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Potassium and Organic Matter Increased Carrot Production in Acidic Terrace Soil

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ABSTRACT

Background: Soil acidification is a key abiotic factor that hinders plant growth and diminishes agricultural output on a worldwide scale. The purpose of this experiment was to look at how carrot growth, yield and quality on acidic terrace soil were affected by organic amendments (OA) and mineral fertilization with or without potassium (K).

Methods: A field experiment was carried out using a randomized complete block design (RCBD) with three replicates. Organic amendments and K levels are: control (Co), recommended fertilizer (RF) excluding potassium (RF-K), RF, RF+25% excess K, RF- K+ Poultry manure (PM) (5 t ha^{-1}), RF + PM (5 t ha^{-1}), RF- K+ household compost (HC) (5 t ha^{-1}), RF + HC (5 t ha^{-1}). Statistix 10 version was used to analyze the variance (ANOVA) of growth and yield parameters of carrots.

Result: Carrot yield and plant vegetative growth were negatively impacted by untreated acidic soil. OA with K enrich RF enhanced vegetative growth, biomass yield, carrot yield, nutrient contents, â Carotene, anthocyanin, ascorbic acid and total sugar content of carrot of acidic terrace soil carrot plants, indicating its alleviating effects on carrot production in acidic soil. The exclusive use of chemical fertilizer did not have a noticeable impact on the yield and quality of acidic stressed carrots. Among the amending substances, T_8 [RF + HC 5 t ha^{-1}] showed significant enhancement in the fertility indices of acidic-stressed terrace soil and resulted in increased growth, yield and profitability of carrots. Incorporating OA and K-enrich RF to terrace soil has preserved a ranking of T_8 > T_4 > T_6 in terms of their potential to improve productivity. These results suggested that RF and K-enrich RF fertilization might mitigate the antagonistic impact of soil acidity on carrot yield by adjusting soil fertility and creating a favorable environment in acidic terrace soils.

Key words: Acidity, Carrot, Organic amendments, Potassium, Terrace soil.

INTRODUCTION

Currently, the escalation of degraded land productivity is a significant issue in order to address the growing global food crisis. The growth of the world's population is expected to reach 9 billion by 2050, resulting in a sharp rise in the need for agricultural production (Ibeto *et al.,* 2020). In densely populated developing countries like Bangladesh, agriculture in devastated lands requires increased attention. Terrace soil plays a significant role in Bangladesh's agriculture; covering 1,028,030 ha or approximately 342 km^2, which is 8.35% of the country's total land area (Islam *et al.,* 2017; Bramer, 1996b; FAO/ UNDP, 1988). Overall, the geomorphological features of terrace soils have a greater impact on agricultural challenges present in these soils (Siddique *et al.,* 2014). The soils on the terrace naturally have low to medium levels of organic matter, poor fertility, low water retention, lower stability of surface soil aggregates and a very strong to slightly acidic pH, results in a region depleted in nutrients (FRG, 2018; Islam *et al.,* 2021). Increased agronomic difficulties in terrace farming have resulted in, it becoming a problem soil in Bangladesh (Bramer, 1996a; Chapagain and Raizada, 2017).

Inherent acidity of the terrace soil triggers challenges in plant nutrient assess and microbial populations, leading to the release of harmful elements like A13$^+$, Fe^{3+} and Mn^{2+}, which in turn impacts plant metabolism and crop yield (Binte *et al.,* 2021; Khanam *et al.,* 2022). Applying organic and inorganic fertilizers could be a good strategy for addressing soil fertility issues in terrace farming (Ahmad *et al.,* 2014). In essence, adding organic amendments initially increases soil pH by oxidizing anions or releasing OH^- ions, while also lowering Mn and/or Fe oxides and hydrous oxides during decomposition (Sparling *et al.,* 1999; Angelova *et al.,* 2013). Furthermore, organic matter enhances soil aggregation stability and releases various nutrients (such as N, P and S), can boost microbial activity and improve the yield potential of problematic soil (Appiah

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et al., 2017). Besides these, by increasing organic carbon and nitrogen levels, reducing soil compactness and boosting porosity, organic fertilizers can greatly enhance the quality of soil aggregates (Wang *et al.,* 2019). Therefore, organic fertilizer has the potential to enhance soil health and decrease environmental degradation, supporting the long-term progress of agriculture (Chen *et al.,* 2018). However, terrace land farming in Bangladesh did not place much focus on incorporating organic amendments. Exploring the potential of organic amendments, evaluating if the organic method could offer a successful way to improve the productivity of degraded land becomes an urgent issue (Meena *et al.,* 2020; Ahmed *et al.,* 2022).

Nevertheless, modern agricultural land intensification and improved crop production, it is not sufficient to rely solely on one source of plant nutrients, whether organic or inorganic fertilization (Paramesh *et al.,* 2023). Fertilizer quickly addressed the issue of soil nutrient deficiency and enhanced the metabolic and translocation activity of carbohydrates from source to sink (Parry *et al.,* 2005). The use of inorganic fertilizer in Bangladesh is linked to a 50% increase in total crop production (BARC, 1997). But, the indiscriminate use of inorganic fertilizers without organic matter can deteriorate soil quality by causing soil acidity and compromising soil structure, rather than improving productivity on degraded land (Zhang *et al.,* 2009; Mehedi *et al.,* 2012). Hence, using both organic and inorganic amendment wisely could be crucial in overcoming agricultural limitations in terrace soil. Yet, the research data on promising mitigation approaches for terrace soils are lacking, even though their agricultural importance is well recognized. This study examines the efficacy of different nutrient management to enhance productivity in acid-prone terrace soil in the Madhupur tract.

