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EFFECT OF SOIL AMENDMENTS ON TOMATO YIELD AND SOIL CHARACTERISTIC IN ACIDIC SOIL AT MOULVIBAZAR

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Abstract

Different soil amendments have various effects on crop growth, yield, and soil properties. The experiment was followed a Randomized Complete Block Design (RCBD) with three replications. Data on tomato growth and yield were collected, and soil samples were analyzed before and after the cropping seasons. Results showed that all amendments significantly increased tomato growth and yield compared to the control (no soil amendments). However, the amendments did not significantly affect days to first flowering (DFF), fruit length (FL), fruit diameter (FD), average fruit weight (AFW), fresh weight per plant (FWPP), or dry matter per plant (DMPP). In contrast, days after 50% flowering (D50 %F), plant height (PH), number of branches per plant, number of fruits per plant (NFPP), number of fruits per plot (NFPP), and yield per hectare (YPH) were significantly influenced by the soil amendments. Additionally, the shelf life of tomatoes was significantly ($p > 0.001$) affected by the amendments on acidic soil. Regarding soil properties, lime, phosphorus, and *Trichoderma* improved soil chemical properties. The findings confirm that applying soil amendments enhances tomato growth, yield, and quality.

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is the most popular vegetable globally grown (Araujo *et al*., 2016). The popularity of tomato among consumers is not only because of its good taste, but also because it contains high levels of vitamin C, lycopene, and beta-carotene, which are antioxidants that promote good health.

Soil acidity is a significant challenge in many agricultural regions, particularly in tropical and subtropical areas, where acidic soils often have low fertility and poor structure, limiting crop production. The cultivation of tomatoes (*Solanum lycopersicum*), a widely grown and economically important crop, is especially impacted by such unfavorable soil conditions. Soil amendments, including the use of lime, organic materials, and chemical fertilizers are commonly applied to improve both soil characteristics and crop yield in acidic environments.

One of the most effective strategies for managing soil acidity is liming, which neutralizes acidic soils by increasing pH, improving the availability of essential nutrients, and reducing toxic elements like aluminum and manganese (Rengel, 2011). Phosphorus (P) availability is also a key issue in acidic soils, as it becomes less accessible to plants when soil pH is low. Amending the soil with P fertilizers can improve nutrient uptake and support root growth, which is critical for enhancing crop yield (Fageria and Baligar, 2008). Organic amendments, such as compost and biochar, can improve soil structure, water retention, and microbial activity, further boosting plant growth and soil health (Sohi *et al*., 2010). Additionally, the introduction of *Trichoderma* fungi has been demonstrated to improve plant resistance to pathogens, enhance nutrient absorption, and promote plant growth by modifying root systems and soil properties (Harman *et al*., 2004).

Research on the combined effects of these amendments has shown that the application of lime, P, and organic materials in acidic soils can significantly improve tomato yield by enhancing soil physical and chemical properties. Studies have reported increases in soil pH, improved nutrient availability, and better root development, all of which contribute to higher crop productivity. Previous findings also suggest that a balanced application of lime, P, and *Trichoderma* significantly enhances tomato yield by improving soil characteristics, such as pH balance, nutrient availability, and microbial activity. The integration of organic and inorganic amendments offers a sustainable approach to managing acidic soils and improving long-term soil fertility in agricultural systems. The study was done to assess the effect of soil amendments on tomato growth, yield and soil properties.

Materials and Methods

Experimental location and soil

The experiment was conducted at the Regional Agricultural Research Station, BARI, Akbarpur, Moulvibazar during *Rabi* season of 2021-2022 and 2022-23 to find out the effects on tomato growth, yield and soil properties at acidic soil condition. The site belongs to the Agro-Ecological Zone of Eastern Surma-Kushiyara Floodplain (AEZ-20) and Northern and Eastern Hills (AEZ-29). The experimental field situated at 24°24′-24°38′ N latitude and 91°37′-91°37′ E longitude. The soil series belongs to the "Khadimnagar" having sandy loam in texture which consist moderate organic matter content (1.45%), N 0.80%, K 0.07m mol 100 $g^{-}1$ of soil, P was 25 µg g^{-1} of soil and S was 10 µg g^{-1} of soil with pH value 4-5. Each year, soil chemical properties in the experimental field were measured before and after the cultivation of groundnut (Table 1.) to check whether leguminous crop increases soil pH and organic matter or not. The metreological data such as maximum temperature (°C), minimum temperature (°C), UV index, precipitation (mm), and relative humidity (%) of the research site throughout the study duration from September 2021 to May of 2022 and September 2022 to May of 2023 cropping seasons are presented in Fig. 1 and 2. which were collected from weather station of Sreemongal, Sylhet, 12 km far from the experimental field.

