

Original Research Article

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Growth, Yield and Yield Attributes as Influenced by Treated Distillery Effluent Application in Maize (*Zea mays* L.) under Vertisols

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ABSTRACT

A field experiment was conducted to find out the effect of treated distillery effluent (TDE) and bio-compost (BC) application on productivity of maize crop grown in vertisols having clay loam texture. Five levels each of organic fertilizers in main plot (control, TDE at 50 kL ha⁻¹, TDE at 100 kL ha⁻¹, BC at 5 t ha⁻¹ and FYM at 12.5 t ha⁻¹ + bio-fertilizers and inorganic fertilizers in sub plot (control, 50, 75, 100% recommended dose (RD) of N (nitrogen) & P (phosphorus) and 100% RD of N+P+K (potassium) were tested in split plot design and replicated thrice. Application of TDE at 100 kL ha⁻¹ along with either 100% RD of NPK or NP increased the grain and stover yield by 18.3–26.3 and 37.6–47.15% respectively, over control. However, this treatment was found comparable with FYM at 12.5 t ha⁻¹ + bio-fertilizers along with either 100% RD of NPK or NP. Similarly, dry matter production was also found maximum with the application of TDE at 100 kL ha⁻¹ and FYM 12.5 t ha⁻¹ + bio-fertilizers. The growth and yield attributes of maize viz., plant height, leaf area index, cob length, cob girth, number of grain rows cob⁻¹, number of grains row⁻¹, number of grains cob⁻¹, 100-grains weight and cob weight were significantly increased by TDE application and the highest values were recorded at 100kL ha⁻¹ along with 100% RD of NPK as well as NP fertilizers. TDE contain considerable level of plant nutrients which were made available to the plant, thus resulted in better growth and productivity yield of maize.

Keywords

Maize,
Zea mays,
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Introduction

Maize has its significance as a source of a large number of industrial products besides its uses as human food and animal feed. In India, maize is cultivated on 9.07 million hectares (Mh) with a production of 27.30 million tons (Mt) and the average yield is 2627 kg ha⁻¹

(Agricoop, 2018). By 2020, the requirement of maize for various sectors will be around 100 Mt, of which poultry sector needs 31 Mt. Therefore, to meet the demand to various sectors it is indispensable to increase the production of maize. Further, for increasing the production and productivity of crops synthetic fertilizers play a vital role.

However, sole application of chemical fertilizer results in leaching and runoff of nutrients, especially N and P which leads to environmental degradation (Dass *et al.*, 2014), adverse effect on soil properties and produce quality (Gupta *et al.*, 2018). Therefore, integrated application of organic and inorganic sources of nutrients along with bio fertilizers on the other hand could provide a good substrate for crop growth and development through congenial nutrient supply environment to the crops (Choudhary *et al.*, 2010).

In this regard, sugar and distillery complex generates large quantities of solid and liquid bio-wastes like bagasse (the fibre residue of sugarcane), press mud (filter cake), molasses and distillery effluent or spent wash. However, some of these wastes are recycled for agricultural purpose, mainly for reclamation of salt affected soil as well as for nutrient supplement to the various crops. Presently the distillery industrial wastes, which are considered unusable, have found to be useful in support of sustainable agriculture. At present, there are 319 distilleries in India with an installed capacity of 3.25 billion liters of alcohol and generating 48 billion litres of distillery effluent annually (Uppal, 2004; Dinesh *et al.*, 2020).

In general, the treated effluent contains considerable amount of primary (N P, K), secondary (Ca, Mg, S) and micro nutrients (Haroon and Bose, 2004). The distillery effluent after treatment (pH correction and BOD reduction) can be a good source of nutrients. The TDE improves the soil biological and biochemical activities (Murugaragavan, 2002). It has been also observed that application of distillery effluent in acid soil is not accounting for any change that affect the soil quality (Das *et al.*, 2010). Therefore, this could be used as fertilizer for improving crop growth and soil fertility

(Suganya *et al.*, 2002; Joshi *et al.*, 2000). In order to harness its full manurial potential, there is a recommendation of one time land application of distillery effluent as a source of plant nutrients (Baskar *et al.*, 2003). Keeping the above facts in view, the current study was aimed to find out the repose of TDE and BC application on maize grown under vertisols and their effect on growth yield and yield attributes.

