrients are mainly accountable for limiting crop development (Antil and Singh, 2007; Pandey and Chandra, 2013). Nitrogen, the most intensively used element, is accessible in almost infinite quantities in the atmosphere and is repeatedly recycled among plants, soil, water, and air. However, it is often unavailable in the right form for proper absorption and synthesis by the plant (Togay *et al.*, 2008).

As a vegetable tomato (*Lycopersicon esculentum*) is the most essential vegetable crops for human nutrition in most countries (Javaria and Khan, 2010; Pandey and Chandra, 2013). Tomato is one of the vital vegetable crops cultivated in India. Among the major contributing states Andhra Pradesh, Uttarakhand, Orissa, Karnataka, Madhya Pradesh, West Bengal, Uttar Pradesh, Bihar and Maharashtra the average productivity is highest in (35 t/ha) mostly due to the favorable environmental conditions and adoption of high yielding hybrids. However, India yet to attain the yield potential (80-120 t/ha) due to low adoption of hybrids and incidence of pests, diseases and other abiotic factors (Pandey and Chandra, 2013).

The dearth of plant nutrients causes different alteration in the physiological and biochemical processes within the plant cell resulting in a reduction of growth, delay of development and qualitative and quantitative decrease of yield (Saxena and Diwakar, 2012). The organic sources besides supplying N, P and K also formulate unavailable basis of elemental nitrogen, bound phosphorus, and other micronutrients, and decomposed plant residues into an obtainable form to make possible to plant to take up the nutrients. But, it is also the fact that most favorable yield of maize yield can not be achieved by using only organic manures due to their low nutrient content (Nehra and Hooda, 2002; Islam *et al.*, 2012). The usefulness of organic sources to meet the nutrient requisite of crop is not as assured as mineral fertilizers, but the joint employ of chemical fertilizers along with various organic sources is capable of improving soil quality and higher crop productivity on long- term basis (Islam *et al.*, 2012). Highest productivity of crops in sustainable manner with no worsening the soil and other natural resources could be achieved only by applying proper amalgamation of different organic manures and inorganic fertilizers (Chandrashekara *et al.*, 2000; Das *et al.*, 2004; Chopra *et al.*, 2012). It is important to identify the appropriate type of available organic resources which can be used as fertilizers and their best combination with appropriate proportion of inorganic fertilizer (Venugopalan and Pundarikakshudu, 1999; Rochester *et al.*, 2001; Basavanappa and Biradar, 2002; Hepperly *et al.*, 2009; Pandey and Chandra, 2013). Keeping in view, this experimental trail was carried out to study the effects of integrated nutrient management on agronomical attributes of tomato (*Lycopersicon esculentum* L.) under field conditions.

MATERIALS AND METHODS

Experimental design: The field experiments were conducted in the Experimental Garden of the Department of Zoology and Environmental Sciences, Gurukula Kangri University Haridwar, India (29°55'10.81" N and 78°07'08.12" E) during the year 2013 and 2014. For the cultivation of *L. esculentum*, ten plots (each plot had an area of 9× 9m²) were selected for the ten treatments viz., without nutrient (control) (T₁), recommended dose of fertilizer (RDF) (T₂), agro residue vermicompost (ARV) @ 5 t ha⁻¹ (T₃), sugarcane pressmud compost (SPC) @ 5 t ha⁻¹ (T₄), cattle dung compost (CDC) @ 12.5 t ha⁻¹ (T₅), sewage sludge (SS) @ 2 t ha⁻¹ (T₆), T₇ (50 % RDF + ARV @ 5 t ha⁻¹), T₈ (50 % RDF + SPC @ 5 t ha⁻¹), T₉ (50 % RDF + CDC @ 12.5 t ha⁻¹) and T₁₀ (50 % RDF + SS @ 2 t ha⁻¹) (Table 1). All the treatments were placed within randomized complete block design.

Preparation of nursery and transplantation of *L. esculentum*: Seeds of a high yield variety of *L. esculentum*, cv. F₁ Hybrid Arka Rakshak, were procured from Indian Council of Agriculture Research (ICAR), Pusa, New Delhi, and sterilized with 0.01% Thiram. The nursery was prepared before one month of transplantation of *L. esculentum*. For the nursery preparation 0.6 g seeds of *L. esculentum* were sown in the nursery beds (farm yard manure mixed soil). The bed for nursery preparation was covered with mulch of wheat straw till the germination of seeds. The plants were watered as per requirement and other agronomical practices like weeds removal and hoeing for soil preparation were performed till the plants were transplanted in the field. Four weeks old plants of *L. esculentum* were transplanted in 6 rows with a distance of 60×60 cm between plants (Chopra and Kanwar, 1976; Saxena and Diwakar, 2012). The plants in each plot were irrigated twice in a month with 100 gallons of bore well water and necessary agronomical practices were performed.