Carrot is one of the major economic vegetable crops grown throughout the world (Nisar *et al.,* 2019). Carrot (*Daucus carota* L.) is rich in beta-carotene, phenolic content, flavinols as well as vitamins (A, B and C) and various minerals. K, Fe, Cu and Mn (Subba *et al.,* 2016). Carrots, a type of root crop, thrive in soil with high potassium levels (Singh *et al.,* 2019). Potassium is essential in many biochemical processes such as net photosynthetic rate, translocation of assimilates and regulating plant turgor pressure (Shaban *et al.,* 2018). Additionally, potassium triggers the anti-oxidative defense mechanism to combat various biotic and abiotic stresses such as drought, diseases and pest infestations. The presence of potassium in the soil significantly impacts the yield, quality and shelf life of root crops (Malavika, *et al.,* 2022). In our country, terrace farmers often overlook the proper use of potassium fertilizers and maintaining soil potassium balance, thereby leading to a significant decrease in yields. This sense of potassium application is extremely important in the cultivation of carrots in terrace soil. Farmers in this region are decidedly interested in growing carrots because of their higher nutritional and economic value. There is still a significant lack of understanding regarding nutrient management, quality crop production and maintaining a nutrient balance on terraces. In this current research, we hypotheses that the combination of organic matter and potassium can improve the bio-physicochemical condition of exhausted terrace soil and enhance its crop yield. Therefore, the key aim of the study is to improve terrace soil carrot productivity by adding potassium and organic matter. Thus, the research was conducted to evaluate the effect of different organic amendments and potassium on carrot yield and productivity efficiency of terrace soil.

MATERIALS AND METHODS

Experimental site

The investigation was led at a research site in Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, from November 2018 to March 2019, located at latitude 24°02′10.94″N, longitude 90°23′42.45″ E and altitude 8.4 meters above the sea level. The location of the site is in the middle of Madhupur Tract (AEZ -28). Throughout the growth of carrots, the mean air temperature, relative humidity and evaporation varied between 11.3-33.2°C, 78.5-89.6% and 18.7-96.09 mm, respectively. The geographical area being investigated is characterized by terrace landforms and falls under the general soil type Shallow Red Brown Terrace Soil. The soil classification according to USDA in the area is Inceptisol order. The topsoil had a pH of 5.43 (Strongly acidic soil), with organic carbon at 0.79%, total nitrogen at 0.08%, available phosphorus at 7.80 mg kg^{-1}, available sulphur at 12.85 mg kg^{-1}, exchangeable potassium at 0.12 cmol (+) kg^{-1} and counted bacterial colony population at 4.00 × 10^6 cfu g^{-1} soil. Its bulk density was 1.38g/cm^3, belonging to the clay loam textural class with sand at 17.30%, silt at 45.30% and clay at 36.90%.

Experimentation and planting material growing system

Terrace land with strong acidic soil received seven different treatments of potassium doses and organic manures, plus recommended fertilizers. We utilized untreated plots for comparison purposes. The treatments include: T_1= absolute control soil (no fertilizer) (Co), T_2 = soil test based recommended dose of fertilizer (RF) excluding potassium (RF-K), T_3 = RF, T_4 = RF+ excess 25% potassium (RF+K), T_5: T_2 + poultry manure (PM) (5 t ha^{-1}) (RF-K+PM), T_6 = RF + PM (5 t ha^{-1}) (RF+PM), T_7 = T_2 + household compost (HC) (5 t ha^{-1}) (RF-K+HC), T_8= RF + HC (5 t ha^{-1}) (RF+HC). A field study utilized three replications of a randomized complete block design (RCBD) to organize the treatments. Every plot measured 2.5 × 2.0 m and was divided by a 0.5 m drainage system. The current study used the high yielding, improved and superior color, taste and uniform root cultivar Sakata (Kuruda) carrot, enriched with carotene, as the test crop. We adopted standard cultivation methods like soil preparation and fertilization that are typically done in a carrot field in Bangladesh. On 26 November 2018, seeds were sown in rows at a uniform rate of 4 kg ha^{-1}, with a spacing 25 × 10 cm between rows and plants and 3 seeds per hill. Seedling thinning was conducted during the 2nd week after germination, leaving only one final plant per hill. We engaged in weeding, applying irrigation and performing other intercultural tasks as needed. The experimental field was irrigated with tap water as required, keeping the soil moisture at field capacity (FC = 30.7%). Soil test-based fertilization with 304.90 kg of urea, 230 kg of triple superphosphate (TSP), 211 kg of muriate of potash (MoP) and 105.5 kg of gypsum per ha^{-1} was done according to Fertilizer Recommendation Guide (FRG, 2018). Final land preparation included basal application of one-third of urea, TSP, MoP, gypsum and full volumes of organic amendments. Two top dressing applications of the leftover computed urea were made 3rd and 5th weeks of sowing. Decomposed poultry manure collected locally (aged one month) and household waste were left in natural conditions for a week to reduce excess moisture. After storing household waste in a compost pile, the compost is ready for use in the field after 6 weeks. Table 1 displays the chemical characteristics of the added organic compounds.

Carrot growth and yield parameters are measurement

Several growth parameters including plant height, number of leaves $plant^{-1}$, canopy spread diameter $plant^{-1}$ were evaluated during the active vegetative stage at 65 DAS. The yield traits of carrots were observed in five selected plants plot-1 and their mean value was calculated. Carrot roots were harvested on March 12, 2019 after the foliage began to pale its color. The carrots were gathered, washed, dried and separated into marketable root and shoot. The average measurements of root and shoot length and weight were recorded for each plant, as well as the total biomass per plot. Afterwards, the root's fresh weight was converted into tons per hectare in order to determine carrot yield.