Materials and Methods

Experimental site and growing condition

Field experiment was conducted in Tenkizhani village of Vellore district, Tamil Nadu. The soil of the study area belongs to *Idayapatti* series which is fine montmorillonitic hyperthermic family of *Typic Haplusterts*, vertisols. The geographical location of the experiment site was 12 ° 51' N latitude 79 ° 18' E longitudes with an altitude of 246 m above the mean sea level. In initial stage the soil was slightly alkaline (pH 8.4) and EC of 0.30 dS m⁻¹. The organic carbon content was found to be low (7.40 g kg⁻¹). The N was low (210 kg ha⁻¹) and the K (309 kg ha⁻¹) and P (23 kg ha⁻¹) level were high in status. The Mn (10.5 mg kg⁻¹), Fe (8.68 mg kg⁻¹), Cu (3.00 mg kg⁻¹) and hot water soluble Boron (0.52 mg kg⁻¹) were found to be sufficient in the soil but the availability of Zn (0.67 mg kg⁻¹) was found to be deficient. The microbial populations of experiment soils were 1.50 × 10⁶ CFU g⁻¹ of soil for bacteria, 8.20 × 10⁴ CFU g⁻¹ of soil for fungi and 4.5 × 10² CFU g⁻¹ of soil for Actinomycetes.

Experimental design and treatments

Five levels each of organic fertilizers in main plot (control, TDE at 50 kL ha⁻¹, TDE at 100 kL ha⁻¹, BC at 5 t ha⁻¹ and FYM at 12.5 t ha⁻¹ + bio-fertilizers and inorganic fertilizers in sub plot (control, 50, 75, 100% RD of N + P

and 100% RD of N+P+K were tested in split plot design and replicated thrice. The soil was ploughed well and the calculated quantities of TDE, BC and FYM as per the treatment schedule were applied uniformly to the concerned plots before 30 days of sowing. After 30 days, surface of the treated plots were inverted manually with spade to facilitate aeration and oxidation. Then, the ridges and furrows were formed as the test crop was maize (local farmers preferred variety used) and the fertilizer schedule of 150:75:75 kg N, P₂O₅, K₂O ha⁻¹ was adopted as 100% recommended dose (TNAU, 2007). Bio compost was prepared by utilizing the press mud (an organic solid material obtained as by-product from sugar industries) as a raw material and the composting process is being carried out by mechanized open window system with the use of treated distillery spent wash and bio inoculants for about 70–80 days. The product is then sun dried ground and sieved by mechanical separator and then used as BC for manuring purpose. Bio-fertilizers (*Azospirillum* and *Phosphobacteria*) were used at 2.0 kg ha⁻¹ in respective treatment. Calculated quantities of fertilizers were applied in each treatment as per the treatment schedule. Entire dose of P was applied as basal while N and K were applied in two splits at 25 and 50 days after sowing (DAS). To avoid micro nutrients deficiency, the TNAU micronutrient mixture at 12.5 kg ha⁻¹ as enriched with FYM was applied, uniformly. All other cultural practices including gap filling, thinning, weeding and plant protection measures were carried out as per the recommendations of crop production guide of Tamil Nadu Agricultural University.

Biometric observations

Plant samples were collected on 30 and 60 DAS and also at harvest stage. Five samples were collected from each treatment plot, chopped to small pieces separately, air dried for one week and then oven dried at 60-70°C

till a constant weight was reached. The oven dry weight of each sample was determined and the total dry matter production (DMP) kg ha⁻¹ was calculated. These samples were finally powdered and used for chemical analysis. Height of the plants were measured from the base of the plant to the tip of the top most opened leaf in ten representative plants at various stages of crop growth and expressed in cm. From ten randomly selected plants in each treatment plot, maximum length and breadth of the fully opened third leaf from the top of the plant was measured. The total number of leaves in all the five plants was counted. The mean values were worked out for the maximum length, breadth and number of leaves plant⁻¹. The leaf area index (LAI) was calculated by using the following formula as suggested by Mckee (1964).

$$LAI = \frac{L \times B \times N \times 0.796}{\text{Spacing (cm)}}$$

L - Length of the leaf (cm)

N - No. of leaves

B - Breath of the leaf (cm)

0.796 - Constant

The cobs from the net plot were harvested separately. The cobs were sun dried shelled, cleaned and grain yield were recorded for individual treatments and expressed in kg ha⁻¹. After the harvest of cobs, the stover in the net plot area were cut close to the ground level and left in the field for one week for sun drying. After drying, weight of stover from each treatment plot was recorded and expressed in kg ha⁻¹. Cob length, cob girth, grain rows cob⁻¹, number of grains row⁻¹, test weight ten representative plants at harvest were calculated according to standard procedure. The data of the experiment were statistically analyzed by adopting appropriate statistical methods as outlined by Gomez and Gomez (1984). The critical differences were

calculated at 5% level of probability.

