Effect of soil enzyme activity on different nitrogen fertilizer and irrigation regimes in tomato production

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Abstract

The field study investigated the effect of soil enzyme activity on tomato production under different irrigation regimes and various source of nitrogenous fertilizer. Soil enzymes play a crucial role in nutrient cycling and availability, thereby influencing the plant growth and productivity. The field experiment was carried out in a split plot design with two main plots having irrigation regimes and five subplots are different source of nitrogenous fertilizers. The results obtained from the experimentation indicated that soil enzyme activity was significantly influenced by the interaction of irrigation and nitrogen fertilizer. Higher soil enzyme activity (cellulase, urease and phosphatase activity) were observed in treatment combination of 0.6 IW/CPE ratio with vermicompost and neem coated urea fertilizer applied treatments. The lower value in the soil enzymes were observed in the nano-urea applied treatments. The present study results shows that higher irrigation will reduce the microbial activity in the soil and also the organic fertilizer like vermicompost will increase the soil microbial than other synthetic fertilizers. Additionally, optimal irrigation conditions positively influenced the soil enzyme activity leads to increase the tomato fruit yield.

Key words: Tomato, nitrogen fertilizer, IW/CPE ratio, cellulase, urease and phosphate activity

1. Introduction

Soil ecosystems health and productivity are vital for critical for sustainable agriculture due to the activity of soil enzymes and microbial populations which are the key factors for sustaining soil fertility. The selection of nitrogen fertilizers (Fageria *et al*., 2005) and appropriate irrigation regimes (Zhang *et al*., 2018) and their interaction (Sadras *et al*., 2016) significantly influenced the soil enzyme activity and microbial populations thereby impacting on overall soil health in tomato production systems. Nitrogen fertilizer is an essential for promoting plant growth and maximizing the crop yields (Leghari *et al*., 2016). However, the type of nitrogenous fertilizer applied could have diverse effects on soil microbial communities and enzyme activities (Yue *et al*., 2019 and Zhao *et al*., 2019)). Urea was widely used nitrogen fertilizer in agriculture production provides a readily available source of

nitrogen for plants, but its application can potentially affect the soil enzyme activity (Sun *et al*., 2019). Ammonium sulfate is an another commonly used nitrogen fertilizer that releases both ammonium and sulfate ions into the soil could influence the soil enzyme activity (Chien *et al*., 2011). Among the organic nitrogen sources, vermicompost offered to slow-release nitrogen and provide additional benefits to soil health thereby enhanced the soil enzyme activities, potentially improving nutrient cycling and overall soil fertility (Saranraj and Stella, 2012). Nano urea, a nanotechnology-based nitrogen fertilizer has gained attention for its potential to increase nutrient use efficiency and reduce environmental impacts (Kannoj *et al*., 2022). Understanding the effects of nano urea on soil enzyme activity is crucial for assessing its suitability in sustainable tomato production.

Furthermore, irrigation regimes play a crucial role in soil enzyme activities. The ratio of irrigation water to crop evapotranspiration (IW/CPE) is an important parameter that affects the soil moisture content and nutrient availability. Irrigation regimes with different IW/CPE ratios can influence soil enzyme activity and microbial populations. A higher irrigation levels may enhance nutrient transport, while lower irrigation levels can potentially affect enzyme functioning.

Tomato production systems heavily rely on soil enzyme activity for nutrient cycling, organic matter decomposition, and disease suppression (Hou *et al*., 2020 and Khan *et al*., 2021). Understanding the effects of different nitrogen fertilizers and irrigation regimes on soil enzyme activity and microbial populations (Feng *et al*., 2015) in tomato production is essential for optimizing nutrient management practices and promoting soil health. This knowledge could contribute to the development of sustainable agricultural systems that minimize environmental impacts while maintaining or enhancing tomato yields and quality.

Hence this study aims to investigate the effects of different nitrogen fertilizers, including urea, ammonium sulfate, vermicompost, nano urea, and neem coated urea with two irrigation regimes (0.6 and 0.8 IW/CPE ratio), on soil enzyme activity and microbial populations in tomato production. By examining the interactions between nitrogen fertilization, irrigation practices, soil enzymes and microbial communities, this research strives to improve our understanding of sustainable soil management strategies for tomato cultivation and enhance overall soil health in agricultural ecosystems.

