



P-ISSN: 2349-8528

E-ISSN: 2321-4902

[www.chemijournal.com](http://www.chemijournal.com)

IJCS 2021; 9(1): 2578-2585

© 2021 IJCS

Received: 14-11-2020

Accepted: 23-12-2020

**C Prabakaran**Agricultural Research Station  
Thirupathisaram, Kanyakumari,  
Tamil Nadu, India

## Effect of fertigation through treated paperboard mill effluent on soil microbial properties and growth of banana

**C Prabakaran**DOI: <https://doi.org/10.22271/chemi.2021.v9.i1aj.11616>**Abstract**

A field experiment was conducted at agricultural farm belonging to ITC paperboard mill situated at Thekkampatty Village, Coimbatore District to evaluate the influence of fertigation through treated board mill effluent on microbial property of soil and the growth of banana. From the study it was observed that biometric observations *viz.*, the plant height, pseudostem girth, number of leaves, number of suckers and leaf area increased due to fertigation of effluent with 75 per cent NK over basin application of the effluent and farmer's practice. Combined addition of fly ash + biocompost + green manure recorded more number of leaves. Application of green manure along with fly ash and biocompost under effluent fertigation with 75 per cent NK improved, soil biological properties (soil bacterial, fungal, actinomycetes population and soil enzymatic activity (urease, amylase, phosphatase, invertase, catalase, peroxidase activity). The above findings indicated that the treated effluent from paperboard mill could possibly be used through drip irrigation along with fertigation to banana crop without any adverse effect on soil properties and crop growth.

**Keywords:** Drip fertigation, soil enzymes, soil organism, soil enzymes, plant growth**Introduction**

Pulp and paper industries use large volume of water, the bulk of which is released as effluent requiring proper treatment and disposal. The ITC limited, located at the foothills of Western Ghats of Thekkampatty Village, Coimbatore District is producing fine quality duplex paper and paperboard from waste papers discharges around 2100 – 2600 m<sup>3</sup> d<sup>-1</sup> wastewater which is being used to irrigate about 40 ha of sugarcane crop through surface irrigation. Since this treated effluent fall in borderline as saline water, they can be considered as potential source for irrigation (Prabakaran *et al.*, 2003a, Prabakaran, 2003b; Prabakaran 2013c; Prabakaran and Udayasoorian, 2003; Prabakaran and Udayasoorian, 2008b) <sup>[1-36]</sup>. These effluents contain nutrients that enhance the growth of crop plants but also have undesirable pollutant especially Na, which increases the salinity of the effluent making unfit for further use in crop production through conventional irrigation practices. Brackish water could effectively be used in drip irrigation. When brackish water is applied frequently under drip irrigation the salinity and sodicity of the soil especially in the root zone of the crop is maintained at low level suggesting that the treated paper mill effluent which is saline in nature as per State Pollution Control Board (SPCB) norms could possibly be used in drip irrigation for high water requiring crops like banana and sugarcane to alleviate soil salinity hazards in the root zone and to prevent the possible ground water contaminations with organic and inorganic pollutants (Prabakaran, 2008a) <sup>[1-36]</sup>. Several studies (Prabakaran, 2004; Prabakaran, 2008 b, c; Prabakaran, 2020) <sup>[1-36]</sup> have also indicated that the irrigation water with total salt concentration of 2 g L<sup>-1</sup> could safely be utilized in drip irrigation.

Banana is well known for its high-water requirement, high evaporative demand, high transpiration, shallow root system, poor ability to draw water from soil beneath field capacity and high sensitivity to soil water deficiency. Thus, it requires liberal supplies of irrigation water throughout its life cycle, emphasizing the importance of correct irrigation scheduling. Fertigation has been proved to be of great success in banana in terms of water and labour saving with increased water use efficiency culminating in early cropping and heavy yield and it is an environmentally safer technology which prevents ground water contamination.

**Corresponding Author:****C Prabakaran**Agricultural Research Station  
Thirupathisaram, Kanyakumari,  
Tamil Nadu, India

The literatures regarding the effect of effluent fertigation on soil properties and growth of banana is meagre. Hence this study was proposed

### Materials and Method

Field experiment conducted in ITC Company of Thekkampatty village of Coimbatore district. The experiment was conducted in a split plot design (with two replication). In the main plots, irrigations (fertigation) treatments were imposed. Treated board mill effluent was filtered and utilized for drip fertigation and surface irrigation treatments. Suitable NK fertilizers were applied through drip irrigation with 75 and 50 per cent NK for banana while basin irrigation was done with 100 and 75 per cent NK. Surface irrigation with river water along with 100 per cent NK (farmer's practice) was used as control for comparison. In the subplots amendments viz., fly ash, biocompost, fly ash + biocompost + green manure were applied.

The experiment was laid out in a split plot design with two replications. In the main plots, irrigations (fertigation) were taken. The effluent obtained from the paper board mill was treated using aerobic treatment then it was filtered using sand filter. Banana was fertigated through drip irrigation with 75 (I<sub>6</sub>) and 50 (I<sub>7</sub>) per cent NK for banana while basin irrigation was done with 100 (I<sub>4</sub>) and 75 per cent NK (I<sub>5</sub>) using treated effluent. Farmer's practice (I<sub>1</sub>) (Surface irrigation with river water along with 100 per cent NK) was adopted as control. In addition to effluent drip fertigation, river water was also used

for drip fertigation with 75 per cent NK (I<sub>2</sub>) and 50 per cent NK (I<sub>3</sub>). In the subplots, amendments viz., fly ash (A<sub>1</sub>), biocompost (A<sub>2</sub>), fly ash + biocompost + green manure (A<sub>3</sub>) were applied. Banana variety Robusta was raised and observations were made on soil biological properties and crop growth using standard procedures. The data obtained were statistically analyzed by following standard procedures.