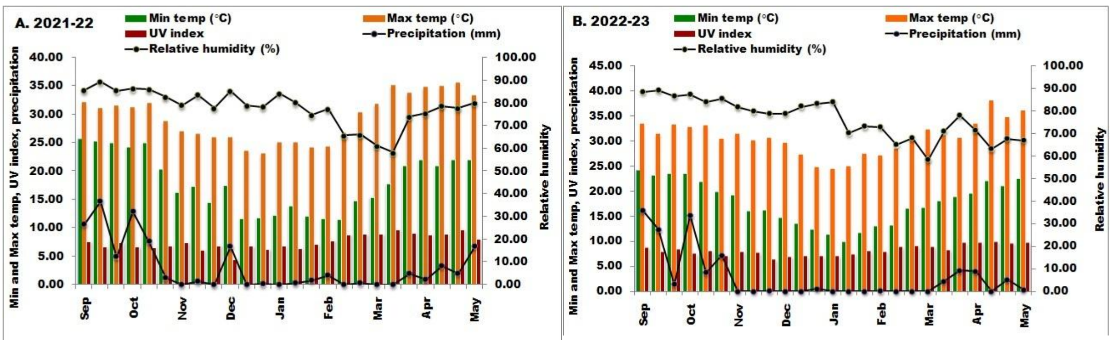

Fig. 1 (A-B). Meteorological data for the research site, showing maximum temperature (°C), minimum temperature (°C), UV index, number of rainy days and relative humidity (%) during the years 2021-2022 and 2022-2023.

Design and Treatments

The experiment was laid out in randomized complete block design (RCBD) with three replications. The treatments of the experiment were 5 (five) viz., T_1= Fertilizer

Recommendation Guide (FRG); T_2= FRG with P (60 kg ha^{-1}); T_3= FRG with Lime (2 t ha^{-1}); T_4= FRG with P (30 kg ha^{-1}) + Lime (2 t ha^{-1}), and T_5= FRG with Lime (2 t ha^{-1}) +*Trichoderma* (2 t ha^{-1}).

Fertilizer management

The crop was fertilized with 160-60-80-28-3-1.5 kg ha^{-1} N-P-K-S-Zn-B in the form of urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate, and boric acid, respectively (FRG, 2018). Half of the quantity of K and organic fertilizer, entire P, Zn, and B were applied during land preparation. The remaining half of the organic fertilizer was used during pit preparation. The rest of K and entire N were applied at two equal installments at 15 and 30 days after transplanting under moist condition and mixed thoroughly with soil as soon as possible. Before applying the fertilizer doses, the chemical properties of the experimental plots were recorded and presented in Table 1A. Post harvest soil analysis was also done which depicted in Table 1B.

Table 1A. Initial chemical properties of experimental soil at RARS, Akbarpur, Moulvibazar

Location	pH	OM (%)	Ca	Mg	K	Total	P	S	B	Cu	Fe	Mn	Zn
			meq 100 g^{-1}			N%	µg g^{-1}						
RARS, Moulvibazar	4.3	1.61	1.70	0.42	0.40	0.08	42.5	13	0.54	0.76	63	19.11	0.24
Critical level		C: N=10:1	2.0	0.8	0.20	0.12	10	10	0.2	1	10	5	0.6

Table 1B. Final chemical properties of experimental soil at RARS, Akbarpur, Moulvibazar