2. Materials and Methods

To study the effects of different nitrogen fertilizers and irrigation regimes on the soil characteristics and the growth of tomato, an experiment was conducted at eastern block farm in Tamil Nadu Agricultural University, Coimbatore. The mean annual precipitation of 746.5

mm was recorded in 47 rainy days. The mean daily maximum and minimum temperature is 31.8°C and 21.4°C, respectively. The soil of the experimental site is calcareous, with a clay loam texture. The soil characteristics of the study site are pH, 8.2; electrical conductivity (EC) is 1.23 dSm^{-1}; organic matter content about 21.7 g kg^{-1} and total N value is 1.93 g kg^{-1}.

The field experiment was conducted during July 2022 and December 2022 and laid out in split plot design with two main plots and five subplots. The two irrigation regimes are 0.6 and 0.8 IW/CPE and five different nitrogenous fertilizers are urea, neem coated urea, ammonium sulfate, nano-urea and vermicompost.

For each crop, uniform seedlings were transplanted to each plot. The cultural operations were carried out as per HCPG (2019). Pre-germinated 25 days old seedlings were transplanted in the field in the spacing of 60x45 cm. Gap filling was done on 7^{th} DAT to maintain a uniform plant population in the field. All plots were irrigated when it reached particular IW/CPE ratio. The recommended fertilizer dose of 200:250:250 kg NPK ha^{-1} was applied to all the treatment plots. Nitrogen was applied in five different sources as mentioned above. In case of nano-urea given as liquid fertilizer in the ratio of 45 kg of urea equal to 500 ml of Nano-urea. Nitrogen fertilizer was applied at basal, 15 DAT, 30 DAT and 45 DAT. Hand weeding was done to manage the weeds and no pesticides were applied. As per HCPG (2019) all other cultivation practices were carried out. All the treatments were replicated three times in a split plot design. Soil samples from each plot were collected and sieved through a 2 mm mesh and was then stored at 2°C for soil enzyme analysis. Soil enzyme analysis procedure were given below.

2.1. Soil enzyme analysis

2.1.1. Cellulase activity

Five grams of sieved (2 mm) soil was placed in an Erlenmeyer flask. 15 mL each of acetate buffer and carboxy methyl cellulose (CMC) solution were added and capped. Eventually, this flask was incubated for 24 h at 50° C and the resulting soil suspension was filtered. The control was prepared by adding 15 mL CMC solution after the incubation but without filtration. 1 mL of the filtrate was diluted to 20 mL with distilled water. 1 mL of the diluted filtrate was pipetted into glass tubes followed by addition of 1mL of reagent A (Annexure) and 1mL of reagent B (Annexure). The aliquots were mixed well and kept in water bath (100° C) for 15 min. 5 mL of reagent C (Annexure) was added to the solution and mixed well. Finally, the assay mixture was kept aside at 20° C for 60 min for colour development. The optical density was measured at 690 nm against the blank (Schinner and von Mersi, 1990).

$$\text{Glucose equivalent } (\mu g\ g^{-1} \text{ dwt. of soil } h^{-1}) = \frac{C \times v \times f}{sw \times dwt \times 24}$$

Where C is the measured glucose concentration (µg of glucose mL^{-1} of filtrate), v is the volume of the test suspension (in this system 20 mL), f is the dilution factor, sw is the weight of the moist soil used (5 g), dwt is the weight of 1g moist soil and 24 is the incubation time.

2.1.2. Urease activity

One gram soil (2 mm) was taken to a 100 mL volumetric flask. 1 mL of toluene was added and allowed to stand for 15 minutes. 10 mL of buffer solution and 5 mL of 10% urea solution were added to the tube, shaken well and incubated at 37^0 C for 3 h. After incubation the volume was made up to 100 mL by adding distilled water. The contents were filtered through filter paper. 0.5mL filtrate was taken in 25 mL volumetric flask and 5 mL distilled water was added. 2mL phenolate solution and 1.5 mL sodium hypochlorite solution were added to the volumetric flask. Final volume was made upto 25 mL and the optical density was measured at 630 nm (McGarity and Myers, 1967).

$$\text{Urease } (\mu g\ g^{-1} \text{ dwt. of soil } h^{-1}) = \frac{C \times 25}{dwt \times t \times 10}$$

Where C is the measured NH_4-N concentration, dwt is the dry weight of 1 g moist soil, t is the incubation time in hours, and 25 is the total volume of the soil suspension in mL (Kandeler and Gerber, 1988).