### Result and Discussion

#### Biological properties

##### Bacteria, fungi and actinomycetes

The soil bacterial population at growth, shooting and harvest stages were 6.0 to 52.0, 11.9 to 29.6 and 10.6 to 25.5 x 10<sup>6</sup> CFU g<sup>-1</sup> of dry soil, respectively (Table 1). The bacterial population was significantly influenced by irrigation treatments, amendments and their interactions. In general, effluent irrigation significantly increased the bacterial population over river water fertigation and farmer's practice. Among the effluent irrigation treatments, effluent fertigation with 50 per cent NK (I<sub>7</sub>) recorded higher bacterial population at all the stages whereas lower value was recorded due to farmer's practice (I<sub>1</sub>). Among the amendments, application of fly ash + compost + green manure (A<sub>3</sub>) recorded higher value whereas lower value was recorded due to incorporation of fly ash (A<sub>1</sub>). The treatment combinations I<sub>4</sub>A<sub>2</sub> recorded the highest bacterial population while the least value was in I<sub>1</sub>A<sub>2</sub> both at shooting and harvest stages

**Table 1:** Effect of effluent irrigation and amendments on soil bacteria (x 10<sup>6</sup> CFU g<sup>-1</sup> of dry soil)

Irrigation (I)/amendments (A)	Growth stage				Shooting stage				Harvest stage			
	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean
I <sub>1</sub>	6.0	25.0	38.0	23.0	17.2	11.9	21.6	16.9	11.9	10.6	18.5	13.7
I <sub>2</sub>	8.0	27.0	40.0	25.0	18.6	15.9	22.8	19.1	12.8	14.2	19.5	15.5
I <sub>3</sub>	12.0	29.0	44.0	28.3	20.0	23.9	25.0	23.0	13.8	21.2	21.4	18.8
I <sub>4</sub>	15.0	32.0	48.0	31.7	22.0	29.8	27.3	26.4	15.2	26.6	23.4	21.7
I <sub>5</sub>	12.0	35.0	46.8	31.3	24.1	23.9	26.6	24.9	16.6	21.2	22.8	20.2
I <sub>6</sub>	14.0	35.0	52.0	33.7	24.1	27.8	29.6	27.2	16.6	24.8	25.5	22.3
I <sub>7</sub>	13.0	32.0	48.0	31.0	22.0	25.9	27.3	25.1	15.2	23.0	23.4	20.5
Mean	11.4	30.7	46.0	29.1	21.1	22.7	26.2	23.2	14.6	20.2	22.1	18.95
	I	A	I at A	A at I	I	A	I at A	A at I	I	A	I at A	A at I
S.Ed	0.9	1.1	2.4	2.8	0.9	0.7	1.7	1.7	0.6	0.5	1.3	1.4
CD (0.05)	2.1	2.3	NS	NS	2.1	1.4	3.7	3.7	1.2	1.1	2.9	3.0

Fungal population showed a marked difference among the various irrigation treatments and amendments. The soil fungal population at growth, shooting and harvest stages ranged from 7.5 to 24.4, 5.2 to 13.9 and 4.6 to 11.9 x 10<sup>4</sup> CFU g<sup>-1</sup> of dry soil, respectively (Table 2). Among the irrigation treatments, effluent fertigation with 75 per cent NK (I<sub>6</sub>) recorded higher fungal population and it was on par (I<sub>7</sub>) whereas the lowest fungal population was observed in farmer's practice (I<sub>1</sub>) at all

stages. In general, the fungal population decreased at later stages of crop growth. Within the various amendments, addition of fly ash + compost + green manure (A<sub>3</sub>) recorded higher fungal population at all the stages whereas lower fungal population were recorded due to incorporation of fly ash (A<sub>1</sub>). Interaction between irrigation treatments and amendments was not significant.

**Table 2:** Effect of effluent irrigation and amendments on soil fungal populations (x 10<sup>4</sup> CFU g<sup>-1</sup> of dry soil)

Irrigation (I)/amendments (A)	Growth stage				Shooting stage				Harvest stage			
	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean
I <sub>1</sub>	7.5	10.0	15.0	10.8	5.2	6.9	8.5	6.9	4.6	4.7	7.3	5.5
I <sub>2</sub>	7.5	11.0	16.0	11.5	5.2	7.6	9.1	7.3	4.6	5.2	7.8	5.9
I <sub>3</sub>	9.0	13.0	19.0	13.7	6.2	9.0	10.8	8.7	5.5	6.2	9.3	7.0
I <sub>4</sub>	10.5	14.0	22.0	15.5	7.2	9.6	12.5	9.8	6.4	6.6	10.7	7.9
I <sub>5</sub>	10.5	14.0	18.9	14.5	7.2	9.6	10.7	9.1	6.4	6.6	9.2	7.8
I <sub>6</sub>	12.6	16.5	24.4	17.8	8.5	11.3	13.9	11.2	7.6	7.8	11.9	9.1
I <sub>7</sub>	12.0	16.0	24.0	17.3	8.3	11.0	13.7	11.0	7.4	7.6	11.7	8.9
Mean	9.9	13.5	19.9	14.4	6.8	9.3	11.3	9.1	6.1	6.4	9.7	7.4
	I	A	I at A	A at I	I	A	I at A	A at I	I	A	I at A	A at I
S.Ed	0.5	0.5	1.1	1.2	0.3	0.3	0.7	0.7	0.3	0.2	0.6	0.6
CD (0.05)	1.2	1.0	NS	NS	0.7	0.6	NS	NS	0.7	0.4	NS	NS

Higher actinomycetes population was recorded in I<sub>7</sub> which was on par with I<sub>6</sub>. Lower value was recorded in I<sub>1</sub> (farmer's practice) and on par with I<sub>2</sub> (fertigation with 75 per cent NK through river water). Among the amendments, combined application of fly ash + biocompost + green manure (A<sub>3</sub>) recorded higher actinomycetes population whereas lower

population was recorded due to addition of fly ash alone (A<sub>1</sub>). Similar trend was noticed at all stages of observation. Interaction between irrigation treatments and amendments was not significant on the actinomycetes populations which ranged from 8.0 to 27.5, 5.5 to 15.8 and 4.7 to 13.5 x 10<sup>3</sup> CFU g<sup>-1</sup> dry soil, respectively (Table 3).