Results and Discussion

Grain and stover yield

Application of TDE, BC and FYM significantly affected the grain (Fig.1) and stover yield (Fig. 2). The results revealed that among the main plot treatments, application of TDE at 100 kL ha⁻¹ registered the highest grain (5128 kg ha⁻¹) and stover yield (9813 kg ha⁻¹). However, this treatment was comparable with FYM at 12.5 t ha⁻¹ + bio-fertilizers. With respect to the organic manures *viz.*, FYM and BC both of them were found comparable, while FYM was better than BC and both of them registered higher grain and stover yield than control. Causes of increase in yield under organic treatments were ascribed to synergism between bio-fertilizers and FYM, which increased the concentrations of N, P and K ions in soil solution, which led to vigorous root development, and better growth and development of plant (Rathod *et al.*, 2015). Among the subplot treatments application of 100% RD of NPK recorded the higher grain (5510 ha⁻¹) and stover yield (10518 kg ha⁻¹) compared to other treatments. However, this treatment was comparable with 100% RD of NP. The interaction of treatments was significant wherein the superiority of the application of TDE at 100 kL ha⁻¹ over the rest of the main plot treatments.

The effects of organic manure *viz.*, BC and FYM were found comparable at all sub plot treatments as well as all the main plot treatments other than control. Hati *et al.*, (2007) reported an increase in the grain yield of wheat in the distillery effluent applied treatments.

The distillery effluent is essentially of plant origin and contains high level of plant nutrients which were made available to the

plant, thus resulting in better growth, development and yield of the crops. Similar effects with the usage of distillery effluent were also reported by Ramana *et al.*, (2002); Dinesh *et al.*, (2017) in maize. In contrast, Baskar *et al.*, (2001) reported that the pre-plant application of distillery spent wash markedly increased the cane yield of sugarcane. Bhalerao *et al.*, (2005) reported that the pre-sowing application of distillery spent wash recorded similar impact on the yield of *Dhaincha* and sugarcane.

Growth parameters

The dry matter production (DMP), plant height, number of leaves, leaf length and LAI of maize were significantly influenced by the application of TDE, BC, FYM and RD of NPK and NP. DMP and plant height ranged from 0.57 to 18.4 t ha⁻¹ (Table 1) and 71.0 cm to 201 cm (Table 2) respectively. Application of TDE and organic manures significantly increased the DMP and plant height of maize crop at all stages of observation. Application of TDE at 100 kL ha⁻¹ registered significantly higher DMP and plant height which was followed by FYM at 12.5 t ha⁻¹ + bio-fertilizer and were found superior to control at almost all the stages of crop growth. Combination of organic sources of nutrients with bio-fertilizers results in more uptake of nutrients as compared to sole use of organic ones (Patil and Padmani, 2007).

This may be due to the fact that the balanced and combined use of various plant nutrient sources results in optimum absorption, translocation and assimilation of those nutrients. This ultimately leads to increase in the dry-matter accumulation and other growth parameters (Gupta *et al.*, 2020). Kayalvizhi *et al.*, (2001) observed higher values of growth parameters and cane yield due to application of distillery spentwash at 1:30 dilutions.

Table.1 Effect of TDE, BC and FYM application on dry matter production (DMP) yield (t ha⁻¹) of maize crop