2.1.3. Phosphatase activity

One gram of soil (2 mm) was taken in a 50 mL Erlenmeyer flask. 4 mL modified universal buffer, 0.25 mL toluene and 1 mL p-nitrophenol phosphate were added, mixed thoroughly and incubated at 37^0 C for 1 h. After incubation, 1 mL calcium chloride and 4 mL sodium hydroxide were added. The contents were mixed well and filtered through Whatman No. 12 filter paper. The resulted filtrate was measured for absorbance at 400 nm (Tabatabai and Bremner, 1969).

$$\text{P-nitrophenol } (\mu g\ g^{-1} \text{ dwt. of soil } h^{-1}) = \frac{C \times 10}{dwt \times t}$$

Where C is the measured p-nitrophenol concentration (µg of p-nitrophenol mL^{-1} of filtrate), dwt is the dry weight of 1 g moist soil, t is the incubation time in hours, 10 is the total volume of the soil suspension in mL.

3. Results and Discussion

Influence of irrigation regimes and different nitrogen fertilizer on soil enzymes was analyzed and presented in Table 1.

3.1. Cellulase activity

Cellulase activity was significantly altered with the application of different irrigation regimes and source of nitrogenous fertilizer. Based on the irrigation regimes, treatment I_1 (Irrigation at 0.6 IW/CPE ratio) was performed better than I_2 (Irrigation at 0.8 IW/CPE ratio). In regard with different sources of nitrogenous fertilizers, vermicompost applied treatment was recorded a greater cellulase activity while a lower cellulase activity was observed in nano-urea fertilizer applied treatments. The results indicated on the interaction of among the various irrigation regimes and nitrogen fertilizer, the treatment combination I_1N_5 and I_2N_5 were documented a higher cellulase activity whereas the treatment combination I_1N_4 and I_2N_4 were performed a lower activity on cellulase enzyme.

At I_1 (Irrigation at 0.6 IW/CPE ratio) irrigation regimes, Higher (542.04) cellulase activity value was recorded higher in the treatment N_5 (vermicompost) than N_2 (neem coated urea). The treatment with application Nano-urea was recorded lower cellulase activity (346.13) than all other treatments. At I_2 (Irrigation at 0.8 IW/CPE ratio) irrigation regimes, the treatment N_5 (vermicompost) was recorded highest cellulose activity (379.58) value than all other treatments but it was on par with neem coated urea applied treatment. The treatment N_4 (Nano-urea) was observed lower cellulose activity than others and it was on par with N_3 (Ammonium sulfate) and N_5 (Urea).

The results shows that organic fertilizer increase the cellulase activity and also the lower irrigation will increase the cellulase activity. The results in the present study were agreed with those observed in a study on soils amended with sludge containing cellulose (Hattori 1988) or manure with straw (Dick *et al.* 1988).

3.2. Urease Activity

Urease enzyme that catalyzes the hydrolysis of urea and which is widely used in the evaluation of changes in soil quality for soil management (Díaz-Marcote and Polo 1995).

Urease activity was significantly differed with different irrigation regimes and nitrogen fertilizer sources. Based on the irrigation regimes, Irrigation at 0.6 IW/CPE ratio (I_1) regime was observed a greater value on urease activity than Irrigation at 0.8 IW/CPE ratio (I_2). Among the various nitrogenous fertilizer treatments, N_5 (vermicompost) and N_2 (neem coated urea) were recorded significantly an increased urease activity whereas a lower urease

activity was observed in Nano-urea (N_4) and Ammonium sulfate (N_3) fertilizer applied treatments. Among the combination of both different irrigation and nitrogen fertilizer, the treatment combination I_2N_5 and I_1N_5 were documented an increased urease activity while treatment combination I_1N_4 was recorded a lower soil urease activity.

At I_1 irrigation regimes, the higher urease activity (163.48) was recorded in the treatment N_5 (vermicompost). The lower urease activity (138.23) was recorded in the treatment Nano-urea applied treatment. At I_2 irrigation regimes, the vermicompost applied treatment was recorded higher urease activity (148.82) value than others and it was on par with neem coated urea fertilizer applied treatment. The lower urease activity (117.06) was recorded in Nano-urea applied treatment and it was on par with ammonium sulfate applied treatment.

Similar results have been reported (García *et al*., 1994; Pascual *et al*., 1999 and Chakrabarti *et al.,* 2000).

3.3. Phosphatase Activity

Deng and Tabatabai (1996, 1997) reported that an activity of phosphatase were highly correlated with soil organic C content and suggested that organic matter plays an important role in protecting soil enzymes.