**Table 3:** Effect of effluent irrigation and amendments on soil actinomycetes (x 10<sup>3</sup> CFU g<sup>-1</sup> of dry soil)

Irrigation (I)/ amendments (A)	Growth stage				Shooting stage				Harvest stage			
	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean
I <sub>1</sub>	8.0	10.0	18.0	12.0	5.5	6.9	10.2	7.5	4.9	4.7	8.8	6.1
I <sub>2</sub>	8.0	11.0	19.0	12.7	5.5	7.6	10.8	8.0	4.9	5.2	9.3	6.5
I <sub>3</sub>	9.0	13.0	22.0	14.7	6.2	9.0	12.5	9.2	5.5	6.2	10.7	7.5
I <sub>4</sub>	10.0	14.0	25.0	16.3	6.9	9.6	14.2	10.2	6.1	6.6	12.2	8.3
I <sub>5</sub>	10.0	14.0	21.6	15.2	6.9	9.6	12.3	9.6	6.1	6.6	10.5	7.7
I <sub>6</sub>	11.0	16.0	27.0	18.0	7.6	11.0	15.0	11.2	6.7	7.6	13.2	9.2
I <sub>7</sub>	11.4	16.6	27.5	18.5	7.9	11.4	15.8	11.7	6.9	7.9	13.5	9.4
Mean	9.6	13.5	22.9	15.3	6.6	9.3	13.0	9.6	5.9	6.4	11.2	7.8
	I	A	I at A	A at I	I	A	I at A	A at I	I	A	I at A	A at I
S.Ed	0.5	0.5	1.2	1.4	0.3	0.3	0.7	0.8	0.3	0.3	0.6	0.7
CD (0.05)	1.2	1.1	NS	NS	0.7	0.7	NS	NS	0.6	0.6	NS	NS

### Enzymatic activity

The soil urease, amylase and phosphatase activity at harvest soils varied from 2.70 to 6.90 μg of ammonia released g<sup>-1</sup> soil h<sup>-1</sup>, 0.3 to 0.7 μg of glucose released g<sup>-1</sup> and from 0.29 to 0.81 μg inorganic phosphate released g<sup>-1</sup> h<sup>-1</sup>, respectively (Table 4). Within the irrigation treatments, effluent fertigation with 75 per cent NK (I<sub>6</sub>) recorded higher urease activity while

lower enzyme activity was recorded in farmer's practice (I<sub>1</sub>). Among the amendments, incorporation of fly ash + compost + green manure (A<sub>3</sub>) increased the enzyme activity whereas lower enzyme activity was recorded due to application of fly ash (A<sub>1</sub>). Soil urease activity was not significantly influenced due to interactive effects.

**Table 4:** Effect of effluent irrigation and amendments on soil urease, amylase, Phosphatase activity

Irrigation (I)/ amendments (A)	Urease (μg of NH <sub>3</sub> released g <sup>-1</sup> soil h <sup>-1</sup> )				Amylase (μg of glucose released g <sup>-1</sup> soil h <sup>-1</sup> )				Phosphatase (μg of inorganic P released g <sup>-1</sup> soil h <sup>-1</sup> )			
	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean
I <sub>1</sub>	3.00	2.70	3.80	3.17	0.30	0.40	0.70	0.47	0.29	0.42	0.67	0.46
I <sub>2</sub>	3.10	2.70	3.80	3.20	0.30	0.40	0.70	0.47	0.30	0.42	0.68	0.47
I <sub>3</sub>	3.20	2.90	4.00	3.37	0.30	0.40	0.70	0.47	0.32	0.44	0.69	0.48
I <sub>4</sub>	3.40	3.00	4.10	3.50	0.30	0.50	0.70	0.50	0.34	0.46	0.71	0.50
I <sub>5</sub>	3.60	3.10	3.87	3.52	0.40	0.50	0.63	0.51	0.36	0.47	0.65	0.49
I <sub>6</sub>	6.20	5.70	6.90	6.27	0.30	0.50	0.70	0.50	0.46	0.57	0.62	0.55
I <sub>7</sub>	4.90	4.40	5.60	4.97	0.40	0.50	0.70	0.53	0.44	0.56	0.81	0.60
Mean	3.91	3.50	4.58		0.33	0.46	0.69		0.36	0.48	0.69	
	I	A	I at A	A at I	I	A	I at A	A at I	I	A	I at A	A at I
S.Ed	0.20	0.13	0.34	0.33	0.01	0.02	0.04	0.04	0.01	0.02	0.04	0.04
CD (0.05)	0.50	0.27	NS	NS	0.03	0.03	NS	NS	0.03	0.03	NS	NS

In general, the soil amylase activity was increased due to effluent irrigation than basin irrigation. Among the effluent treatments, effluent fertigation with 50 per cent NK (I<sub>7</sub>) recorded the highest amylase activity and it was on par with I<sub>6</sub>. The lowest value was observed in farmer's practice (I<sub>1</sub>) which was on par with I<sub>2</sub>. Addition of fly ash + compost + green manure (A<sub>3</sub>) increased the soil amylase activity where as incorporation of fly ash alone (A<sub>1</sub>) reduced it at all the stages. Interaction between irrigation treatments and amendments was not effective in increasing soil amylase activity.

The highest soil phosphatase activity was recorded due to effluent fertigation with 75 per cent NK (I<sub>6</sub>) was followed by I<sub>7</sub>. Lower activity was recorded due to farmer's practice (I<sub>1</sub>) which was on par with I<sub>2</sub>, I<sub>3</sub>, I<sub>5</sub> and I<sub>4</sub>. Among the amendments, application of fly ash (A<sub>1</sub>) decreased the phosphatase activity. Interaction effect was not significant.