Treatments	Vegetative Stage						Flowering Stage						Harvesting Stage					
	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean
M₁	0.57	0.77	0.96	1.04	1.18	0.90	3.3	4.1	4.2	4.7	5.1	4.3	7.1	9.9	11.1	12.3	13.4	10.7
M₂	0.71	0.97	1.33	1.55	1.61	1.23	5.2	6.1	7.8	8.0	8.2	7.0	10.8	13.0	14.9	16.0	16.5	14.2
M₃	0.91	1.07	1.44	1.60	2.03	1.41	5.2	7.7	8.0	9.7	10.0	8.1	11.4	14.8	16.5	18.0	18.4	15.8
M₄	0.74	1.17	1.39	1.52	1.77	1.32	5.1	5.8	6.2	7.0	7.2	6.2	11.0	13.5	15.2	16.5	17.1	14.7
M₅	0.66	1.06	1.29	1.62	1.71	1.27	5.2	6.6	7.1	7.5	8.6	7.0	11.1	14.0	15.8	18.0	18.5	15.5
Mean	0.72	1.01	1.28	1.46	1.66	1.23	4.8	6.1	6.7	7.4	7.8	6.5	10.3	13.0	14.7	16.2	16.8	14.2
	SEd		CD (0.05)				SEd		CD (0.05)				SEd		CD (0.05)			
M	0.04		0.10				0.11		0.2				0.45		1.0			
S	0.07		0.14				0.24		0.5				0.28		0.6			
M x S	0.15		0.30				0.48		1.0				0.71		1.5			
S x M	0.16		0.32				0.53		1.1				0.62		1.3			

Table.2 Effect of TDE, BC and FYM application on plant height (cm) of maize crop

Treatments	Vegetative stage						Flowering stage					
	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean
M₁	71.0	78.0	83.6	79.2	89.8	80.3	173	187	189	183	190	185
M₂	73.9	77.1	82.1	92.8	92.8	83.7	183	195	195	190	200	193
M₃	70.6	74.6	87.7	90.3	98.7	84.4	192	194	181	196	201	193
M₄	71.6	78.3	83.7	91.6	92.2	83.5	191	186	193	190	196	191
M₅	73.7	76.1	95.3	94.2	101.1	88.1	192	196	194	204	199	197
Mean	72.2	76.8	86.5	89.6	94.9	84.0	186	192	190	193	197	192
	SEd		CD (0.05)				SEd		CD (0.05)			
M	2.82		6.5				3.24		8			
S	3.40		6.9				2.39		5			
M x S	7.36		NS				5.77		NS			
S x M	7.60		NS				5.33		NS			

Table.3 Effect of TDE, BC and FYM application on number of leaves plant⁻¹ of maize crop

Treatments	Vegetative stage						Flowering stage					
	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean
M₁	8.2	9.1	9.5	9.1	9.4	9.0	12.4	13.5	13.5	13.9	13.6	13.4
M₂	8.8	9.1	9.1	9.7	9.7	9.3	12.9	13.9	13.5	13.9	13.7	13.6
M₃	8.7	8.8	9.4	9.6	9.9	9.3	13.9	13.3	13.7	13.5	13.7	13.7
M₄	8.6	9.6	9.2	9.9	10.1	9.5	13.7	13.5	13.7	13.9	13.9	13.7
M₅	8.7	8.9	9.2	10.0	10.3	9.4	13.9	13.9	13.7	14.5	14.5	14.1
Mean	8.6	9.1	9.3	9.7	9.9	9.3	13.4	13.6	13.6	13.9	13.9	13.7
	SEd			CD (0.05)			SEd			CD (0.05)		
M	0.19			NS			0.19			0.5		
S	0.23			0.5			0.16			0.3		
M x S	0.50			NS			0.37			NS		
S x M	0.52			NS			0.35			NS		

Table.4 Effect of TDE, BC and FYM application on leaf length (cm) of maize crop

Treatments	Vegetative stage						Flowering stage					
	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean
M₁	55.0	59.8	62.3	59.5	64.4	60.2	74.3	78.5	76.0	79.1	74.6	76.5
M₂	56.2	60.9	61.8	66.1	69.1	62.8	77.6	81.5	80.1	76.5	82.7	79.7
M₃	54.5	56.4	65.7	69.5	74.0	64.0	79.7	82.1	84.2	82.2	84.4	82.5
M₄	54.9	63.5	61.6	69.1	73.6	64.5	79.1	80.2	80.5	78.8	83.0	80.3
M₅	54.8	60.6	70.9	69.1	76.1	66.3	78.8	81.7	80.9	82.7	83.8	81.6
Mean	55.1	60.2	64.5	66.6	71.4	63.6	77.9	80.8	80.3	79.8	81.7	80.1
	SEd			CD (0.05)			SEd			CD (0.05)		
M	2.73			NS			1.21			2.8		
S	5.46			5.0			1.84			NS		
M x S	5.62			NS			3.87			NS		
S x M	5.50			NS			4.11			NS		