Treatment	pH	OM (%)	Ca	Mg	K	Total N%	P	S	B	Cu	Fe	Mn	Zn
			meq 100 g^{-1}				µg g^{-1}						
T_1	4.5	1.71	1.73	0.96	0.45	0.048	93.38	86.91	0.68	0.87	355.20	15.00	3.69
T_2	4.6	1.86	1.60	0.93	0.55	0.038	107.05	97.49	0.66	0.93	378.60	17.10	3.75
T_3	4.8	1.96	3.87	1.46	0.53	0.048	78.16	107.49	0.40	0.93	346.50	12.00	2.64
T_4	4.9	2.26	5.58	1.29	0.48	0.065	78.94	124.02	0.50	1.02	350.70	11.10	2.97
T_5	5.0	2.57	7.22	1.02	0.51	0.089	90.76	27.20	0.52	0.99	289.50	4.80	2.01

T_1=FRG recommendation, T_2= FRG with P (60 kg ha^{-1}), T_3= FRG with Lime (2 t ha^{-1}), T_4= FRG with P (30 kg ha^{-1}) + Lime (2 t ha^{-1}), T_5= FRG with Lime (2 t ha^{-1}) +*Trichoderma* (2 t ha^{-1}).

Crop management and protection

A light irrigation was done at just after transplanting in each seedling for establishment. Thereafter, flood irrigation was applied for three times at 30, 40, and 80 DAP, and other intercultural operations were done as when necessary, following the recommended production technologies of the Tomato crops (BARI, 2020). Hand weeding was done twice at the plant establishment and flowering stage. Some leaves and emerging twigs were pruned during the cropping season. Diseases like leaf spot, root rot, rust, wilt, and insect pests viz., termite, leaf minor were control through recommended insecticides and fungicide. The seedlings of tomato variety (BARI Tomato-15) were transplanted on 15 and 18 November, 2022 and 2023, respectively. The crops were harvested when attained to their respective physiological maturity. The unit plot size was 3 m × 2.75 m.

Statistical analysis

Data were collected in relation to phenology, yield attributes, yield, and quality of tomato. The data recording for each trait (3) was carried out from all replications. The recorded agronomic data were subjected to the analysis of variance (ANOVA) using R software, version

4.3.1 (R core Team, 2019), and mean separation was carried out using the least significant difference (LSD) test at a 5% probability level by Gomez and Gomez (1984).

Results and Discussion

Changes of post-harvest soil properties

The results of the study showed that soil pH and organic matter increased significantly when added P, lime, and *Trichoderma* with approved fertilizers to acidic soils. Depending on different treatments Soil pH increased by 5-16% and organic matter increased by 6-60%. The maximum soil pH (16%) and organic matter (60%) were increased where lime and *Trichoderma* were applied with recommended fertilizers where the lowest value was observed where only approved fertilizers were used. The order of soil acidity and organic matter among different treatments was $T_5>T_4>T_3>T_2>T_1$. Similar results were observed for Ca. In case of Mg, higher values were obtained where lime was applied with recommended fertilizers (T_3) and lower where P was applied (T_2). For K higher values were obtained where P was applied (T_2) and lower values where only approved fertilizer levels were used (T_1). The percentage of total Nitrogen (N) was lower where P was applied with approved fertilizers (T_2) and higher where lime and *Trichoderma* were added (T_5). Naturally P excess was observed where P was applied with approved fertilizers (T_2) and P deficiency was observed where lime was applied (T_3). S values were found to be higher when P and lime were added with recommended fertilizers (T_4) and significantly reduced S values where lime and *Trichoderma* were added (T_5). B values were observed to be higher at the approved fertilizer levels (T_1) and lower where lime was applied (T_3). Cu was higher where P and lime were added (T_4) and lower where only P or lime was applied (T_2 and T_3). Fe content was found to be higher where P was applied (T_2) and lower where lime and *Trichoderma* were applied (T_5). Similar results were obtained for Mn and Zn.

Overall, the results provide key insights into the effects of adding P, lime, and *Trichoderma*, along with approved fertilizers, on acidic soils. The combination of lime and *Trichoderma* with approved fertilizers had the most significant positive impact on soil pH, organic matter, and N content (T_5). P applications led to higher K and Fe levels but resulted in lower N and Mg content. Lime application played a key role in increasing Ca and Mg levels but led to P and B deficiencies. These results suggest that amendments involving lime, P, and *Trichoderma*, depending on the target nutrients, can optimize soil health in acidic environments.