Soil and organic matter properties assessment

To study the soil properties, soil sample was collected from 0-30 cm depth, air dried, ground to pass through a 2 mm sieve and stored for analysis. The study's organic materials were also dried in the air for analysis. The soil sample's textural class was determined using Bouyoucos hydrometer method (Bouyoucos, 1962). The terrace soil's bulk and particle density were analyzed using core sampler and pycnometer method, respectively (Blake, 1965a; Blake, 1965b). Soil pH (1; 2.5) was measured by using glass electrode pH meter (Jackson, 1973a). The soil organic carbon content was determined using the wet oxidation method (Walkey and Black, 1965). Total nitrogen is determined by Micro-Kjeldahl method (Black, 1965). Available phosphorus (Bray and Kurtz- P) is determined by Bray and Kurtz- P method (Bray and Kurtz,1945). Ammonium acetate solution method was used to determine exchangeable potassium (Jackson 1973b). Available sulphur was calculated by turbidimetric method (Hunter, 1984). Enumeration of bacteria on collected soil samples from different treatments was done by using serial dilutions through the drop plate count method (MacFaddin, 2000).

Economic analysis

Economic auditing involved calculating the expenses in crop production (from planting to harvesting) and determining the economic value of all the products based on market prices. The total cost of carrot production included fixed costs like loan interest, land revenue and miscellaneous fees, along with variable costs such as seeds, organic manure, chemical fertilizers, tillage operation cost, labor wages and plant protection measures *etc.* Therefore, total cost of production.

(TC) = Total fixed cost (TFC) + Total variable cost (TVC)

The gross returns represented the economic value of the total output, with net return, benefit cost ratio (BCR), profitability and production efficiency were calculated by the following equations:

Gross return (US$ ha^{-1}) =

Total carrot yield (kg ha^{-1}) × Per unit price of carrot (US$ kg^{-1})

Net return (US$ ha^{-1}) =

Gross return (US$ ha^{-1}) - Total cost of production (US$ ha^{-1})

$$\text{BCR} = \frac{\text{Gross return (US\$ ha}^{-1})}{\text{Total cost of production (US\$ ha}^{-1})}$$

$$\text{Profitability (US\$ ha}^{-1}\text{ day}^{-1}) = \frac{\text{Gross return (US\$ ha}^{-1})}{\text{Duration of crop (days)}}$$

$$\text{Production efficiency (Kg ha}^{-1}\text{ day}^{-1}) = \frac{\text{Economic yield (Kg ha}^{-1})}{\text{Duration of crop (days)}}$$

Statistical analysis

The statistical significance of data for soil parameter, yield and quality of carrot were subjected to analyzed through one-way analysis of variance (ANOVA) to investigate how the treatments affected all the measured parameters. When a significant effect of additions combined with potassium was observed, Tukey's HSD test at $p<0.05$ level was performed as post hoc on all parameters subjected to

Table 1: Chemical properties of added organic materials.

Organic matter	pH (1/2.5)	OC (%)	Total N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)
Household compost	7.67	22.86	1.24	0.65	1.33	1.55	0.54	0.23
Poultry manure	8.18	33.23	1.37	0.72	0.92	1.48	0.52	0.27

OC = Organic carbon; N = Nitrogen; P = Phosphorus; K = Potassium; Ca = Calcium; Mg = Magnesium; Zn = Zinc.

ANOVA test. The results of the tested parameters were the means ± standard deviation of three replicates. The Statistix 10.0 software package was used for all statistical analyses.

RESULTS AND DISCUSSION

Growth traits

Carrot plants grown in untreated acidic soil had lower plant height (PH) (30.10 cm), number of leaves plant^{-1} (NLP) (8.33) and canopy spread plant^{-1} (CSP) (38.81 cm), hence exhibiting significant inhibition of plant growth (Fig 1). The application of different organic amendments and potassium doses plus RF significantly improved the growth characteristics of carrot plants grown in strong acidic terrace soil Table 2. Treatment T_8 [RF + HC (5 t ha^{-1})] showed the highest PHT (46.04 cm) and statistically similar data in T_3 (RF), T_4 (RF+ excess 25% K), T_5 (T_2 + PM (5 t ha^{-1}), T_6 (RF + PM (5 t ha^{-1})], T_7 (T2 + HC (5 t ha^{-1}), treatment (Table 2). Treatment T_6 [RF + PM (5 t ha^{-1})], showed the maximum NLP (11.33) and responses were similar for all organic amendments and potassium treated plants (Table 2). Meanwhile, the T8 treatment showed canopy spread plant^{-1} *i.e.* CSP (85.40 cm) (Table 2). Organic amended plants along with potassium doses showed more CSP i.e., in T_2 (49.87%), T_3 (81.36%), T_4 (105.34%), T_5 (86.67%), T_6 (114.12%), T_7 (105.54%) and T_8 (120.05%) than plots with untreated acidic soil (Table 2).

Yield and yield features

Yield-promoting parameters of acidic soil carrot plants were significantly influenced by the application of organic amendments and potassium doses plus soil test-based (SBTF) other fertilizers (Table 3). Plants in the control treatment had the lowest measurement for carrot root length (RL) (8.93 cm), root diameter (RD) (1.51 cm), stem fresh weight plant-1 (SFWP) (18.90 g) and root fresh weight plant^{-1} (RFWP) (41.35 g). The highest measurements for RL (16.58 cm), RD (3.64 cm) and RFWP (91.97 g) were observed in the T_8 treatment. The maximum SFWP (37.23 g) was recorded in T4 treatment. Significantly increased by 56.16 - 85.63%, 78.19 -140.53%, 92.50 - 120.31%, 71.05 - 122.41%, RL, RD, SFWP and RFWP showed notable improvement when organic amendment and potassium rates were applied to plants grown in highly acidic soil (Table 3). The addition of organic amendments, in combination with potassium application, resulted in better yield traits.

