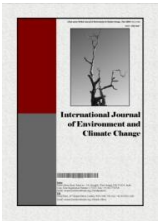

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Evaluation of Yield and Quality Attributes of Grafted Brinjal under Treated Paperboard Mill Effluent Irrigation and Sludge Application

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Authors' contributions

This work was carried out in collaboration among all authors. Author MA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors GB, PT, TS and MM managed the analyses of the study. Author MP managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Field experiment was conducted to assess the impact of paperboard mill sludge compost and treated paperboard mill effluent irrigation on growth and yield of grafted brinjal. Among the different treatment combinations, application of phosphorus enriched ETP sludge compost at 5 t ha^{-1} along with treated effluent through drip irrigation and recommended level of NPK (200:150:100 kg NPK ha^{-1}) resulted the highest brinjal yield of 42.7 t ha^{-1}. There were no adverse effects on soil properties due to sludge compost application and treated effluent irrigation. Quality attributes of the fruits which include anthocyanin content, total phenol content, ascorbic acid content, titrable acidity and protein content were not affected due to the composted sludge application along with treated effluent irrigation. Thus, the treated effluent and the composted sludge which complies with the state pollution control board norms can be used as a viable alternative source of irrigation and nutrients for grafted brinjal cultivation without adversely affecting on crop quality.

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Keywords: Paperboard mill; treated effluent; composted sludge; grafted brinjal; yield; quality attributes.

1. INTRODUCTION

Indian industries have contributed to high economic growth during the past few decades, but at the same time, have resulted in severe environmental pollution by generating enormous quantity of solid wastes and effluents. Reuse of wastewater in agriculture is expected to increase dramatically as fresh water sources are scarce and expensive since ground water is being dwindling rapidly. Application of treated effluent as irrigation water offers a promising replacement and help in improving soil properties [1]. Similarly, the sludge incorporation in agricultural and forest soils had shown numerous benefits like increased plant growth, yield and improved soil moisture (Prasanthrajan et al.,2004).

Brinjal is an economically and nutritionally important vegetable crop of tropical and subtropical zones. In 2019, world production of brinjal was around 55.56 million metric tons with China as top producer followed by India. The area under Indian brinjal cultivation is estimated to be 7.27 lakh hectares with a total production of 12.68 million metric tons (FAOSTAT, 2019). Generally, vegetable grafts are used to overcome both biotic and abiotic stresses and to improve yield and for prolonging the harvest period which ensures limited use of fertilizers and pesticides in order to protect the environment [2]. Hence the yield and quality of fruits from grafted brinjal plants grown under treated paperboard mill effluent irrigation along with composted sludge application has been studied under field conditions.

2. MATERIALS AND METHODS

2.1 Field Trial

An experiment was carried out at Thekkampatty village, Mettupalayam taluk, Coimbatore district, Tamilnadu with the experimental layout of split-split plot design having eight treatments and four replications with grafted brinjal as a test crop. Root stock of the grafted brinjal was *Solanum torvum* and the scion material was the brinjal hybrid (Simran) widely used in this location. Treatments comprised of three main factors with two levels in each factor *viz*., Factor 1: Source of irrigation (I_{1-} well water, I_{2-} Treated effluent), Factor 2: Method of irrigation (M_1- Flood irrigation, M_2 – Drip irrigation) and Factor 3: Sludge application (S_1- ETP sludge compost at 5 t ha^{-1}, S_2- ETP phosphorous enriched sludge compost at 5 t ha^{-1}) (ETP - Effluent Treatment Plant) and the treatment combinations were $I_1M_1S_1$, $I_1M_1S_2$, $I_1M_2S_1$, $I_1M_2S_2$, $I_2M_1S_1$, $I_2M_1S_2$, $I_2M_2S_1$ and $I_2M_2S_2$. The amendments mentioned in the treatment were applied before planting and the study was conducted during the year 2019-2020.

In each replication, plants were grown on a plot of 6 m x 4.5 m size, accommodating 12 plants with a row to row spacing of 1.5 m and plant to plant spacing of 1.5 m. All the intercultural operations were carried out as per the recommended package of practices. In each treatment and replication, 5 fruits were randomly taken for the analysis.

2.2 Fruit Yield

Brinjal fruits were picked at harvestable maturity stage in weekly intervals. The fruit yield was calculated by weighing all the fruits from ten pickings from each plot and the pooled yield expressed in t ha^{-1}.

2.3 Quality Attributes

The anthocyanin content in fruit peel was estimated spectrometrically by taking 10 g of fruit tissue including peel and was extracted with 10 ml of ethanolic HCl. The acid lowers the pH of extractant solution and prevents the degradation of non-acylated anthocyanin pigment. Later, extract was filtered and used for estimation. The absorbance of filtered extracts was measured at 535 nm. The anthocyanin content in the fruit peel was calculated and expressed in mg 100 g^{-1} of fresh fruit (Koundinya et al., 2019).