Phenology, yield contributing traits and yield of tomato

The results showed that soil amendments had no significant effect on days to first flowering (DFF), fruit length (FL), or fruit diameter (FD) of tomatoes grown in acidic soil (Table 2). However, amendments significantly influenced days after 50% flowering (D50 %F), plant height (PH), number of branches per plant, and number of fruits per plant (NFPP) in tomatoes. T_1 treatment recorded the longest days after 50% flowering (D50 %F) (35 days), followed by T_4 with 34 days and T_5 with 34 days. T_1 also showed the highest D50 %F at 40 days, followed by T_5 (40 days) and T_4 (39 days). In terms of plant height, T_5 produced the maximum plant height (112.42 cm), followed by T_2 at 110.77 cm in acidic soil. These findings suggest that soil amendments with fertilizers were effectively utilized by the tomato plants, leading to significant growth in plant height. This supports previous research by Ortas (2013), which showed that soil amendments in various fertilizer forms enhanced tomato plant height. The number of tomato branches was also positively influenced by the amendments, promoting greater vegetative growth. Treatment T_4 recorded the maximum NFPP (52.00), followed by T_3 with 49.67 fruits, and T_1 with 47.67 fruits. This variation in fruit number was due to differences in nutrient release from the amendments. As shown in Table 3. the NFPP and fruit yield per hectare (YPH) were significantly influenced by the soil amendments, while shelf life was highly significant. However, average fruit weight (AFW), fresh weight per plant (FWPP), and dry matter per plant (DMPP) were not significantly affected. Treatment T_5 recorded the maximum NFPP (858.0), followed by

T_2 (846.33), while T_4 had the lowest (700.0). Treatment T_2 produced the maximum YPH (68.99 t ha^{-1}), followed by T_3 (68.04 t ha^{-1}) and T_4 (63.38 t ha^{-1}), while T_1 had the lowest fruit yield (59.32 t ha^{-1}). The results showed that yield-contributing factors were higher in P-treated plants compared to control. Regarding shelf life, T_3 and T_4 showed the longest shelf life after harvest (30 and 28 days, respectively), followed by T_2 (25 days). Treatment T_1 recorded the shortest shelf life (14 days) for tomatoes.

Table 2. Effect of different soil amendments on yield and yield-related traits on tomato at acidic soil (pooled average of 2021-2022 and 2023-24)

Treatment	Days to first flowering (days)	D50 %F (days)	Plant height (cm)	Flowering length (cm)	Fruit diameter (cm)	Branches plant^{-1}	Number of fruits plant^{-1}	Average fresh weight (g)
T_1	35	40	109.2	4.9	4.23	4.76	47.67	42.89
T_2	32	37	110.77	5.47	4.46	4.43	46.33	46.45
T_3	34	39	108.87	5.07	4.23	4.77	49.67	45.12
T_4	34	39	107.97	5.07	4.4	4.89	52	45.99
T_5	34	40	112.42	5.17	4.13	4.89	44.33	50.63
CV (%)	5.51	4.95	4.04	8.95	8.7	14.5	12.54	8.79
LSD $_{(0.05)}$	3.51	3.63	8.35	0.86	0.70	1.23	11.33	7.64

Here, T_1=FRG (2018), T_2= FRG with P (60 kg ha^{-1}), T_3= FRG with Lime (2 t ha^{-1}), T_4= FRG with P (30 kg ha^{-1}) +Lime (2 t ha^{-1}), T_5= FRG with Lime (2 t ha^{-1}) +*Trichoderma* (2 t ha^{-1}).

Table 3. Effect of different soil amendments on yield and yield-related traits on tomato at acidic soil (pooled average of 2021-2022 and 2023-24)

Treatment	Fresh weight per plant (g)	Dry matter per plant (gm)	Fruits plot^{-1}	Yield Per Plot (kg)	Yield (t ha^{-1})	Shelf Life (days)	Total soluble solids
T_1	250.67	31.23	740.67	16.31	59.32	13.51	4.75
T_2	282.67	35.18	846.33	18.97	68.99	25.08	4.73
T_3	262.67	32.86	710.67	18.71	68.04	30.91	4.97
T_4	330.22	33.71	700.67	17.43	63.38	28.06	4.7
T_5	200.33	34.21	858.67	17.76	64.59	21.68	4.81
CV (%)	14.53	14	8.62	18.78	18.78	13.83	6.03
LSD $_{(0.05)}$	72.58	8.81	125.22	6.30	22.94	6.21	0.55

Here, T_1=FRG (2018), T_2= FRG with P (60 kg ha^{-1}), T_3= FRG with Lime (2 t ha^{-1}), T_4= FRG with P (30 kg ha^{-1}) +Lime (2 t ha^{-1}), T_5= FRG with Lime (2 t ha^{-1}) +*Trichoderma* (2 t ha^{-1}).