The activity of soil invertase, cellulase and catalase at harvest stage varied from 8.42 to 20.88 μg of glucose released g<sup>-1</sup>, from 6.19 to 12.22 μg glucose released g<sup>-1</sup> soil h<sup>-1</sup> and from

3.02 to 11.92 mg H<sub>2</sub>O<sub>2</sub> consumed h<sup>-1</sup> g<sup>-1</sup> soil, respectively (Table 3). The invertase activity was increased due to effluent fertigation with 75 and 50 per cent NK (I<sub>6</sub> and I<sub>7</sub>). Farmer's practice (I<sub>1</sub>) and fertigation with 75 per cent NK through river water (I<sub>2</sub>) recorded lower activity. Addition of fly ash + compost + green manure (A<sub>3</sub>) increased the invertase activity whereas lower enzymatic activity was recorded in fly ash (A<sub>1</sub>). Interaction effect was not significant.

The soil cellulase activity in post-harvest soils increased (10.24 μg of glucose released g<sup>-1</sup> soil h<sup>-1</sup>) due to effluent fertigation with 75 per cent NK (I<sub>6</sub>) and it was on par with I<sub>7</sub>. The lowest activity (7.41 μg of glucose released g<sup>-1</sup> soil h<sup>-1</sup>) was in farmer's practice (I<sub>1</sub>). Among the amendments, application of fly ash + compost + green manure (A<sub>3</sub>) significantly increased the cellulase activity while fly ash (A<sub>1</sub>) which was on par with biocompost (A<sub>2</sub>) reduced it. Soil cellulase activity was not significantly influenced due to interaction between irrigation and amendments.

The irrigation treatments and amendments significantly increased the soil catalase activity (Table 5). The interaction

effect was not significant. Within the irrigation treatments, the highest catalase activity (8.48 mg H<sub>2</sub>O<sub>2</sub> consumed g<sup>-1</sup> soil h<sup>-1</sup>) was recorded in I<sub>6</sub> was on par with I<sub>7</sub>. Farmer's practice (I<sub>1</sub>) recorded the lowest values (5.12 mg H<sub>2</sub>O<sub>2</sub> consumed g<sup>-1</sup> soil h<sup>-1</sup>). Among the amendments, the highest activity was recorded in combined addition fly ash + compost + green manure (A<sub>3</sub>) whereas the lowest activity was in the plots applied with fly ash (A<sub>1</sub>) alone.

Both qualitative and quantitative data on soil micro flora provide a useful index of soil fertility. The present investigation revealed a decrease in bacterial population towards harvest stage. Fertigation of effluent with 75 per cent NK increased the bacterial population. The increase in

bacterial population may be due to the presence of nutrients viz., N, P, K and other nutrients in the effluent and rich in moisture content suitable for the growth of bacteria through fertigation. Among the amendments application fly ash + biocompost + green manure increased the bacterial population. Prabakaran (2004) [1-36] stated that increase in organic carbon lead to proportionate increase in the bacterial population. Similar trend occurred in fungal and actinomycetes population also. The interaction effect was significant indicating that the treated effluent fertigation provides essential nutrients and green manure provides organic matter, which is additive in increasing the microbial population.

**Table 5:** Effect of effluent irrigation and amendments on soil invertase, cellulase and catalase activity

Irrigation (I)/ amendments (A)	Invertase ( $\mu\text{g}$ of glucose released g <sup>-1</sup> soil h <sup>-1</sup> )				Cellulase ( $\mu\text{g}$ of glucose released g <sup>-1</sup> soil h <sup>-1</sup> )				Catalase (mg H <sub>2</sub> O <sub>2</sub> consumed g <sup>-1</sup> soil h <sup>-1</sup> )			
	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean
	I	A	I at A	A at I	I	A	I at A	A at I	I	A	I at A	A at I
I <sub>1</sub>	8.42	12.63	15.12	12.06	6.19	7.20	8.84	7.41	3.02	5.14	7.20	5.12
I <sub>2</sub>	8.84	13.22	15.84	12.63	6.50	7.54	9.26	7.76	3.27	5.58	7.81	5.55
I <sub>3</sub>	9.76	14.56	17.46	13.92	7.18	8.29	10.21	8.56	3.83	6.53	9.14	6.50
I <sub>4</sub>	10.72	16.06	19.26	15.34	7.82	9.07	11.16	9.35	4.43	7.54	10.56	7.51
I <sub>5</sub>	10.63	15.92	17.17	14.57	7.88	9.14	10.14	9.05	4.37	7.45	9.39	7.07
I <sub>6</sub>	11.65	17.44	20.88	16.66	8.57	9.94	12.22	10.24	5.00	8.51	11.92	8.48
I <sub>7</sub>	11.64	17.47	20.88	16.66	8.21	9.52	11.72	9.82	4.99	8.50	11.90	8.46
Mean	10.24	15.33	18.08		7.48	8.67	10.51		4.13	7.04	9.70	
S.Ed	0.42	0.44	1.03	1.15	0.29	0.25	0.62	0.67	0.22	0.23	0.55	0.61
CD (0.05)	1.04	0.93	NS	NS	0.71	1.54	NS	NS	0.54	0.50	NS	NS

The enhanced microbial activity due to incorporation of organic and green manure was observed. The organic could have stimulated the growth of microorganisms like bacteria, actinomycetes and fungi. The organic addition coupled with fly ash application produced a stimulation influence on the preponderance of microbial population in soil.

The organic matter not only provided the carbonaceous materials but also released the various nutrients from fly ash, which in turn would have increased the microbial activity of the soil. Lal *et al.* (1996) stated that simultaneous application of organic manure and fly ash appears to help in chelating the trace metals in fly ash and reduce their detrimental effect on microbial activity.