The total phenol content was determined by using the Folin-Ciocalteu method [3]. For that, 0.5 g fresh fruit sample was taken and cut into small bits. The fruit bits were transferred to a test tube and 5 ml of 80% ethanol was added. The test tube was kept in hot water bath for 10 minutes and then, the contents were cooled. The fruit sample was again macerated with another 5 ml of 80% ethanol and it was centrifuged at 5000 rpm for 10 minutes. The supernatant was

collected and volume was made up to 25 ml with distilled water. 1 ml of this solution was taken and 2 ml of 20% sodium carbonate and 1ml of Folin Reagent was added. After colour development, the OD value was measured at 660 nm. The total phenol content in brinjal fruits was expressed in mg 100 g^{-1} of fresh fruit.

Ascorbic acid, being a reducing agent, was estimated by titration with an oxidizing agent namely 2,6-di chlorophenol indophenol dye. 10 g of fresh fruit was blended in pestle and mortar with 4% oxalic acid and the mixture was made up to the known volume. 10 ml of this solution was taken into a 250 ml conical flask and titrated against standard indophenols dye until a permanent pink colour was obtained. The ascorbic acid content in brinjal fruits was expressed in mg 100 g^{-1} of fresh fruit [4].

The titrable acidity in fruit sample was analysed by macerating 20 g of fruit sample including seeds and peel using pestle and mortar and transferred the contents to 250 ml volumetric flask and the volume was made up. 10 ml of this solution was taken and added with 20-30 ml of water. A few drops of phenolphthalein indicator was added and titrated against 0.1 N NaOH till the appearance of pink colour. The titrable acidity in the fruits was expressed as g of citric acid 100 g^{-1} of fresh fruit [5].

The total protein content [6] was evaluated by macerating 0.25 g of fruit sample with 10 ml of phosphate buffer solution. The contents were then centrifuged at 3000 rpm for 10 minutes and the supernatant was collected and made upto 25 ml. 1 ml of this solution was taken in a test tube and 5 ml of alkaline copper tartarate and 0.5 ml of Folin Reagent was added. After the colour development, the absorbance was measured at 660 nm in spectrophotometer. The total protein content of fresh brinjal fruits was expressed in percentage.

2.4 Statistical Analysis

The obtained experimental data was statistically analysed using the standard procedures [7]. Results are presented and discussed at five per cent probability level uniformly to compare differences between treatment means. Treatment differences that are not significant were noted as non significant (NS).

3. RESULTS AND DISCUSSION

3.1 Fruit Yield

The highest total yield (42.7 t ha^{-1}) was observed in treatment ($I_2M_2S_2$) and the least yield (29.2 t ha^{-1}) was obtained in treatment ($I_1M_2S_1$). The yield trend was observed in the order $I_2M_2S_2$ > $I_2M_2S_1$ > $I_2M_1S_2$ > $I_2M_1S_1$ > $I_1M_2S_2$ > $I_1M_1S_2$ > $I_1M_1S_1$ > $I_1M_2S_1$. Observations from the mean comparison showed that treated effluent irrigation (I_2) performed better with the mean yield of 39.1 t ha^{-1} when compared with well water irrigation (I_1) (32.5 t ha^{-1}). Drip irrigation (M_2) gave the highest mean yield of 38.6 t ha^{-1} than flood irrigation (M_1) 35.5 t ha^{-1}. Application of phosphorus enriched sludge compost (S_2) recorded higher mean yield of 37.1 t ha^{-1} in comparison to the sludge compost (S_1) 34.5 t $ha^{-1}$and there was a significant difference among the treatments. Hence, the treatment combination of treated paperboard mill effluent through drip irrigation with application of phosphorus enriched sludge compost had outperformed the other treatment combinations and the fruit yield tends to be high in this treatment combination ($I_2M_2S_2$) from fourth harvest and it was observed to continue in the remaining harvests. This is in line with the findings of Ponmani et al. [8] who reported that the chilli plant yield was more under the application of biomanure at 5 t ha^{-1}, vermicompost at 3.5 t ha^{-1} and fly ash at 5 t ha^{-1}under treated paperboard mill effluent irrigation which recorded the highest fruit yield when compared with well water irrigation.

Like ETP sludge application in our experiment, Kumar [9] investigated the effects of integrated nutrient management practices on soil fertility and crop yield of hybrid cultivar of brinjal with the application of 50% recommended dose of fertilizer with sewage sludge at 2 t ha^{-1} and observed that these dosages performed well and had given maximum crop yield. Similar results were expressed by Prasanthrajan et al.,(2004) in a study with the application of sludge biocompost by mixing sludge, fly ash, coir pith at 2:1:1 ratio in combination with recommended level of NPK (20:20:60 kg NPK ha^{-1}) under treated paperboard mill effluent irrigation produced the highest vegetable cowpea yield.