Biomass yield of carrot plant

Different types of organic fertilizers and the addition of potassium plus rest RF had significant positive effects on the total fresh biomass plant^{-1} (TBP) and the total fresh biomass yield (TFBY) of carrot cultivated in acidic terrace soil (Fig 1). Unmanaged acidic soil resulted in the lowest TBP (58.25 g) and TFBY (23.30 t ha^{-1}) in carrot plants. The organic amendments and potassium treated carrot plants displayed higher TBP and TFBY, contrast to abandoned acidic soil (control treatment). The T_8-treated carrot plant produced the highest amounts of TBP and TFBY, with 129.20 g and 51.68 t ha^{-1}, respectively. Alike TBP and TFBY were produced in T_4 (123.17 g and 49.27 t ha^{-1}, respectively) and T_6 (122.26 g and 48.91 t ha^{-1}, respectively), treatment.

Economic productivity

The use of organic sources in combination with or without potassium and other chemical fertilizer exerted a notable and statistically significant ($p<0.05$) influence on carrot yield in strongly acidic terrace soil Table 4. The averaged data revealed that treatment T_8 [RF + HC (5 t ha^{-1})] resulted in the highest marketable yield of carrot at 36.79 t ha^{-1}. These outcomes were found to be comparable with those obtained under T_4 (RF+ excess 25% K) and T_6 [RF + PM (5 t ha^{-1})] treatment and remained significantly superior to the other treatments. Treatment T_2 (RF- K) exhibited a 31.33% rise in carrot production, which was statistically equivalent to that of untreated control treatment T_1.

Profitability

The T_8 plot, that received RF + HC (5 t ha^{-1}), had the highest total cultivation cost of 2477.08 US$ ha^{-1} compare to other

Table 2: Growth attributes of carrot influenced by different organic amendments and potassic fertilizer in terrace soil.

Treatments		PHT (cm)	NLP	CSP (cm)
T_1	(Co)	30.10±1.39c	8.33±0.58b	38.81±4.47e
T_2	(RF-K)	37.97±1.93b	8.83±0.29ab	58.17±4.18d
T_3	(RF)	43.08±1.66ab	9.97±0.76ab	70.39±5.39c
T_4	(RF + K)	45.49±1.90a	10.45±1.26ab	79.69±2.87abc
T_5	(RF - K +PM)	42.09±2.09ab	10.42±0.87ab	72.45±6.36bc
T_6	(RF + PM)	45.12±1.68a	11.33±0.50a	83.10±3.10abc
T_7	(RF - K + HC)	41.52±1.67ab	9.67±1.06a	79.77±6.67abc
T_8	(RF + HC)	46.04±1.93a	11.00±0.48a	85.40±5.31a
Significance level		<0.001***	<0.007**	<0.001***

PHT= Plant height; NLP = Number of leaves plant-1; CSP = Canopy spread plant^{-1}. The value indicates the mean (± SD); $p<0.05$; n=9; Treatments combinations are T_1 = control (Co), T_2 = RF excluding potassium (RF-K), T_3 = RF, T_4 = RF+ excess 25% potassium (RF+K), T_5= T_2 + poultry manure (PM) (5 t ha^{-1}) (RF-K+PM), T_6 = RF + PM (5 t ha^{-1}) (RF+PM), T_7 = T_2+ household compost (HC) (5 t ha^{-1}) (RF-K+HC), T_8= RF + HC (5 t ha^{-1}) (RF+HC).

plots using various sources to apply OA +/- potassium (Table 4). On the flip side, the control plot had the lowest overall cultivation cost (2172.30 US$ ha^{-1}). The significantly ($p<0.05$) higher gross return (5025.92 US$ ha^{-1}) and net return (2548.85 US$ ha^{-1}) was registered under treatment, T8 comparable with T_6 and T_4. The treatment T8 listed the highest BCR (2.03) which was statistically at par with T_6 and T_4, but significantly better than all other treatments. The highest profitability (50.26 US$ ha^{-1} day^{-1}) and production efficiency (350.35 kg ha^{-1} day^{-1}) were significantly noted in T_8 comparable with T_6 and T_4.

Carrot yield and quality traits

The terrace soil is naturally acidic and impoverished, with low fertility and organic matter content, leading to disruptions in nutrient availability, buildup of acid-forming cations and consequently inhibiting crop growth and yield (Binte *et al.,* 2021; Khanam *et al.,* 2022). The findings demonstrated that plant development, carrot yield and biomass productivity were significantly reduced in acid-prone terrace soil (Fig 1 and Table 2, 3). This might be due to soil acidification induced restriction of nutrient uptake and microbial activities such as organic materials mineralization, recycling of nutrients, nitrification and nitrogen fixation are inhibited or slowed down (Gazey and Davies, 2009; Binte *et al.,* 2021). Moreover, the build-up of toxic cations like Al^{3+} can hinder root growth by inhibiting cell growth and elongation, reducing cell division at the root tip, which in turn limits water and nutrient uptake, impacting plant growth and development (Lauricella *et al.* 2020). The decrease in plant height, number of leaves and canopy area of carrot plants may be due to the soil acidity-induced macro-nutrients imbalance, which reduces the availability of nutrients to the roots and eventually disturbs the plant tissues. This would lead to a decrease in meristematic tissue activity and cell expansion. Although, chemical fertilizers contain higher amounts of nutrients and are in readily available forms, but cannot compensate for the decrease in biomass production brought on by low pH, due to the inherent terrace soil characteristics, losses and low uptake (Nisar *et al.,* 2020). The application of organic manure is important approaches for increasing of quantity and quality of plant products (Arebu, 2022). A combination of organic and chemical fertilizers is more effective at increasing yield in acid soil than chemical fertilizer alone (Wang *et al.,* 2019).