The enzymatic activities viz., urease, amylase, phosphatase, cellulase, invertase and catalase were increased due to effluent fertigation (75 per cent NK). Farmer's practice recorded lower enzymatic activity. Combined application of fly ash + biocompost + green manure increased the activity while application of fly ash decreased it. Nutrient cycling in soil involves chemical, biochemical and physiological reactions. Enzymes in soil catalyze biochemical reactions, there by mediate the transformation of organically bound nutrients into inorganic plant available forms. Urease is present in large amounts in biologically active soil, since many microorganisms hydrolyze urea enzymatically. Assay of urease activity give information on the rate of degradation of nitrogen containing compounds especially proteins and the activity of different fertilizers. Soil with vegetation contains more urease than that without vegetation. The speed of urea hydrolysis in soil and associated changes in the soil chemical environment strongly influence the fertilizer efficiency and environmental hazards of ground water pollution. In surface soil urease showed a direct positive and significant relation with organic and forms of N, P and S. A high degree of correlation and no relation between these enzyme activities

and organic carbon had been reported (Prabakaran, 2004) [1-36]. Amylase, invertase, cellulase are the extra cellular enzymes secreted mostly by soil microorganisms as free enzymes.

Free enzymes in soil have many fates, first they function independently before being altered by other groups and secondly they might be denatured (inactivated) permanently by external stress. The role of phosphatase is to make the unavailable P into available form for the plants. The soil phosphatase activity was positively correlated with total P. In the present investigation, the P content of the treated effluent might have increased the activity. Increased invertase activity with time might be due to the increase in the root exudates of banana with maturity and also due to the addition of organic matter in the form of amendments. The factors like soil moisture, microbial population in the rhizosphere and non-rhizosphere and temperature, which affect the activity of catalase activity. Similarly, the increase in enzyme activity due to addition of amendment might be due to addition of organic matter. The green organic matter is said to enrich the soil enzyme.

Crop duration was advanced due to fertigation treatments and amendments. Number of days to shooting, shooting to harvest and total crop duration varied from 194 to 244, 91 to 111 and 286 to 355 days, respectively (Table 6). Effluent fertigation with 75 per cent NK (I<sub>6</sub>) recorded earlier days to shooting, shooting to harvest and total crop duration as compared to farmer's practice (I<sub>1</sub>). Increased days were recorded due to basin irrigation of effluent either with 100 (I<sub>4</sub>) or 75 per cent NK (I<sub>3</sub>). Incorporation of fly ash (A<sub>1</sub>) reduced the crop duration while fly ash + compost + green manure (A<sub>3</sub>) increased the crop duration. Interaction between irrigation and amendments did not have marked difference on the days to shooting.

In banana, the total crop duration can be divided into two phases viz., days taken from planting to shooting (vegetative

phase) and the days taken from shooting to harvest (bunch development). Fertigation of effluent with 75 per cent NK decreased the days to shooting, shooting to harvest and total crop duration. The accurate placement of fertilizers in the solution form at the active root zone of the banana might have resulted in earlier cropping. Probably, this might have also minimized the delay between application and uptake that resulted in quicker growth and maturation of banana plants (Mahalakshmi, 2000). Drip irrigation is known to reduce the crop duration in banana. Frequent irrigation and fertilization might have caused low C:N ratio which would have promoted

early flowering. Early shooting in fertigated plants could be further explained by rapid production of leaves with large leaf area, which would have resulted in better photosynthate activity. Thus, the required net assimilation presumably would have reached early in plants receiving both N and K fertigation. This might have hastened the process of initiation of emergence inflorescence. The promotive effect of N in hastening the flowering. Higher K application caused early flowering and faster development of bunches. In the present study, presence of all the essential nutrients in the treated effluent might have induced the early flowering.

**Table 6:** Effect of effluent irrigation and amendments on crop duration (days)

Irrigation (I)/ amendments (A)	Days to shooting				Shooting to harvest				Total crop duration			
	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean
I <sub>1</sub>	207	216	221	215	99	102	104	101	306	318	324	316
I <sub>2</sub>	203	212	212	209	95	100	99	98	302	312	311	308
I <sub>3</sub>	206	209	216	210	97	98	102	99	308	307	318	311
I <sub>4</sub>	221	226	244	230	104	106	111	107	331	332	355	339
I <sub>5</sub>	227	230	212	223	106	108	101	105	338	338	312	329
I <sub>6</sub>	194	204	198	199	91	96	93	93	286	301	291	293
I <sub>7</sub>	198	203	207	203	93	95	97	95	295	298	304	299
Mean	208	214	216	—	98	101	101	—	309	315	316	—
	I	A	I at A	A at I	I	A	I at A	A at I	I	A	I at A	A at I
S.Ed	3.4	2.7	6.8	7.1	1.6	1.2	3.2	3.3	5.0	4.0	10.0	10.0
CD (0.05)	8.3	5.8	NS	NS	3.9	2.7	NS	NS	12	NS	NS	NS

From this study it is evident that water has a major role to play with the morphology especially in banana which has higher moisture content in it and requiring large quantity of water. When irrigated frequently in adequate amounts, banana plants tend to grow tall, stout, producing more leaves and suckers, higher leaf area, reduced phyllochron and crop duration with early maturity. Banana being a voracious feeder of water and nutrients with more possibilities of its cultivation perennially, the crop is highly amenable for effluent fertigation technique.