Study of crop parameters: The agronomic parameters of *L. esculentum* at different stages (0-110 days) were determined following standard methods for plant height, root length, number of flowers and crop yield (Saxena and Diwakar, 2012); dry weight was estimated as per method of Denison and Russotti, 1997; chlorophyll content was determined by Porra, 2002 and leaf area index (LAI) was measured by following Milner and Hughes (1968). The biochemical parameters like crude protein, dietary fiber, total carbohydrate and total sugar in *L. esculentum* were determined following standard methods (Cerning and Guilhot, 1973; Chaturvedi and Sankar, 2006).

Soil and heavy metals analysis: The soil was analyzed after harvest of *L. esculentum* for various physico-chemical parameters like EC, pH, OC, TKN, PO₄³⁻, Na⁺, K⁺, Ca²⁺, Mg²⁺, Cd, Cr, Cu, Fe, Mn and Zn following standard methods (Jackson, 1973; Chaturvedi and Sankar, 2006). For heavy metals analysis 1.0 g of air dried soil or plants were taken in digestion tubes separately. For each sample 3 ml of concentrate HNO₃ was added and digested in an electrically heated block for 1 hour at 145°C. To this mixture 4

ml of HClO₄ was added and heated to 240°C for 1 hour. The mixture was cooled and it was filtered using the filter paper Whatman # 42. The volume was made to 50 ml by adding double distilled water and used for analysis. Metals were analyzed using an atomic absorption spectrophotometer (PerkinElmer, Analyst 800 AAS, GenTech Scientific Inc., Arcade, NY) following methods (Chaturvedi and Sankar, 2006).

Data analysis: Data were statistically analyzed using Origin (ver. 6.1). Data were subjected to one-way analysis of variance (ANOVA). The means of the values were calculated with Microsoft Excel (ver. 2013, Microsoft Redmond Campus, Redmond, WA) and graphs were prepared through Sigma plot (ver. 12.3, Systat Software, Inc., Chicago, IL).

RESULTS AND DISCUSSION

Effects of integrated nutrients on soil characteristics:

The physico-chemical characteristics of soil after harvest of *L. esculentum* with different treatments are presented in Table 2. The results indicated that the treatments showed significant ($P < 0.05/P < 0.01$) change in EC, OC, TKN, PO₄³⁻, Na⁺, K⁺, Ca²⁺, Mg²⁺, Cd, Cr, Cu, Fe, Mn and Zn of the soil. Among various treatments the most values of EC (1.12 dS m⁻¹), OC (24.85 mg Kg⁻¹), TKN (245.90 mg Kg⁻¹), PO₄³⁻ (64.30 mg Kg⁻¹), Na⁺ (68.25 mg Kg⁻¹), K⁺ (140.34 mg Kg⁻¹), Ca²⁺ (280.75 mg Kg⁻¹) and Mg²⁺ (149.23 mg Kg⁻¹) in the soil were recorded with 50 % RDF + ARV @ 5 t ha⁻¹ treatment (Table 2) and it might be due to the presence of more contents of these parameters in ARV. The most contents of Cd (1.54 mg Kg⁻¹), Cr (1.13 mg Kg⁻¹), Cu (1.83 mg Kg⁻¹), Fe (2.88 mg Kg⁻¹), Mn (1.84 mg Kg⁻¹) and Zn (3.55 mg Kg⁻¹) of the soil were observed with treatment T₆ i.e. sewage sludge (SS) (Figure 1). The higher contents of heavy metals in the soil after treatment with T₆ might be due to the presence of more contents of heavy metals in sewage sludge. Patil *et al.* (2003) reported that use of FYM in the soil reduced soil pH from 7.99 to 7.65 with each dose of FYM, the soil pH changed appreciably due to organic generation of acids during its decomposition. Application of organic manures such as FYM, vermicompost, crop residues improved the soil accessible nitrogen, phosphorus and potassium as compared to recommended dose of fertilizers (Patil *et al.*, 2003).