Carrots require a lot of nutrients and can reach their maximum sustainable yield in poor soil with better nutrient management (Ahmad, 2014; Paramesh *et al.* 2023). Employing a diverse range of integrated organic and inorganic amendments decreased soil acidity effects and significantly boosted carrot plant growth (*e.g.* PHT, NLP and TFBY) and yield attributes (*e.g*. RL, RD, RFWP), showing effectiveness in alleviating soil acidity stress (Fig 1 and Table 2, 3). The significant higher amount of plant biomass and carrot yield was discovered in carrot plants treated with OA and potassium. The study demonstrates that among the amendment combinations, application of household compost with potassium gave the superior carrot yield in terrace soil (Table 4). Combining organic and inorganic amendments attributed to their positive impact on maintaining prolonged nutrient availability and uptake mechanism, positively impacting soil physical and biological properties, ultimately leading to increased biomass and yield of carrots (Isaac and Verghese, 2016; Nisar *et al.,* 2019). The root size was directly impacted by the increased vegetative growth of the plants. This leads to more carbohydrates being stored, leading to an enlarged root diameter, which serves as a storage organ for food (Bhandari *et al.,* 2012; Annisha Afrin *et al.,* 2019). The collective use of OA (*i.e.* poultry manure and household compost) and potassium promoted auxin functions in plants, leading to higher RL, RD, RFW and consequently, the overall carrot production (Table 3 and 4). Utilizing organic amendments such as poultry manure and household compost improved the presence of essential nutrients like N, P, K and S, thus promoting nutrient sustainability in acidic degraded soil and enhancing crop productivity (Hailu *et al.,*

Table 3: Different organic amendments and potassic fertilizer application impacts on yield attributes of carrot grown in terrace soil.

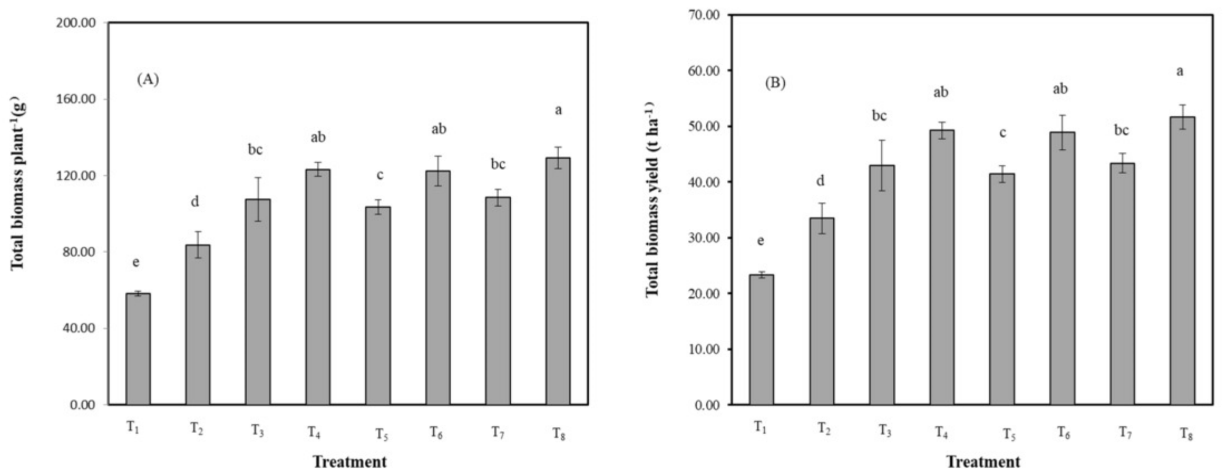
Treatments		RL (cm)	RD (cm)	SFWP (g)	CFWP (g)
T_1	(Co)	8.93±0.50d	1.51±0.14d	16.90±1.85c	41.35±1.69d
T_2	(RF - K)	11.55±0.82c	2.17±0.15cd	29.42±3.96b	54.31±4.80d
T_3	(RF)	13.95±0.28bc	3.04±0.37abc	33.13±3.65ab	74.30±8.59bc
T_4	(RF + K)	15.33±0.40ab	3.58±0.38ab	34.69±3.03ab	88.48±1.79ab
T_5	(RF - K +PM)	14.02±0.73bc	2.70±0.29bc	32.53±2.34ab	71.05±2.23c
T_6	(RF + PM)	14.62±0.96ab	3.23±0.45ab	36.13±4.79a	86.13±4.58ab
T_7	(RF - K + HC)	14.28±0.63abc	2.93±0.27abc	34.02±5.23ab	74.40±5.06bc
T_8	(RF + HC)	16.58±0. 39a	3.64±0.45a	37.23±2.61a	91.97±4.22a
Significance level		< 0.001***	< 0.001***	< 0.001***	< 0.001***

RL= Root length; RD = Root diameter; SFWP = Stem fresh weight $plant^{-1}$, CFWP = Carrot fresh weight $plant^{-1}$ The value indicates the mean (± SD); $p<0.05$; n = 9; Treatments combinations are T_1 = control (Co), T_2 = RF excluding potassium (RF-K), T_3 = RF, T_4 = RF+ excess 25% potassium (RF+K), T_5= T_2 + poultry manure (PM) (5 t ha^{-1}) (RF-K+PM), T_6 = RF + PM (5 t ha^{-1}) (RF+PM), T_7 = T_2+ household compost (HC) (5 t ha^{-1}) (RF-K+HC), T_8= RF + HC (5 t ha^{-1}) (RF+HC).

Table 4: Productivity and profitability of carrot influenced by organic amendment and potassium management practices in terrace soil.