Correlation analysis among the studied traits

Under the study, all the phenological and yield contributing traits were exhibited positive and negative correlation from each other's (Fig. 2). The traits DFF perform positive significant correlation (p= 0.05 level) with days to flowering (DF), fruit length (FL), DMPP, yield per plot (YPP) and yield per hactare (YPH). This indicates that as the DFF increase, these traits tend to increase as well, potentially leading to higher yields per plot and per hectare. Plant height showed positive significant correlation (p=0.05 level) with number of fruits plant^{-1} (NFPP) and number of fruit plot^{-1} (NFPP). This suggests that taller plants are associated with an increased number of fruits, which may contribute to higher overall yield. Similarly, FL, NFPP and YPP traits present positive significant correlation with DMPP, FPP and YPH, respectively. These relationships suggest that improvements in these traits are likely to enhance the dry matter content, fruit count, and overall yield. Rest of the traits showed positive and negative insignificant correlation with one to another. The lack of significance in some cases implies that these traits might not directly influence one another in a consistent manner under the conditions studied. For instance, early flowering (DFF) might be negatively associated with traits such as pH, suggesting that earlier flowering plants may be shorter and potentially produce fewer fruits per plant. These findings have practical implications for tomato breeding programs. Traits that exhibit strong positive correlations with yield components, such as DFF with YPP and YPH and PH with NFPP and FPP are valuable targets for selection. Improving these traits may lead to higher yields, both per plot and per hectare.

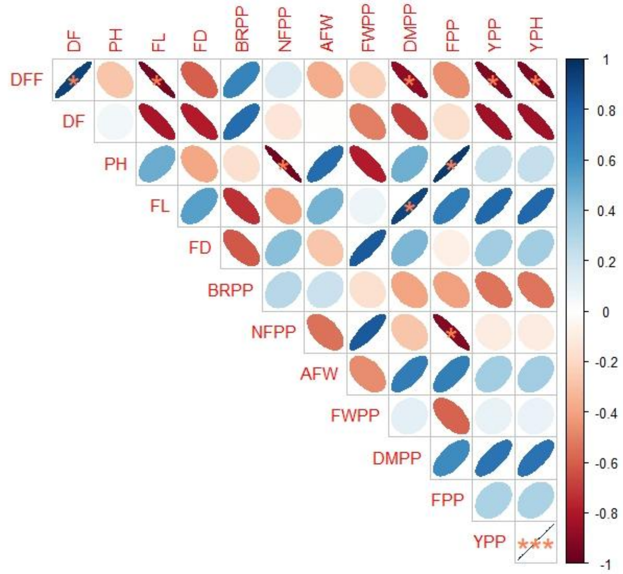

Fig. 2. Correlation of phenological and yield contributing traits with fruit yield of tomato (DFF= Days to first flowering; DF= Days to flowering (50%), PH= Plant Height; FL= Fruit Length; FD= Fruit Diameter; BRPP= Branches Plant^{-1}; NFPP= Number of Fruits Plant^{-1}; AFW= Average fruit weight; FWPP= Fresh weight plant^{-1}; DMPP= Dry matter plant^{-1}; FPP= number of Fruit Plot^{-1}; YPP= Yield per plot; YPH= yield per hectare)

Conclusion

The study showed that soil amendments such as lime, P, and *Trichoderma* significantly improved tomato growth, yield, and soil properties in acidic soil. The combination of lime and *Trichoderma* with recommended fertilizers was particularly effective, enhancing soil pH, organic matter, and nitrogen content. P application resulted in higher K and Fe levels but reduced Mg and N. The findings confirm that appropriate soil amendments not only boost tomato productivity but also improve soil chemical characteristics, providing a sustainable solution for managing acidic soils in agriculture.

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