Effects of integrated nutrients on agronomical characteristics of *L. esculentum*:

The mean values of agronomical parameters of *L. esculentum* cultivated with different treatments are shown in Table 3. The most values of plant height (125.40 and 145.86 cm), root length (16.20 and 18.90 cm), dry weight (78.90 and 94.50g), chlorophyll content (4.50 and 4.68 mg/gfw), LAI (4.78 and 4.84), number of flowers/plant (45.78 and 50.53), fruits/plant (38.21 and 45.12), crop yield/plant (4680.20 5680.88 g) of *L. esculentum* were recorded with sole ARV (T₃) and 50% RDF along with ARV @ 5 t ha⁻¹ (T₇), respectively and it is likely due to the presence of optimum contents of various nutrients required by *L. esculentum*. The agronomical performance of *L. esculentum* was recorded in the order of T₇ > T₁₀ > T₉ > T₈ > T₃ > T₆ > T₅ > T₄ > T₂ > T₁ treatments (Table 3). Thimma Naik (2006) also reported that mixture of different organic fertilizers as 50% farm yard manure, 50% poultry manure, 50% vermicompost, 50% poultry manure, 50% neem cake and poultry manure@7.5 t ha⁻¹ to fertilize the chilli crop significantly increased number of branches per plant and plant height, leaf area. The findings are also in the conformity with Sable *et al.* (2007) who reported higher number of branches and fruit yield with the combination of 50% nitrogen by adding neem cake and 50% nitrogen by applying vermicompost. Moreover, vermicompost moreover as a rich supply of micronutrients also acts as chelating agent and regulates the accessibility of metallic micronutrients to the plants and enhances the plant growth and yield by supplying nutrients in the accessible form and based on crop requirement. The use of organics *viz.*, farm yard manure at the rate of 10 t ha⁻¹ resulted in higher fruit yield and uptake of nutrients like N, P, K, Ca, Mg, S and Fe over RDF alone (Kattimani, 2004).

Effects of integrated nutrients on biochemical characteristics of *L. esculentum*:

The mean values of biochemical parameters of *L. esculentum* cultivated with different treatments are shown in Figure 2. During the present study, the most values of crude protein (1.05 g/100g), dietary fiber (1.36 g/100g), total carbohydrates (4.05 g/100g) and total sugar (2.78 g/100g) of *L. esculentum* was recorded with T₇ (i.e. 50 % RDF + ARV @ 5 t ha⁻¹). It may be likely due to the maximum production of these biochemical parameters in the occurrence of most favorable uptake of essential nutrients needed by *L. esculentum*. Prabakaran

Table 1. Description of various treatments used for the cultivation of tomato (*L. esculentum*).

Treatment	Description
T ₁	Without nutrient (Control)
T ₂	Recommended dose of fertilizer (RDF)
T ₃	Agro residue vermicompost (ARV)@ 5 t ha ⁻¹
T ₄	Sugarcane pressmud compost (SPC) @ 5 t ha ⁻¹
T ₅	Cattle dung compost (CDC) @ 12.5 t ha ⁻¹
T ₆	Sewage sludge (SS)@ 2 t ha ⁻¹
T ₇	50 % RDF + ARV @ 5 t ha ⁻¹
T ₈	50 % RDF + SPC @ 5 t ha ⁻¹
T ₉	50 % RDF + CDC @ 12.5 t ha ⁻¹
T ₁₀	50 % RDF + SS @ 2 t ha ⁻¹

Table 2. Changes in physico-chemical characteristics of soil used for the cultivation of tomato (*L. esculentum*) after use of various treatments.