The impact of wastewater irrigation combined with recommended fertilizer dose of 20 kg ha^{-1} nitrogen and 60 kg ha^{-1} phosphorus increased

the nutritional growth and fruit yield of chilli when compared with the ground water irrigation [10].

3.2 Quality Attributes

3.2.1 Anthocyanin

The anthocyanin in brinjal peel represents the increased oxygen scavenging properties against lipid peroxidation and DNA damage [11]. Anthocyanin content in the brinjal fruit peel Table 2 was recorded higher (6.56 mg 100 g^{-1}) in ($I_2M_2S_2$) and the least (5.09 mg 100 g^{-1}) in ($I_1M_1S_1$). The results obtained were significant in all aspects except the method of irrigation in which the anthocyanin content was not affected. The combination of all the factors *viz.*, irrigation source and method of irrigation and the sludge application showed significant results. The cultivated brinjal had the low anthocyanin content because its light purple-green variegated type which was previously proved (Koundinya et al*.,* 2019).

3.2.2 Total phenols

Phenols are secondary metabolites synthesized by plants as a response to environment stress conditions. Higher phenol content in brinjal demonstrates higher antioxidant content [12]. Total phenols content Table 2 was observed to be higher (62.3 mg 100 g^{-1}) in ($I_1M_1S_2$) and the least (46.5 mg 100 g^{-1}) in ($I_2M_1S_1$). Significant treatment difference was observed in case of interaction of three factors. The phenol contents estimated were relatable with the research findings of Koundinya et al*. (*2019).

3.2.3 Ascorbic acid

Ascorbic acid is another powerful antioxidant, which is neutraceutically important that tends to improve the colour and flavour (Bhushan and Samnotra, 2016). The acid content Table 2 was recorded higher ($I_2M_2S_2$) with 15.6 mg 100 g^{-1} and the least in ($I_1M_1S_1$) with 13.0 mg 100 g^{-1}. In case of irrigation source, effluent irrigation recorded the highest ascorbic acid content than the well water and drip irrigation performed better when comparing the results with flooding. But, there was no significant difference in the sludge application with respect to interaction of all the three factors, significant treatment difference was observed in the treatment combinations. The results obtained are in accordance with the study performed by Kandoliya et al., (2015).

3.2.4 Acidity

Titrable acidity Table 2 was recorded higher (0.28 g citric acid 100 g^{-1} of fruit) in ($I_2M_1S_2$ and $I_2M_2S_2$) while it was the least in (0.16 g citric acid 100 g^{-1} of fruit) ($I_1M_1S_1$ and $_1M_2S_1$). With respect to the method of irrigation and the combination of source and method of irrigation there was no significant differences observed. Significant treatment differences were observed in case of interaction of all the factors. Kandoliya et al., (2015) also notices similar acidity trends in the brinjal fruits.

3.2.5 Total protein

Total protein content ranged from 0.51 to 0.72% Table 2 and it was recorded the highest (0.72%) in ($I_2M_1S_1$) and the least (0.51%) in ($I_1M_1S_2$). It was observed that, the interaction of three factors has significant treatment differences and there were no significant treatment differences among the factors method of irrigation and in sludge application individually. The protein content was found to be higher in the treated effluent irrigation than the well water irrigation. The estimated protein content was similar to the study conducted by Koundinya et al*.,* (2019).

The quality attributes of brinjal which include anthocyanin content, total phenol content, ascorbic acid content, percent titrable acidity and protein content were higher in treatments with paperboard mill effluent irrigation. This wss ascribable to the application of phosphorus enriched sludge along with treated effluent irrigation. This might be attributed to the use of treated effluent along with the P enriched paperboard mill sludge compost application which could have provided adequate nutrients which amended the soil fertility and provided superior quality of brinjal fruits. Similar results are reported in vegetable crops like chilli (Ponmani et.al., 2014) and tomato [13-17] when grown under paperboard mill effluent irrigation with organic amendments, hence support the findings of this study.