#### Plant growth parameters

The pseudostem height of banana at growth and shooting stages ranged from 82 to 158 and 136 to 263 cm, respectively (Table 7). Fertigation treatments recorded taller plants than basin irrigation at growth and shooting stages of banana. Among the irrigation treatments, higher values were recorded due to effluent fertigation with 75 per cent NK (I<sub>6</sub>) and lower values were recorded due to basin irrigation of effluent with 75 per cent NK (I<sub>5</sub>) irrespective of stages of crop growth. Addition of amendments significantly increased the plant height only at growth stage. Incorporation of fly ash + biocompost + green manure (A<sub>3</sub>) recorded the highest value of 134 cm at growth stage followed by fly ash (A<sub>1</sub>) and the

lowest value of 82 cm was recorded in biocompost (A<sub>2</sub>). The interaction between irrigation treatments and amendments was significant only at growth stage. The treatment combination I<sub>6</sub>A<sub>3</sub> (effluent fertigation with fly ash + biocompost + green manure) recorded the tallest plant (158 cm) and the shortest plant (82 cm) was recorded in I<sub>5</sub>A<sub>2</sub> (basin irrigation with effluent + 75 per cent NK) at growth stage. Similar trend was noticed at shooting stage of banana. The pseudostem girth was found to increase due to advancement of crop growth. Fertigation treatments increased the stem girth at growth and shooting stages (Table 7). The stem girth of banana ranged from 31 to 52 and 50 to 83 cm at growth and shooting stages, respectively. There was a significant difference due to irrigation treatments both at growth and shooting stages. Among the irrigation treatments, higher stem girth was recorded in I<sub>6</sub> (effluent fertigation with 75 per cent NK) followed by I<sub>5</sub>, I<sub>2</sub>, I<sub>3</sub> which were on par with each other. Lower values were recorded in I<sub>4</sub> (basin irrigation of effluent with 100 per cent NK). The same trend was followed in shooting stage also. The stem girth was not significantly influenced due to amendments at both the stages. Also the interaction effect between irrigation treatments and amendments was found to be non-significant.

**Table 7:** Effect of effluent irrigation and amendments on pseudostem height and girth (cm)

Irrigation (I) / amendment (A)	Pseudo stem height								Pseudo stem girth							
	Growth stage				Shooting stage				Growth stage				Shooting stage			
	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean
I <sub>1</sub>	141	137	144	141	235	229	240	234	42	41	43	42	66	65	69	67
I <sub>2</sub>	153	149	156	153	255	248	260	254	49	48	50	49	77	75	80	77
I <sub>3</sub>	147	143	150	147	245	238	250	244	48	47	49	48	75	73	78	75
I <sub>4</sub>	93	91	95	93	155	151	158	155	32	31	33	32	50	50	53	51
I <sub>5</sub>	84	82	86	84	140	136	143	140	33	32	34	33	51	51	54	52
I <sub>6</sub>	155	151	158	154	258	251	263	257	51	50	52	51	80	78	83	80
I <sub>7</sub>	150	146	153	150	250	243	255	249	50	49	51	50	78	77	82	79
Mean	132	128	134	132	255	249	259	219	44	43	45	44	68	67	71	69
	I	A	I at A	A at I	I	A	I at A	A at I	I	A	I at A	A at I	I	A	I at A	A at I
S.Ed	4.2	0.16	4.2	4.5	16	11	29	39	3.1	2.2	5.8	6.0	4.8	3.6	9.1	9.5
CD (0.05) SEd m± CD (P=0.05)	10.3	0.3	10.4	9.5	39	NS	NS	NS	7.5	NS	NS	NS	11.8	NS	NS	NS

Irrigation treatments significantly influenced the number of leaves of banana at all stages except growth stage (Table 8). The number of leaves were 10 to 15, 13 to 20 and 11 to 17 at growth, shooting and harvest stages, respectively. Among the irrigation treatments, effluent fertigation with 75 or 50 per cent NK (I<sub>6</sub>, I<sub>7</sub>) recorded higher number of leaves at all stages of crop growth. Less number of leaves were recorded due to

basin irrigation of effluent with 100 per cent NK (I<sub>4</sub>). Addition of fly ash + biocompost + green manure (A<sub>3</sub>) recorded more number of leaves at all stages of banana crop. The interaction between irrigation treatments and amendments was not effective in producing more number of leaves at growth, shooting and harvest stages.

**Table 8:** Effect of effluent irrigation and amendments on number of leaves

Irrigation (I)/ amendment (A)	Growth stage				Shooting stage				Harvest stage			
	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean
I <sub>1</sub>	11	12	13	12	14	15	17	15	12	14	15	14
I <sub>2</sub>	11	13	14	13	15	16	18	16	13	14	16	14
I <sub>3</sub>	11	13	14	13	15	16	18	16	13	14	16	14
I <sub>4</sub>	10	11	12	11	13	14	16	14	11	13	14	13
I <sub>5</sub>	11	12	13	12	14	15	15	15	12	14	14	13
I <sub>6</sub>	12	14	15	14	16	18	20	18	14	15	17	15
I <sub>7</sub>	12	14	15	14	16	18	20	18	14	15	17	15
Mean	11	13	14	13	15	16	18	16	13	14	16	14
S.Ed	I	A	I at A	A at I	I	A	I at A	A at I	I	A	I at A	A at I
CD (0.05)	0.8	0.6	1.6	1.7	0.6	0.5	1.1	1.2	0.5	0.4	1.0	1.0
	NS	1.4	NS	NS	1.4	1.0	NS	NS	1.2	0.8	NS	NS

The numbers of suckers increased towards the advancement of crop growth (Table 9). Fertigation treatments increased sucker production at all stages of observation over basin irrigation. Among the irrigation treatments, I<sub>6</sub>, I<sub>7</sub>, I<sub>2</sub>, I<sub>3</sub> had more number of suckers and on par with each other at all stages. Less number of suckers were recorded due to basin irrigation of effluent with 75 per cent NK (I<sub>5</sub>) at growth stage.