Treatment	Carrot yield (t ha^{-1})	Gross returns (US$ ha^{-1})	Total cultivation cost(US$ ha^{-1})	Net returns (US$ ha^{-1})	BCR	Profitability (US$ha^{-1}day^{-1})	Production efficiency (kg ha^{-1} day^{-1})
T_1 (Co)	16.54d	2259.77d	2172.30	87.47e	1.04d	22.60d	157.52d
T_2 (RF- K)	21.72d	2967.85d	2356.66	611.18e	1.26d	29.68d	206.88d
T_3 (RF)	29.73bc	4060.66bc	2395.10	1665.56bcd	1.70bc	40.61bc	283.06bc
T_4 (RF + K)	35.39ab	4835.23ab	2404.71	2430.52ab	2.01ab	48.35ab	337.05ab
T_5 (RF - K +PM)	28.42c	3882.87c	2424.98	1457.89d	1.60c	38.83c	270.67c
T_6 (RF + PM)	34.45ab	4706.99ab	2463.41	2243.57abc	1.91abc	47.07ab	328.11ab
T_7 (RF - K + HC)	29.76bc	4065.94bc	2438.64	1627.31cd	1.67c	40.66bc	283.43bc
T_8 (RF + HC)	36.79a	5025.92a	2477.08	2548.85a	2.03a	50.26a	350.35a
SE (±)	<0.001***	<0.001***	-	<0.001***	<0.001***	<0.001***	<0.001***

Treatments combinations are T_1 = control (Co), T_2 = RF excluding potassium (RF-K), T_3 = RF, T_4 = RF+ excess 25% potassium (RF+K), T_5= T_2 + poultry manure (PM) (5 t ha^{-1}) (RF-K+PM), T_6 = RF + PM (5 t ha^{-1}) (RF+PM), T_7 = T_2+ household compost (HC) (5 t ha^{-1}) (RF-K+HC), T_8= RF + HC (5 t ha^{-1}) (RF+HC).



The value indicates the mean (± SD); $p < 0.05$; n = 9; Treatments combinations are T_1 = control (Co), T_2 = RF excluding potassium (RF-K), T_3 = RF, T_4 = RF+ excess 25% potassium (RF+K), T_5= T_2 + poultry manure (PM) (5 t ha^{-1}) (RF-K+PM), T_6 = RF + PM (5 t ha^{-1}) (RF+PM), T_7 = T_2+ household compost (HC) (5 t ha^{-1}) (RF-K+HC), T_8= RF + HC (5 t ha^{-1}) (RF+HC).

Fig 1: Organic amendments and potassium application impacts on fresh biomass yield of carrot grown in terrace soil (A) total biomass plant^{-1} (B) Total biomass yield (t ha^{-1}).

2024). Potassium, as one of the key essential nutrients, has tremendous potential for enhancing the growth of root crops (Shikha *et al.,* 2016). Potassium is a crucial plant nutrient essential for growth, metabolism and development. It activates over 80 enzymes involved in important plant processes like energy metabolism, starch synthesis and photosynthesis, promoting plant growth (Shabon *et al.,* 2018). The weight gain could be explained by the faster movement of photosynthates from the origin to the destination, affected by growth hormones triggered by the combination of OA and potassium, resulting in higher root production (Nisar *et al.,* 2019). The growth in root production could be a result of the combined impact of all components that contribute to yield, such as root diameter, root length and root fresh weight. Mineral composition of carrot root also enthused by addition of OA plus K to terrace soil signposted better nutrient balance in soil. Hence, utilizing a combination of both inorganic and organic sources (such as poultry manure and household compost) along with potassium application could be a suitable strategy for growing carrots in acidic terrace soil.

Profitability

The combined utilization of OA and RF, with or without K, had a notable impact (p<0.05) on the gross return, net return, B: C ratio, profitability and production efficiency of terrace-grown carrots. The absolute control plot had the lowest input cost and did not implement any management practices, resulting in the lowest production total, ultimately leading to the lowest net return, BCR, production and profitability efficiency for carrots. These patterns suggest that acidity is hindering the efficiency of carrot production in terrace soil. The treatment T_8, with RF + HC (5 t ha^{-1}), showed the highest improvement in the B: C ratio, profitability and production efficiency compared to the control, indicating a more effective carrot production in terrace soil (Table 7). Again, treatment T_8 had the highest total production cost could be attributed to the greater expenses related to input costs, labor and other expenditures (Avasthe *et al.,* 2020). The data of the present study explained that organic amendments and fertilizers with potassium improves the soil's physical, chemical and biological characteristics, resulting in higher carrot yields and economic productivity (Babu *et al.,* 2020; Singh and Kumar, 2024). Ultimately, the best economic outcomes, productivity efficiency and profitability in growing carrots was reached by combining potassium-enriched RF with OA. This implies that potassium and OA can offset the detrimental effects of soil acidity and could be a viable method for sustainable root crop production in terrace soil.

CONCLUSION

Application of potassium-rich RF with OA, partially alleviated soil acidification, resulting in a higher average soil pH in soil treated with RF + PM (5 t ha^{-1}) and RF + HC (5 t ha^{-1}). Incorporating OA and K-enrich RF into terrace soil improved the growth, yield and profitability of carrots, while the RF + HC (5 t ha^{-1}) treatment showed superior amendment potential for restoring productivity. In summary, our findings demonstrate that using RF and K-enrich RF fertilization can mitigate the adverse impacts of soil acidity on soil fertility and crop production in terrace soils.

Conflict of interest

All authors declared that there is no conflict of interest.

REFERENCES

Ahmad, T. Amjad, M. Iqbal, Q. Nawaz, A. and Iqbal, Z. (2014). Integrated nutrient management practices improve growth and yield of carrot. Bulgarian Journal of Agricultural Science. 20(6): 1457-1465.

Ahmed, F. Islam, M. Rahman, M.M. Chowhan, S. Bhuiyan, M.S.H. and Kader M.A. (2022). Effect of long-term manuring and fertilization on carbon sequestration in terrace soil. Agricultural Science Digest. 42(1): 14-19. DOI: 10.18805/ag.D-315.