Table.5 Effect of TDE, BC and FYM application on LAI of maize crop

Treatments	Vegetative stage						Flowering stage					
	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean
M₁	1.63	2.14	2.48	2.07	2.63	2.19	5.69	6.11	6.14	6.18	6.19	6.06
M₂	1.94	2.26	2.21	3.12	3.18	2.54	6.09	7.08	7.10	7.18	7.21	6.93
M₃	1.60	1.79	2.90	3.32	3.68	2.66	7.04	7.21	7.28	7.39	7.40	7.42
M₄	1.69	2.75	2.31	3.11	3.70	2.71	6.06	7.09	7.11	7.16	7.18	6.92
M₅	1.83	2.09	3.14	3.30	3.81	2.84	6.05	7.20	7.24	7.31	7.38	7.04
Mean	1.74	2.20	2.61	2.99	3.40	2.59	6.19	6.94	6.97	7.04	7.07	6.87
	SEd			CD (0.05)			SEd			CD (0.05)		
M	0.26			NS			0.21			0.49		
S	0.30			0.61			0.19			0.38		
M x S	0.66			NS			0.43			NS		
S x M	0.67			NS			0.42			NS		

Table.6 Effect of TDE, BC and FYM application on cob length and girth (cm) of maize crop

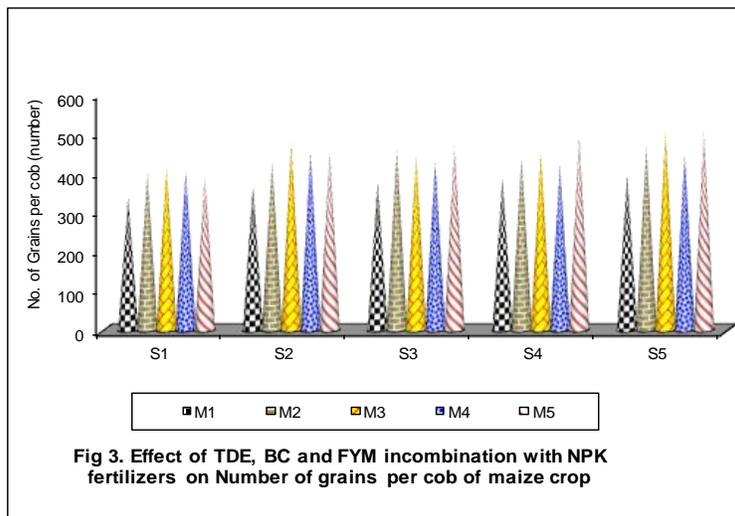
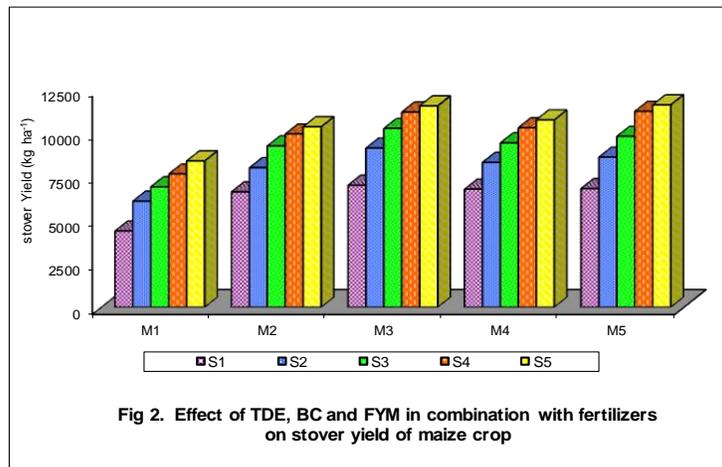
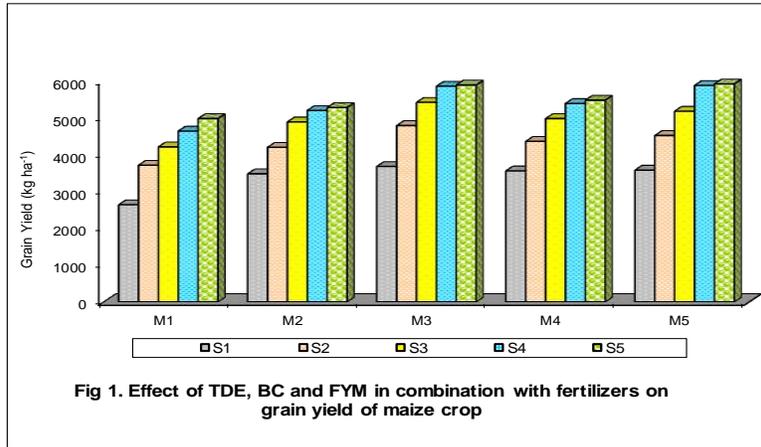
Treatments	Cob length						Cob girth					
	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean
M₁	16.7	17.4	17.0	16.8	18.0	17.2	13.0	13.4	13.0	13.2	13.7	13.2
M₂	17.5	19.0	19.0	19.3	19.5	18.9	14.0	14.9	14.6	14.8	14.6	14.6
M₃	18.1	19.4	18.8	19.0	19.5	19.0	14.0	14.9	14.8	14.5	14.7	14.6
M₄	17.9	17.9	18.0	18.5	18.9	18.3	14.0	14.1	14.4	14.5	14.8	14.4
M₅	17.5	19.5	19.4	20.2	20.4	19.4	13.4	14.2	14.2	14.5	14.2	14.1
Mean	17.5	18.6	18.5	18.8	19.3	18.5	13.7	14.3	14.2	14.3	14.4	14.2
	SEd			CD (0.05)			SEd			CD (0.05)		
M	0.31			0.7			0.33			0.8		
S	0.39			0.8			0.26			0.5		
M x S	0.84			1.7			0.62			1.3		
S x M	0.87			1.8			0.59			1.2		