Treatment	EC (dS m ⁻¹)	pH	OC (mg Kg ⁻¹)	TKN (mg Kg ⁻¹)	PO ₄ ³⁻ (mg Kg ⁻¹)	Na ⁺ (mg Kg ⁻¹)	K ⁺ (mg Kg ⁻¹)	Ca ²⁺ (mg Kg ⁻¹)	Mg ²⁺ (mg Kg ⁻¹)
T ₁	0.35	7.52	10.42	124.50	21.34	23.40	45.00	224.44	34.56
T ₂	0.45ns	7.65ns	10.35ns	140.30*	21.55ns	34.56ns	50.30ns	230.38ns	36.10ns
T ₃	0.68*	7.23ns	11.24ns	156.90*	36.86*	42.80*	87.22*	278.90*	45.90ns
T ₄	0.55*	7.34ns	12.56ns	175.44*	35.36*	50.34*	74.50*	225.66ns	38.00ns
T ₅	0.76*	7.77ns	13.55ns	220.76*	44.98*	47.20*	80.90*	254.60*	40.84ns
T ₆	0.52ns	7.84ns	23.87*	208.34*	58.90*	35.90ns	82.66*	230.80ns	36.92ns
T ₇	1.12**	7.65ns	24.85*	245.90**	64.30**	68.25**	140.34**	280.75*	149.23*
T ₈	0.88*	7.84ns	14.70ns	234.66**	48.77*	54.23*	110.20**	258.45*	124.50*
T ₉	0.95*	7.45ns	18.45*	240.20**	50.34*	56.88*	118.90**	268.40*	118.77*
T ₁₀	1.04**	7.80ns	16.50*	224.80**	46.90*	58.94*	120.86**	260.25*	112.96*
F-calculated	3.02	0.34	3.89	20.18	6.10	8.46	12.80	34.20	10.02
CD	2.34	1.12	2.78	9.45	4.06	3.23	7.54	10.24	5.46

Least square means; *, ** significantly different to the control at P<0.05 and P<0.01 level of ANOVA, respectively; ns-not significant; CD- critical difference.

Table 3. Effects of various treatments on agronomical attributes of tomato (*L. esculentum*).

Treatment	Plant height (cm)	Root Length (cm)	Dry weight (g)	Chlorophyll content (mg/gfw)	LAI	Flowers/ plant	Fruits/ plant	Yield/plant (g)
T ₁	85.25	10.13	20.37	3.45	4.21	30.20	27.12	3245.90
T ₂	96.80*	12.87ns	34.78*	3.56ns	4.26ns	34.50ns	29.40ns	3350.60ns
T ₃	125.40**	16.20ns	78.90**	4.50ns	4.78ns	45.78*	38.21*	4680.20*
T ₄	110.34*	14.20ns	60.55**	3.66ns	4.35ns	37.10ns	31.20ns	3570.55ns
T ₅	112.37*	15.88ns	65.87**	3.75ns	4.40ns	38.90ns	32.08ns	3780.90ns
T ₆	120.70**	14.90ns	72.80**	3.80ns	4.70ns	40.78*	35.26ns	4120.10*
T ₇	145.86**	18.90*	94.50**	4.68ns	4.84ns	50.23**	45.12*	5680.88*
T ₈	126.30**	18.25*	78.90**	4.02ns	4.45ns	40.22*	35.40ns	3890.45ns
T ₉	130.55**	17.34*	82.75**	4.45ns	4.54ns	45.42*	36.22ns	4420.60*
T ₁₀	135.88**	18.55*	84.50**	4.52ns	4.77ns	46.15*	38.08ns	4890.75*
F-calculated	76.34	10.07	8.27	0.24	0.12	4.35	3.55	110.80
CD	12.34	4.52	3.24	1.23	1.10	3.23	2.56	28.57

Least square means; *, ** significantly different to the control at P<0.05 and P<0.01 level of ANOVA, respectively; ns-not significant; CD- critical difference.

and Pichai (2002) reported that the application of recommended quantity of nitrogen in the form of poultry manure recorded highest pH, total soluble solids, titrable acidity, contents of reducing sugar, non-reducing sugar, quantitative crude protein and ascorbic acid content in tomato fruit.

Effects of integrated nutrients on contents of heavy metals in *L. esculentum*: The mean contents of Cd, Cr, Cu, Fe, Mn and Zn in *L. esculentum* cultivated with different treatments are shown in Figure 3. The results revealed that the most contents of Cd (0.35 and 0.32 mg Kg⁻¹), Cr

(0.18 and 0.15 mg Kg⁻¹), Cu (1.28 and 1.26 mg Kg⁻¹), Fe (2.25 and 2.20 mg Kg⁻¹), Mn (0.78 and 0.74 mg Kg⁻¹) and Zn (2.14 and 2.05 mg Kg⁻¹) in *L. esculentum* were recorded with T₆ (i.e. sewage sludge) and T₁₀ (i.e. 50 % RDF + SS @ 2 t ha⁻¹), respectively and it is likely due to the presence of more contents of these metals in the sewage sludge and soil treated with these treatments. Kumar and Chopra (2013) also reported the higher contents of Cd, Cr, Cu, Fe, Mn and Zn in French bean (*Phaseolus vulgaris* L.) amended with sewage sludge.