Angelova, V.R. Akova, V.I. Artinova, N.S. and Ivanov, K.I. (2013). The effect of organic amendments on soil chemical characteristics. Bulg. J. Agric. Sci. 19(5): 958-971.

Annisha Afrin, A.A. Islam, M.A. Hossain, M.M. and Hafiz, M.M.H. (2019). Growth and yield of carrot influenced by organic and inorganic fertilizers with irrigation interval. Journal of Bangladesh Agricultural University. 17(3): 338-343.

Arebu, Y.H. (2022). Role of combined fertilizer application on soil fertility, growth and yield of potato (*Solanum tuberosum* L.): A review. Agricultural Science Digest. 42(6): 665-670. doi: 10.18805/ag.AF-693.

Appiah, F.K. Sarkodie-Addo, J. Opoku, A. (2017). Growth and yield response of Carrot (*Daucus carota* L.) to different green manures and plant spacing. J. Biol. Agril. Healthcare. 7(20): 16-23.

Avasthe, R.K. Babu, S. Singh, R. Yadav, G.S. Kumar, A. (2020). Productivity and proûtability assessment of organically grown vegetables embedded in rice-based cropping sequences in Sikkim Himalayas, North East India. J. Environ.Biol. 41: 111-117.

Babu, S. Singh, R. Avasthe, R.K. Yadav, G.S. Das, A. Singh, V.K. Mohapatra, K.P. Rathore, S.S. Chandra, P. Kumar, A. (2020). Impact of land configuration and organic nutrient management on productivity, quality and soil properties under baby corn in Eastern Himalayas. Sci. Rep. 10: 16129. https://doi.org/10.1038/s41598-020-73072-6.

BARC, (1997). Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council, Farmgate, Dhaka. 196: pp.

Bhandari, S.A. Patel, K.S. and Nehete, D.S. (2012). Effect of integrated nutrient management on growth, yield and quality of garlic (*Allium sativum* L.) cv. Gujarat G-3. Asian Journal of Horticulture. 7(1): 48-51.

Binte, B.I. Akter, M. Khanam, M. Alam, M A. Kabir, M.P. and Kamal, M.Z.U. (2021). Effect of integrated nutrient management on Okra production in acid soil. European Journal of Agriculture and Food Sciences. 3(6): 55-60.

Black, C.A. (1965). Methods of soil analysis part II and I. American Society Agronomy in Madison. Wisconsin: 325-333.

Blake, G.R. (1965 a). Particle density. In methods of soil analysis, part-I. C.A. Black, (Ed.). American Society Agronomy in Madison. Wisconsin: 371-373.

Blake, G.R. (1965 b). Bulk density. In methods of soil analysis, part-I. C.A. Black, (Ed.). American Society Agronomy in Madison. Wisconsin. pp 374-390.

Bouyoucos, G.J. (1962). Hydrometer method improved for making particle size analysis of Soils and Agronomic Journal. 54: 464-465.

Brammer, H. (1996 a). Rice soils of Bangladesh. In Soils and rice, pp. 35-55. Manila. Philippines: The International Rice Research Institute.

Brammer, H. 1996 b. The Geography of the Soils of Bangladesh, University Press Limited, Red Crescent Building, 114 Motijheel C/A, P.O. Box 2611. Dhaka 1000: Bangladesh.

Bray, R.H. and Kurtz, L.T. (1945). Determination of total, organic and available form of phosphorus in soils. Soil Science. 59: 39-45.

Chapagain, T. and Raizada, M.N. (2017). Agronomic challenges and opportunities for smallholder terrace agriculture in developing countries. Frontiers in plant science. 8: 331.

Chen, X. Zeng, D. Xu, Y. and Fan, X. (2018). Perceptions, risk attitude and organic fertilizer investment: evidence from rice and banana farmers in Guangxi, China. Sustainability. 10(10): 3715.

FAO/UNDP, (1988). Land Resources Appraisal of Bangladesh for Agricultural Development. Vol 2: Rome.

FRG Fertilizer Recommendation Guide, (2018). BARC (Bangladesh agricultural research council), Farmgate. Dhaka-1215. (2018).

Gazey C, Davies S. Soil Acidity: A Guide for WA Farmers and Consultants; 2009.

Hailu, F., Hassen, S., Hussen, S., Belete, E. and Alemu, T. (2024). Evaluation of different fertilizer sources for sustainable carrot production in Tehuledere district, Northern Ethiopia. Heliyon. 10(8): e29693. https://doi.org/10.1016/j.heliyon.2024.e29693.

Hunter, A.H. (1984). Soil Analytical Services in Bangladesh. BARI/ Aids Consultancy Report. Contract Aid/388-005, Dhaka. Bangladesh. pp. 1-7.

Ibeto, C.N. Lag-Brotons, A.J. Marshall, R. and Semple, K.T. (2020). The nutritional effects of digested and undigested organic wastes combined with wood ash amendments on carrot plants. Journal of Soil Science and Plant Nutrition. 20: 460-472.

Isaac, S.R. and Varghese, J. (2016). Nutrient management in turmeric (*Curcuma longa* L.) in an integrated farming system in southern Kerala. Journal of Spices and Aromatic Crops. 25(2): 206-209.

Islam, M.A. Hasan, M.A. and Farukh, M.A. (2017). Application of GIS in general soil mapping of Bangladesh. Journal of Geographic Information System. 9(5): 604-621.

Islam, M.R. Talukder, M.M.H. Hoque, M.A. Uddin, S. Hoque, T.S. Rea, R.S. and Kasim, S. (2021). Lime and manure amendment improve soil fertility, productivity and nutrient uptake of rice-mustard-rice cropping pattern in an acidic terrace soil. Agriculture. 11(11): 1070.