Table.7 Effect of TDE, BC and FYM application on cob weight and 100-grain weight (g) of maize crop

Treatments	Cob Weight						100 grain weight					
	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean
M₁	63	90	93	109	118	94	22.3	23.6	24.1	25.3	25.7	24.2
M₂	73	95	104	107	128	101	24.5	25.7	27.3	27.3	27.7	26.5
M₃	88	101	110	121	130	110	25.4	26.5	27.9	27.9	28.3	27.2
M₄	72	79	87	113	125	95	23.0	23.0	26.9	26.5	27.6	25.4
M₅	77	96	109	121	127	106	24.5	26.1	27.3	27.3	29.0	26.8
Mean	75	92	101	114	126	101	23.9	25.0	26.7	26.9	27.6	26.0
	SEd			CD (0.05)			SEd			CD (0.05)		
M	2.85			7			0.56			1.3		
S	6.01			12			0.36			0.7		
M x S	12.36			25			0.92			1.9		
S x M	13.44			27			0.81			1.6		

Table.8 Effect of TDE, BC and FYM application on number of grain row cob⁻¹, number of grains per row⁻¹ of maize crop

Treatments	No. of grain row per cob ⁻¹						No. of grains per row ⁻¹					
	S ₁	S ₂	S ₃	S ₄	S ₅	Mean	S ₁	S ₂	S ₃	S ₄	S ₅	Mean
M₁	13.2	13.3	13.5	13.9	13.7	13.5	25.5	27.8	27.7	27.9	28.8	27.5
M₂	14.1	14.1	14.6	14.3	14.3	14.3	28.1	30.3	31.4	30.8	32.4	30.6
M₃	14.0	14.9	14.5	14.5	15.3	14.6	29.7	31.9	30.6	31.2	33.2	31.3
M₄	14.4	14.6	13.8	14.2	14.1	14.2	28.1	30.8	30.8	29.4	31.6	30.1
M₅	14.3	14.3	14.8	14.6	15.0	14.6	27.7	31.8	31.7	33.2	33.5	31.6
Mean	14.0	14.2	14.2	14.3	14.5	14.2	27.8	30.5	30.4	30.5	31.9	30.2
	SEd			CD (0.05)			SEd			CD (0.05)		
M	0.19			0.45			0.36			0.84		
S	0.20			0.40			0.47			0.96		
M x S	0.44			0.92			1.01			2.08		
S x M	0.44			0.90			1.06			2.14		