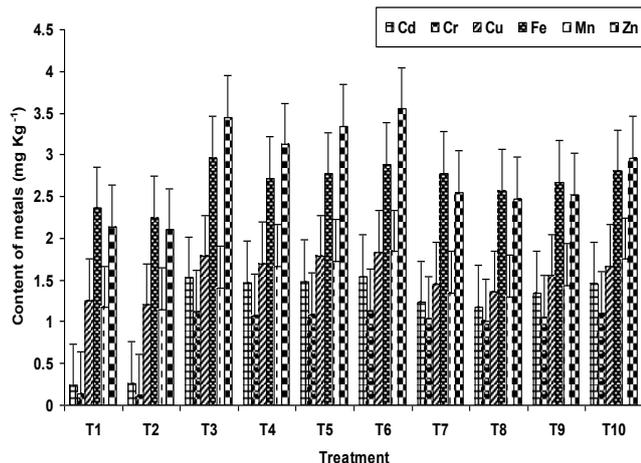


Figure 1. Contents of heavy metals in the soil used for the cultivation of tomato (*L. esculentum*) after use of various treatments. Error bars are standard error of the mean.

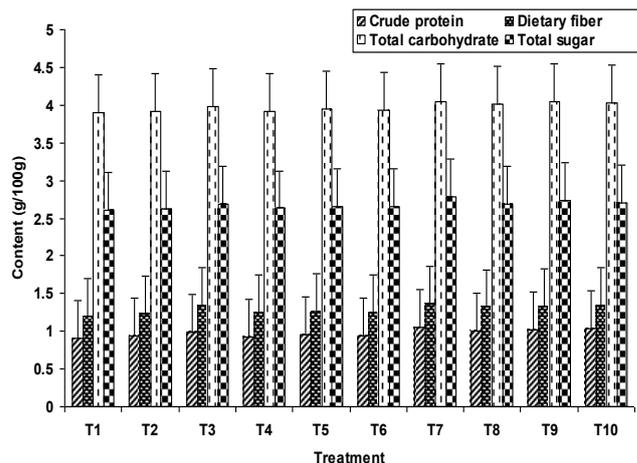


Figure 2. Contents of crude protein, dietary fiber, total carbohydrates and total sugar of tomato (*L. esculentum*) after use of various treatments. Error bars are standard error of the mean.

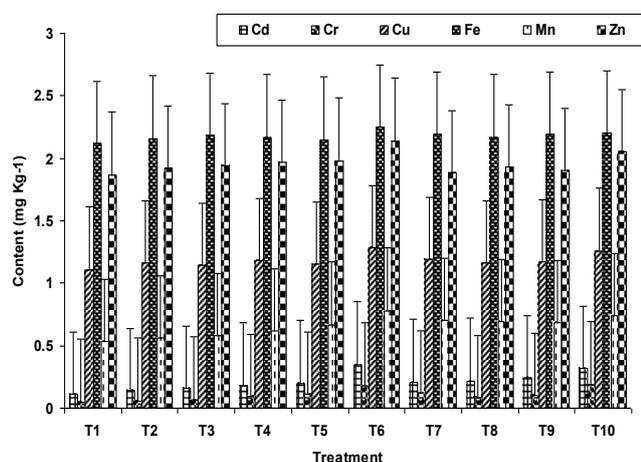


Figure 3. Contents of heavy metals in tomato (*L. esculentum*) after use of various treatments. Error bars are standard error of the mean.

Conclusion

The present study concluded that different treatments showed significant ($P < 0.05/P < 0.01$) change in EC, OC, TKN, PO_4^{3-} , Na^+ , K^+ , Ca^{2+} , Mg^{2+} , Cd, Cr, Cu, Fe, Mn and Zn of the soil. The results showed that the most plant height, root length, dry weight, chlorophyll content, LAI, number of flowers/plant, fruits/plant, crop yield/plant, crude protein, dietary fiber, total carbohydrates and total sugar of *L. esculentum* was recorded with 50 % RDF + ARV @ 5 t ha⁻¹ in the various applied treatments. The agronomical performance of *L. esculentum* was recorded in the order of T₇ > T₁₀ > T₉ > T₈ > T₃ > T₆ > T₅ > T₄ > T₂ > T₁ treatments. Therefore, sole ARV and 50% RDF along with ARV @ 5 t ha⁻¹ can be used to achieve the maximum crop yield of *L. esculentum*.

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