Table 1. Effect of treated effluent irrigation and ETP sludge compost on grafted brinjal fruit yield (t ha^{-1})

Treatments	1st harvest	2nd harvest	3rd harvest	4th harvest	5th harvest	6th harvest	7th harvest	8th harvest	9th harvest	10th harvest	Total yield
$I_1M_1S_1$	1.45	2.29	3.39	3.31	4.63	5.16	3.40	3.35	3.31	2.23	32.5
$I_1M_1S_2$	0.68	1.63	5.67	3.68	5.04	5.03	3.48	3.08	2.94	2.46	33.7
$I_1M_2S_1$	1.14	1.43	3.30	4.01	3.46	3.91	3.38	3.18	2.81	2.62	29.2
$I_1M_2S_2$	1.07	2.04	5.78	3.99	4.78	5.05	3.24	3.00	2.79	2.74	34.5
$I_2M_1S_1$	0.59	1.00	6.15	3.99	4.03	5.22	3.78	3.34	3.99	3.84	35.9
$I_2M_1S_2$	0.58	1.37	4.41	5.38	4.59	5.21	4.15	3.95	3.86	3.85	37.4
$I_2M_2S_1$	0.98	1.76	4.71	5.84	4.71	5.61	4.28	4.15	3.89	4.32	40.3
$I_2M_2S_2$	0.48	1.19	5.20	5.90	5.38	6.03	4.71	4.63	4.63	4.51	42.7

Variables	SE(d)	CD (0.05)
I	0.33	1.04
M	0.31	0.76
S	0.28	0.61
I*M	0.44	1.08
I*S	0.40	0.86
M*S	0.40	0.86
I*M*S	0.56	1.22

Mean comparison of yield (t ha^{-1}) for individual factors

Factors	I_1		I_2	
	M_1	M_2	M_1	M_2
S_1	32.5	29.2	35.9	40.3
S_2	33.7	34.5	37.4	42.7

Factor I	Mean of I	Factor M	Mean of M	Factor S	Mean of S
I_1	32.5	M_1	35.5	S_1	34.5
I_2	39.1	M_2	38.6	S_2	37.1

(I_1 – well water, I_2 – treated effluent , M_1 - flood irrigation, M_2 - drip irrigation, S_1 - ETP sludge compost at 5 t ha^{-1}, S_2 - phosphorous enriched ETP sludge compost at 5 t ha^{-1})

Table 2. Effect of treated effluent irrigation and ETP sludge compost on anthocyanin, total phenols, ascorbic acid, acidity and total protein content in fruits of grafted brinjal

Treatments	Fruit quality attributes									
	Anthocyanin (mg 100 g^{-1})		Total phenols (mg 100 g^{-1})		Ascorbic acid (mg 100 g^{-1})		Acidity (g citric acid 100 g^{-1})		Total protein (%)	
$I_1M_1S_1$	5.09		53.2		13.0		0.16		0.53	
$I_1M_1S_2$	5.66		62.3		13.5		0.22		0.51	
$I_1M_2S_1$	6.09		60.6		14.5		0.16		0.55	
$I_1M_2S_2$	6.51		51.0		13.5		0.20		0.67	
$I_2M_1S_1$	5.62		46.5		14.0		0.24		0.72	
$I_2M_1S_2$	5.13		53.7		13.5		0.28		0.68	
$I_2M_2S_1$	5.70		49.6		14.5		0.22		0.67	
$I_2M_2S_2$	6.56		58.0		15.6		0.28		0.69	
Variables	**SE(d)**	**CD (0.05)**	**SE(d)**	**CD (0.05)**	**SE(d)**	**CD (0.05)**	**SE(d)**	**CD (0.05)**	**SE(d)**	**CD (0.05)**
I	0.10	0.31	5.10	16.24	0.64	2.02	0.01	0.03	0.01	0.02
M	0.03	NS	3.76	NS	0.94	2.30	0.01	NS	0.01	NS
S	0.03	0.07	1.99	4.33	0.92	NS	0.01	0.03	0.02	NS
I*M	0.05	0.11	5.31	12.99	1.33	3.25	0.02	NS	0.02	0.05
I*S	0.05	0.10	2.81	6.13	1.30	2.83	0.02	0.04	0.02	0.05
M*S	0.05	0.10	2.81	NS	1.30	2.83	0.02	0.04	0.02	0.05
I*M*S	0.06	0.14	3.98	8.66	1.84	4.01	0.03	0.06	0.03	0.07

(I_1 – Well water, I_2 – treated effluent , M_1 - flood irrigation, M_2 - Drip irrigation, S_1 - ETP sludge compost AT 5 t HA^{-1}, S_2 - phosphorous enriched ETP sludge compost AT 5 t ha^{-1})

4. CONCLUSION

Yield and quality of grafted brinjal cultivated under treated paperboard mill effluent irrigation combined with composted ETP sludge application was studied in the field and observed that yield and quality of brinjal fruits were increased by 31.17% over the control. This might be due to the sufficient supply of nutrients that improved soil quality as a result of treatment combinations consisting of composted ETP sludge and treated effluent irrigation. Hence, it is concluded that paperboard mill sludge compost and treated effluent could be used as viable input for crop cultivation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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