Phosphatase activity were significantly differ with different nitrogen fertilizer and irrigation regimes. Based on the irrigation regimes, the I_1 (Irrigation at 0.6 IW/CPE ratio) group was performing the best than I_2 (Irrigation at 0.8 IW/CPE ratio). In nitrogen fertilizer based, vermicompost applied treatments was performing best in phosphatase activity and the poor phosphatase activity was observed in nano-urea fertilizer applied treatments. In the combination of both different irrigation and nitrogen fertilizer, the treatment combination I_1N_5 were performing the best and the treatment combination I_1N_4 and I_2N_4 were performing the poor soil phosphatase activity.

At I_1 irrigation regimes, higher phosphatase activity (52.16) was found in vermicompost applied than all other treatments. The lower phosphatase activity (32.71) was recorded in Nano-urea applied treatment than other nitrogen applied treatments. At I_2 irrigation regimes, the higher phosphatase activity (47.33) was recorded in vermicompost applied treatment than others. The lower value of phosphatase activity (31.62) was recorded in nano-urea applied treatment.

The results shows that higher irrigation will reduce the microbial enzyme activity in soil. Martens *et al.* (1992) also reported that the addition of organic matter maintained high levels of phosphatase activity in soil during a long-term study. Dodor and Tabatabai (2003)

found that higher phosphatase activity in soil resulted from higher organic C contents in the soils.

Plant growth and yield as related to enzymatic activities

The correlation between the soil enzymes, growth parameter such as plant height and yield parameter like fruit yield were calculated to know the relationship between the growth and yield parameters with the soil enzymes activities (Growth and yield data not given). The results on correlation values between the all parameters were given under Table 2. In relation with fruit yield, plant height and phosphate activity are positively correlated and cellulase and urease activity were negatively correlated. In plat height relation, cellulase and phosphatase activity were positively correlated and urease activity was negatively correlated.

Table 1. Soil enzymes activity in different nitrogen fertilizer and irrigation regimes of tomato

Treatments	Cellulase Activity			Urease Activity			Phosphatase Activity		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
N_1	387.87	262.63	**325.25**	147.15	123.86	**135.50**	41.43	37.30	**39.36**
N_2	528.29	359.23	**443.76**	160.29	144.28	**152.29**	43.64	42.49	**43.06**
N_3	351.79	238.48	**295.13**	141.23	123.20	**132.22**	40.86	34.85	**37.86**
N_4	346.13	231.90	**289.01**	138.23	117.06	**127.65**	32.71	31.62	**32.17**
N_5	542.04	379.58	**460.81**	163.48	148.82	**156.15**	52.16	47.33	**49.75**
Mean	**431.22**	**294.36**	**362.79**	**150.08**	**131.44**	**140.76**	**42.16**	**38.72**	**40.44**
	I	**N**	**I x N**	**I**	**N**	**I x N**	**I**	**N**	**I x N**
SEd	0.48	4.93	6.27	2.41	3.26	4.77	2.98	1.52	2.04
CD (0.05)	4.85	14.43	18.57	23.87	9.51	22.43	6.89	4.44	7.63

I_1 - Irrigation at 0.6 IW/CPE Ratio
I_2 - Irrigation at 0.8 IW/CPE Ratio

N_1 - Urea
N_2 - Neem coated urea
N_3 - Ammonium sulfate
N_4 - Nano-urea
N_5 - Vermicompost

Table. 2. Correlation between the soil enzymes with fruit yield

	Plant height	Fruit yield	Cellulase Activity	Urease Activity	Phosphatase Activity
Plant height	1	0.57	0.006	-0.55	0.19
Fruit yield	0.57	1	-0.28	-0.11	0.16
Cellulase Activity	0.006	-0.28	1	-0.23	-0.61
Urease Activity	-0.55	-0.11	-0.23	1	-0.08
Phosphatase Activity	0.19	0.16	-0.61	-0.08	1

4. Conclusions

This study highlighted that, significance of soil enzyme activity in tomato production and its interaction with nitrogen fertilizer and irrigation regimes. Optimizing these factors could contribute to enhanced nutrient availability, plant growth that ultimately a higher tomato yields. The results of the field experiment concluded that the irrigation levels of 0.6 IW/CPE ratio was observed a higher yield. And among the different nitrogenous fertilizers, urea, neem coated urea and nano-urea were observed a greater value on enzyme activities than others. Further research on specific soil enzymes and their response to different agronomic practices is recommended to refine management strategies for sustainable tomato cultivation.

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