Similar trend was observed at all stages. The number of suckers were not significantly influenced by various amendments at all growth stages. Interaction between irrigation treatments and amendments was non-significant ranged from 2 to 4, 3 to 7, 5 to 11 at growth, shooting and harvest stages, respectively

**Table 9:** Effect of effluent irrigation and amendments on number of suckers

Irrigation (I)/ amendment (A)	Growth stage				Shooting stage				Harvest stage			
	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	Mean
I <sub>1</sub>	3	3	3	3	3	3	5	4	10	10	10	10
I <sub>2</sub>	4	3	4	4	5	4	6	5	11	10	11	11
I <sub>3</sub>	3	3	4	3	5	4	6	5	10	10	11	10
I <sub>4</sub>	2	2	2	2	3	3	4	3	7	6	7	7
I <sub>5</sub>	2	2	2	2	3	3	3	3	6	6	5	6
I <sub>6</sub>	4	4	4	4	5	6	7	6	11	11	11	11
I <sub>7</sub>	4	3	4	4	5	6	6	6	11	10	11	11
Mean	3	3	3	3	4	4	5	5	9	9	9	9
S.Ed	I	A	I at A	A at I	I	A	I at A	A at I	I	A	I at A	A at I
CD (0.05)	0.2	0.2	0.4	0.4	0.3	0.3	0.6	0.7	0.3	0.1	0.4	0.2
	0.5	NS	NS	NS	0.7	NS	NS	NS	0.9	NS	NS	NS

In banana continuous growth in terms of height, girth of pseudostem, number of leaves and suckers are important parameters to judge the plant vigour but too much height is detrimental because banana is susceptible to lodging. Plant with more girth is desirable because they give good anchorage, heavy bunch and improved fruit characters. Since banana is determinate in growth habit, it should produce and retain sufficient number of leaves to harvest light energy and synthesis adequate photosynthates to induce flower stimulus, early flowering and sink development. Higher number of sucker production is essential for getting more planting materials. Total leaf area is in close relation with biomass production. The growth parameters *viz.*, stem height, girth, number of leaves, leaf area increased up to shooting and decreased at harvest stage whereas sucker production was increased up to harvest stage. Fertigation treatment increased the growth parameters. The effect was more due to fertigation of effluent with 75 per cent NK. Increase in plant girth might be due to higher uptake and accumulation of nutrients in leaf

tissue. More sucker production, which indicate higher nutrient status of the plant.

Increase growth in terms of height and girth might be due to better turgidity of cells, leading to cell enlargement and better cell wall development. Similarly, availability of higher level of nutrients especially N and K through fertigation in the root zone through effluent fertigation might have induced more vigour. Increased leaf area in this present study might be due to increase in number of leaves retained.

Weekly application of water-soluble fertilizers and daily application of effluent with adequate essential elements right at the wetted zone where active roots are concentrated would have helped in efficient absorption and utilization of nutrients. On the other hand high volatilization and leaching commonly associated with conventional system of irrigation and fertilization might be the possible reason for recording less growth under surface irrigated plants with effluent.

Increase in growth parameters through effluent fertigation was due to the drip irrigation in the soil around the active root

zone of the crop always remained at field capacity with no leaching loss of nutrients and increased nutrient content of the effluent enhanced the growth parameters. Basin irrigation of the effluent decreased the growth parameters. This was due to irrigation at long intervals might had created stress in plants by increasing the rate of senescence. Incorporation of fly ash + biocompost + green manure increased the number of leaves to 18 at shooting stage. This was due to combined addition of amendments that increased the soil properties like nutrient addition, improvement in soil physical and biological properties. Addition of fly ash decreased the number of leaves to 15 at shooting stage and the decrease was due to deterioration of soil property. When compared to application of fly ash alone combined application of amendments increased the number of leaves to 27, 20 and 23 per cent at growth, shooting and harvest stages, respectively.

Biometric observation *viz.*, the plant height, pseudostem girth, number of leaves, number of suckers and leaf area were increased due to fertigation of effluent with 75 per cent NK over basin application of effluent and farmer's practice (control). Application of amendments had no significant effect on pseudostem height, girth, number of suckers and leaf area etc. Combined addition of fly ash + biocompost + green manure recorded more number of leaves than fly ash alone. The result of the study indicates that the treated paper board mill effluent can be effectively utilized using drip irrigation without any adverse effect on soil biological properties and growth of banana

#### Acknowledgement

The author acknowledges the above board mill for providing necessary facility for conducting the experiment.