Dinesh *et al.*, (2017) revealed that application of distillery effluent after tillering phase registered significantly higher plant height and DMP. With respect to the subplot treatments, application of 100% RD of NPK recorded highest DMP and plant height however it was comparable with 100% RD of NP in some extent and which were superior to all other subplot treatments at almost all the stages of observation. The interaction effect was significant at all the stages of observation. Application of TDE at 100 kL ha⁻¹ along with 100% RD of NPK recorded a marked increase in the DMP and plant height at all the stage of observation followed by the application of TDE at 100 kL ha⁻¹ along with 100% RD of NP. Similarly, number of leaves, leaf length and LAI of maize crop followed the same pattern as followed under DMP and plant height. Number of leaves, leaf length and LAI ranged from 8.20 to 14.5 (Table 3), 55.0 to 84.4 cm (Table 4), 1.63-6.87 (Table 5) respectively. However, interaction effect was insignificant in these parameters. Ramana *et al.*, (2002) reported that the application of distillery effluent significantly increased the DMP, plant height and other growth parameters of maize over control. The distillery spentwash is essentially a plant extract containing larger amount of most of the plant nutrients. Upon its application, the spentwash not only added plant nutrients, but also favoured mineralization of the nutrients in soil due to enhanced microbial activities. Increase in the availability of these nutrients might have facilitated greater uptake of nutrients by maize which reflected on better growth, development and yield of the crop.

Yield attributes

The yield attributes like cob length and cob girth were significantly influenced by the application of TDE and organic manures. The cob length and cob girth ranged from 16.7 to 19.5 cm and 13.0 to 14.7 cm respectively

(Table 6). The length and girth of cob was found to be higher in the plots which received TDE at 100 kL ha⁻¹ and found on par with FYM at 12.5 t ha⁻¹ + bio-fertilizer. FYM applied at sufficient amount along with bio-fertilizers provides optimum favorable conditions for nutrient release as well as uptake and hence, due to the better response from plants it performed significantly (Pandey *et al.*, 2015). The enhancement in yield attributing characters might be due to improved microbial activity in the rhizosphere with the application of organic manure and bio-fertilizer in conjunction which resulted in balanced nutrient supply, good microbial activity, and optimum moisture availability, anti-pathogenic activity resulting in better growth, yield attributes and yield (Reddy *et al.*, 2011; Gupta *et al.*, 2018). Among the subplot treatments, application of 100 % RD of NPK recorded higher cob length and girth, however, found at par with 100% RD of NP. This was due to the increasing doses of chemical fertilizers contributing to the available nutrient pool in the soil which in turn increased the growth and yield attributes of the crop (Janaki, 2008). Cob weight and 100-grain weight (Table 7) were also followed the same fashion as followed in case of cob length and cob girth. The interaction effect was also significant in the treatment combinations. Application of TDE at 100 kL ha⁻¹ along with 100% RD of NPK followed by 100 kL ha⁻¹ along with 100% RD of NP found to be significant with themselves. The number of grains cob⁻¹ (Fig. 3) number of grain rows cob⁻¹ and number of grains row⁻¹ (Table 8) were also significantly influenced by application of TDE and organic manures. The number of grains cob⁻¹, number of grain rows cob⁻¹ and number of grains row⁻¹ ranged from 336 to 506, 13.2 to 15.3 and 25.5 to 33.2 respectively. The application of TDE at 100kL ha⁻¹ recorded the highest values of these attributes and found at par with FYM @ 12.5 t ha⁻¹ + bio-fertilizers. Among the

subplot treatments, application of 100% RD of NPK recorded the highest values of these attributes and found at par with 100% RD of NP. Chemical fertilizers are concentrated nutrient suppliers which supply plant nutrients in quick manner even with the lower doses (Sahayet *al.*, 2016) and leading to higher photosynthetic activity and translocation of photosynthates to the sink which in turn resulted in optimum development of yield attributes and finally in higher grain and straw yield (Goud and Kale, 2010). The number of grain rows per cob was found to be significantly influenced by the application of TDE and organic manures. The interaction effect was also significant. Application of TDE at 100 kL ha⁻¹ along with 100% RD of NPK resulted in higher values of these parameters followed by FYM at 12.5 t ha⁻¹ + biofertilizers along with 100% RD of NPK and these treatments were found superior to control.

In conclusion the application of TDE at 100 kL ha⁻¹ along with either 100% RD of NPK or NP recorded highest grain and stover yield. However, application of FYM at 12.5 t ha⁻¹ along with either 100 % RD of NPK or 100 % NP found significantly at par because this treatment performed equally better as that of 100% NPK and it could be inferred that complete skipping of K fertilization is also possible if integrated nutrient management involving FYM and bio-fertilizers are practiced. These practices not only save the K fertilizer inputs but also could considerably cut short the fertilizer import bills.

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