Jackson M.L. (1973a). Soil Chemical Analysis. Pritice Hall of India, New Delhi. 371: pp.

Jackson, M.L. (1973b). Soil Chemical Analysis. Advanced Course. 2nd ed. M.L. Jackson, Madison, WI.

Jackson, M.L. (1967). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd, New Delhi, India. 144-197 and 326-338.

Khanam, M. Alam, M.S. Kamal, M.Z.U. Akter, M. Binte, B.I. and Alam, M.A. (2022). Efficacy of organic and inorganic fertilizers on growth, yield and nutrient uptake of cauliflower in acidic soil of Bangladesh. European Journal of Agriculture and Food Sciences. 4(3): 24-29.

Lauricella, D. Butterly, C.R. Clark, G.J. Sale, P.W. Li, G. Tang, C. (2020). Effectiveness of innovative organic amendments in acid soils depends on their ability to supply P and alleviate Al and Mn toxicity in plants. Journal of Soils and Sediments. 20(11): 3951-3962.

MacFaddin, J.F. (2000). Biochemical tests for identification of medical bacteria, williams and wilkins. Philadelphia. PA: 113.

Malavika, M. Cheena, J. and Venkatalaxmi, K. (2022). Studies on the influence of integrated nutrient management on growth and yield of carrot (*Daucus carota* L.) Cv. Super Kuroda.

Meena, R.S., R. Lal and G.S. Yadav. (2020). Long term impacts of topsoil depth and amendments on soil physical and hydrological properties of an Alfisol in Central Ohio, USA. Geoderma. 363: 1141164.

Mehedi T.A. Siddique, M.A. Shahid, S.B. (2012). Effects of urea and cowdung on growth and yield of carrot. J. Bngladesh Agril. Univ. 10(1): 9-13.

Nisar, F. Mufti, S. Afroza, B. Khan, F.A. Din, S. andrabi, N. Saleem, S. Shah, L.R. and Nabi, J. (2019). Effect of integrated nutrient management on growth and yield attributes of black carrot (*Daucus carota* subsp. sativus var. atrorubens Alef.). International Journal of Chemical Studies. 7(4): 2019-2022.

Nisar, F. Mufti, S. Afroza, B. Mushtaq, F. Bhat, R. andrabi, N. and Din, S. (2020). Effect of integrated nutrient management on quality attributes of black carrot (*Daucus carota* subsp. sativus var. atrorubens Alef.). International Journal of Chemical Studies. 8(4): 3991-3994.

Page, A.I. Miller, R.H. Keeny, D.R. (1982). Methods of soil analysis. Part II. Chemical and Microbiological Methods, 2nd ed. Am. Soc. Agron. Madison, WI, USA. pp 225-246.

Paramesh, V. Mohan Kumar, R. Rajanna, G.A. Gowda, S. Nath, A.J. Madival, Y. Jinger, D. Bhat, S. and Toraskar, S. (2023). Integrated nutrient management for improving crop yields, soil properties and reducing greenhouse gas emissions. Frontiers in Sustainable Food Systems. 7: 1173258.

Parry, M.A.J. Flexus, J. Medrono, H. (2005). Prospects for crop production under drought. Research priorities and future directions. Annual Appl. Biol. 147: 211-226.

Shaban, K.A. Mahrous, M.S. Abdel-Azeem, S.M. and Rashad, R.T. (2018). Effect of different sources of potassium on the nutrient status of saline calcareous soil and carrot (*Daucus carota* L.) yield and quality. Asian Journal of Soil Science and Plant Nutrition. 3(3): 1-14.

Shikha, F.S. Sultana, N. Rahman, M.A. Bhuiya, S.H. Rahman, J. Akter, N. (2016). Effect of potassium fertilization on growth, yield and root quality of carrot. Int. J. Appl. Res. Studies. 2(3): 151-156.

Siddique, M.N.A. Islam, M.M. Sultana, J. Kamaruzzaman, M. and Halim, M.A. (2014). Potential of soil sensor EM38 measurements for soil fertility mapping in the Terrace soil of Bangladesh. Journal of Science, Technology and Environment informatics. 1(01): 01-15.

Singh, V.K. Singh, R. Pandey, S. Singh, V. and Singh, V.P. (2019). The study integrated nutrient management on growth, yield and yield attributes of carrot (*Daucus carota* L.). Agri Res and Tech: Open Access J. 22(5): 556211. DOI: 10.19080/ARTOAJ.2019.22.556211

Singh, H. and Kumar, V. (2024). Response of INM, spacing and cycocel on quality attributes of cabbage [*Brassica oleracea* (L.) var. capitata] in Bundelkhand. Agricultural Science Digest. 44(5): 837-842. doi: 10.18805/ag.D-5383.

Sparling, G.P. McLay, C.D.A. Tang, C. and Raphael, C. (1999). Effect of short-term legume residue decomposition on soil acidity. Soil Research. 37(3): 561-574.

Subba, S.K. Chattopadhyay, S.B. Mondal, R. and Dukpa, P. (2016). Effects of potassium and boron on quality parameters of carrot (*Daucus carota* L.). An International Quarterly Journal of Environmental Sciences. 487-490.

Walkley, A.C. and Black, T.A. (1965). Estimation of soil organic carbon by chromic acid titration method. Soil Science. 47: 29-38.

Wang, H. Xu, J. Liu, X. Zhang, D. Li, L. Li, W. and Sheng, L. (2019). Effects of long-term application of organic fertilizer on improving organic matter content and retarding acidity in red soil from China. Soil and Tillage Research. 195:104382.

Zhang, W. Xu, M. Wang, B. and Wang, X. (2009). Soil organic carbon, total nitrogen and grain yields under long-term fertilizations in the upland red soil of southern China. Nutrient cycling in agroecosystems. 84: 59-69.