#### References

- Pitchai GJ, Prabakaran C. Utilization of organic nitrogen sources for improving yield and quality of tomato-A Research Attempt. Dr. C. P rabakaran Publishers, Chennai 2008, P70.
- Pitchai SJ, Prabakaran C, Saliha BB. Evaluation of the effect of different organic nitrogen on yield and quality of tomato. Nation. Seminar, Annamalai University 2001, P118.
- Prabakaran C, Tukkiyannan P. Production of vermicompost without shed, Spice India J 2008;21(8):21-21.
- Prabakaran C. Survey, characterization and composting studies of agricultural product producers and traders association market (APPTA) wastes of Kanyakumari District of Tamil Nadu (India), Int. J Chem. Stud 2020;8(4):395-399.
- Prabakaran C, Udayasoorian C. Utilization of treated paper factory effluent through drip irrigation for banana-A research attempt (e-book). Dr. C. Prabakaran Publishers, Chennai-71 2008, P120.
- Prabakaran C, Udayasoorian C. Utilization of treated paper factory effluent through drip irrigation for banana-A research attempt. Dr. C. Prabakaran Publishers, Chennai-71 2008, P121.
- Prabakaran C, Pitchai GJ. Effect of different organic nitrogen sources on pH, total soluble solids, titrable acidity, crude proteinreducing and non-reducing sugars and ascorbic acid content of tomato fruits 2002;12(2):160-166.
- Prabakaran C, Pitchai GJ. Effect of different organic nitrogen sources on pH, total soluble solids, titrable acidity, crude proteinreducing and non-reducing sugars and ascorbic acid content of tomato fruits 2003;13(1):172-175.
- Prabakaran C, Jayakumar D, Masilamai P. Water hyacinth vermicompost. Spice India J 2010;23(10):19-21.
- Prabakaran C. Composting and Utilization of paper board mill solid wastes for improving yield and quality of cumbu-Napier hybrid grasses. In: Nat. Sem on Biotechnology, Gene fest '03. Held at Dept of Biotechnology, Vivekananda College of Arts and Sciences for Women, Tiruchengodu from 21 Feb to 22 2003, P49-50.
- Prabakaran C. Utilization of treated paper board mill effluent and solid wastes for improving soil fertility, Nat. Soil Elixir of life, held at centre of Relevance and excellence, Agro &Industrial bio Technology Thapar Institute of Engineering and Technology, Patiala between 26-27 2003, P30-30.
- Prabakaran C, Pitchai GJ. E-book on utilization of organic nitrogen sources for improving yield and quality of tomato -a research attempt. Dr. C. Prabakaran Publishers, Chennai-71 2008, P76.
- Prabakaran C, Pitchai GJ. Utilization of organic nitrogen sources for improving yield and quality of tomato-a research attempt. Dr. C. Prabakaran Publishers, Chennai 2008;71:78.
- Prabakaran C. Effect of different organic N sources on yield and quality of tomato. MSc Thesis Submitted to Tamil Nadu Agricultural University 2000.
- Prabakaran C. E-book on-Herbal plants that are found in Tamil Nadu for the treatment of sick animals. Dr. C. Prabakaran Publishers, Chennai-7 2008, P72.
- Prabakaran C. Herbal plants that are found in Tamil Nadu for the treatment of sick animals. Dr. C. Prabakaran Publishers, Chennai-71 2008, P67.
- Prabakaran C. Afforestation of Neyveli mine spoils-my experience, Proc. Natl. workshop on Industrial Agro forestry held at Forest College and Research Institute, Mettupalayam from 21-3-2013 to 23.1.2013, Sponsored by ICAR (NAIP) 2013, P27-27.
- Prabakaran C. Water hyacinth vermi-compost to nutrient poor soils. Proc. Natl. workshop on Industrial Agro forestry held at Forest College and Research Institute, Mettupalayam from 21-3-2013 to 23.1.2013, Sponsored by ICAR (NAIP) 2013, P30-30.
- Prabakaran C. Effect of treated paper board mill effluent and composted biosludge on silvipastoral System. Proc. Natl. workshop on Industrial Agro forestry held at Forest College and Research Institute, Mettupalayam from 21-3-2013 to 23.1.2013, Sponsored by ICAR (NAIP) 2013, P28-28.
- Prabakaran C. Solar powered water pumping for remote industrial agroforestry applications. Proc. Natl. workshop on Industrial Agro forestry held at Forest College and Research Institute, Mettupalayam from 21-3-2013 to 23.1.2013, Sponsored by ICAR (NAIP) 2013, P38-38.
- Prabakaran C. Effect of cement kiln application (CKD) on soil health. Environmental pollution control technologies 2019, Dept of chemical Engineering, Annamalai University 2019, P355-355.
- Prabakaran C, Udayasoorian C. Characteristics of treated paper board mill effluent and its effect on nutrient uptake and yield. Nat. Soil Elixir of life, held at centre of Relevance and excellence, Agro &Industrial bio

- Technology Thapar Institute of Engineering and Technology, Patiala between 26-27 2003, P30-30.
23. Prabakaran C, Udayasoorian C. Effect of different organic Nitrogen sources on soil reaction, salinity, micro nutrient status of soil and yield of tomato under organic farming. *Journal of Ecobiology* 2008;22(4):321-334.
  24. Prabakaran C, Udayasoorian C. Quality assessment of soil under paper mill effluent. *Journal of Ecotoxicology and Environment Monitoring* 2008;18(3):273-276.
  25. Prabakaran C, Udayasoorian C, Arul P. Effect of solid wastes and irrigation sources on oxalic acid and nitrate concentration of cumbu Napier hybrid grasses. In: Nat. Sem on Biotechnology, Gene fest '03. Held at Dept of Biotechnology, Vivekananda College of Arts and Sciences for Women, Tiruchengodu from 21 Feb to 22 2003, P49-50.
  26. Prabakaran C. Influence of organic solid wastes on tomato. *J Ecobiol* 2007;21(1):87-92.
  27. Prabakaran C, Udayasoorian C, Arul P. Effect of solid wastes and irrigation sources on oxalic acid and nitrate concentration of cumbu Napier hybrid grasses. In: Nat. Sem on Biotechnology, Gene fest '03. Held at Dept of Biotechnology, Vivekananda College of Arts and Sciences for Women, Tiruchengodu from 21 Feb to 22 2003, P46-46.
  28. Prabakaran C, Jamespitchai G, Jawahar D. Impact of some organic wastes on soil enzyme activities and plant height at vegetative stage under organic farming of tomato. Nat. Soil Elixir of life, held at centre of Relevance and excellence, Agro & Industrial bio Technology Thapar Institute of Engineering and Technology, Patiala between 26-27 2003:03:22-22.
  29. Prabakaran C. An experiment on composted market waste and aerobic rice for climate smart agriculture. National seminar, ADAC&RI, TNAU, Trichy 2019, P206-207.
  30. Prabakaran C. Effect of treated effluent irrigation on yield and biominerals of banana, *IJERT* 2020;9(7):1460-1464.
  31. Prabakaran C. Impact of some organic N sources on soil physical properties and yield of tomato Madras Agric. J 2006;99(1-6):46-52.
  32. Prabakaran C. Fertigation and ground water quality with treated waste water effluent Eds, Megh R Goyal, Performance Evaluation of Micro Irrigation Management: Principles and Practices, CRC Press, Vol. 3, Innovations and challenges in Micro irrigation, Performance Evaluation of Micro Irrigation Management: Principles and Practices 2016, P151-174.
  33. Ramasamy D, Prabakaran C. E-book on "Ways and means to increase income from milch animals". Dr. C. Prabakaran Publishers, Chennai-7 2008, P80.
  34. Ramasamy D, Prabakaran C. Low cost technology for preparation of value added milk sweets. Dr. C. Prabakaran Publishers, Chennai-71 2008.
  35. Udayasoorian C, Prabakaran C, Thukkaiyannan P. Quality assessment of banana under fertigation. *Journal of ecobiology* 2007;21(3):269.
  36. Udayasoorian C, Prabakaran C. Effect of fertigation on leaf proline, soluble protein and enzymatic activity of banana. *Electronic Journal of Environmental, Agricultural & Food Chemistry* 2010;9(8):1404-1414.