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Response of Maize (*Zea mays* L.) to Treated Sugar Mill Effluent with Different Nutrient Management Approaches

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Abstract

A field experiment was undertaken during *kharif* 2016 to study the 'Response of maize (*Zea mays* L.) to treated sugar mill effluent (TSME) with different nutrient management approaches' at M/s. Chamundeshwari Sugars Limited, Maddur taluk, Mandya district which is located in southern dry zone of Karnataka. The experiment was laid out in RCBD having twelve treatments and replicated thrice. The results showed that significantly higher plant height, leaf area, total dry matter production and SPAD value at 60 DAS 216.1cm, 9091 cm^2 $plant^{-1}$, 366.3g and 61.6, respectively) and higher grain (124.4 q ha^{-1}) and stover yield (193.0 q ha^{-1}) yield of maize was obtained with treated sugar mill effluent with amendment (Gypsum) + SSNM for targeted yield of 120 q ha^{-1} and it was on par with TSME with amendment (Gypsum) + STCR approach for targeted maize yield of 120 q ha^{-1} (209.3 cm, 8834 cm^2 $plant^{-1}$, 357.5g, 57.1, 123.2q ha^{-1}, and 19.1 q $ha^{-1}$of plant height, leaf area, total dry matter production, SPAD value, grain and stover yield, respectively).

Keywords : Maize, SSNM, STCR, Treated sugar mill effluent

MAIZE (*Zea mays* L.) is one of the most versatile emerging crops having wider adaptability to different agro-climatic conditions. Globally, maize is known as queen of cereals as it has the highest genetic yield potential among the cereals. It is cultivated on nearly 150 m ha in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36 per cent (782 mt) of the global cereal production. The USA is the largest producer of maize and contributes nearly 35 per cent of the total production in the world and has the highest productivity (> 9.6 t ha^{-1}) which is double than the global average (4.92 t ha^{-1}), whereas, the average productivity in India is only 2.43 t ha^{-1}.

Maize is the third most important cereal crop in the world after wheat and rice. Approximately 8 to 10 per cent of the corn crop is used as food for human consumption. It is a source of food for human, fodder and feed for animals. In India it occupies an area of 10.20 m ha producing 18.73 m t with an average productivity of 2580 kg ha^{-1} (Anonymous, 2018). Recent trends in growth rate of area (2.6%), production (6.4%) and productivity (3.6%) of maize in India has been of high order and experienced highest growth rate among the food crops. Since 1950-51, the area, production and productivity of maize has increased by more than 3.19, 11.02 and 4.72 times from 3.2 m ha, 1.7 m t and 547 kg ha^{-1} to current level of 10.20 m ha, 18.73 m t and 2580 kg ha^{-1}, respectively due to increasing maize demand for diversified uses (Anonymous, 2016).

Maize grains have greater nutritional value as it contains 72 per cent starch, 10 per cent protein, 4.8 per cent oil, 8.5 per cent fiber, 3.0 per cent sugar and 1.7 per cent ash. In India, it contributes nearly of total 9 per cent to the national food basket and more than ₹ 100 billion to the agricultural GDP at current price apart from the generating employment of 100 million man-days at the farm and industrial sectors.

Maize needs large amounts of nutrients from the soil due to high grain and stover yields. There is a possibility of nutrient mining from the soil if fertilizers are not added as per the requirements for higher target yield of maize. Intensification of maize will therefore need nutrient management that produces high yields, also

preserving soil fertility and the environment. Fertilizer recommendations for crops in the region are usually done over large geographical areas that often fail to meet the demand of high yielding crops like maize.

Among the several approaches of soil test based fertilizer recommendation, Site Specific Nutrient Management (SSNM) and Soil Test Crop Response (STCR) approach provide principles and tools for supplying crop nutrients as and when needed to achieve higher yield and are cost effective and plant need based approaches with specific yield target. Besides, these approaches, increases nutrient use efficiency, thus resulting in more net returns per unit of fertilizer applied.

The disposal of waste water is another major problem faced by Agro based industries, due to generation of high volume of effluent under limited space for land based treatment and disposal. Waste water is also a resource that can be recycled for productive uses, since it contains nutrients that have the potential for use in agriculture, aquaculture and other activities. Keeping all the above relevant aspects in mind, the present field experiments was carried out to study the effect of different nutrient approaches under treated sugar mill effluent (TSME) irrigation on growth, yield and nutrient uptake by maize.

Material and Methods

A field experiment was conducted at M/s. Chamundeshwari Sugars Limited, Maddur taluk, Mandya district during *kharif* 2016. The pH of the soil was saline (8.20) and medium in available nitrogen (336 kg ha^{-1}), medium in available phosphorous (36 kg ha^{-1}) and high in available potassium (415 kg ha^{-1}). The experiment was laid out in RCBD having twelve treatments and replicated thrice. The treatments consisted of T_1: Fresh water + RDF, T_2: Fresh water +STCR approach for targeted maize yield of 120 q ha^{-1}, T_3: Fresh water + Soil test based NPK recommendation, T_4: Fresh water + SSNM for targeted yield of 120 q ha^{-1}, T_5: TSME + RDF, T_6: TSME+ STCR approach for targeted maize yield of 120 q ha^{-1}, T_7: TSME + Soil test based NPK recommendation, T_8: TSME + SSNM for targeted yield of 120 q ha^{-1}, T_9: TSME with amendment (Gypsum) + RDF, T_{10}: TSME with amendment (Gypsum) + STCR approach for targeted maize yield of 120 q ha^{-1}, T_{11}: TSME with amendment (Gypsum) + Soil test based NPK recommendation and T_{12}: TSME with amendment (Gypsum) + SSNM for targeted yield of 120 q ha^{-1}. Hema, the Maize hybrid was used in the study. Representative treated sugar mill effluent samples were collected from M/s. Chamundeshwari Sugars Limited, Maddur taluk, Mandya district . The samples were analyzed for various chemical properties.

The pH of treated sugar mill effluent was slightly alkaline in reaction (8.2). Electrical conductivity (894 µS/cm). The total N, P and K content was 3.88, 1.83 and 37.4 ppm, respectively. The Na and SO_4 concentration was 28 and 52 mg/l, respectively. The total suspended solids and dissolved solids (mg/l) was 30 and 650 mg/l. The chloride content of effluent was 92 mg/l. The values indicate that the parameters are well within the Karnataka state pollution control board (KSPCB) norms.

Five plants from net plot area were randomly selected and observations on growth and yield parameters were recorded at 30, 60 and 90 DAS (days after sowing) and at harvest. All the data pertaining to the present investigation were statistically analyzed as per the method described by Panse and Sukhatme (1967).

Results and Discussion

Plant height at harvest was significantly taller with TSME with gypsum + SSNM for targeted yield of 120 q $ha^{-1}$and it was found to be on par with TSME with gypsum + SSNM for targeted yield of 120 q ha^{-1} (216.1 and 209.3 cm, respectively). The minimum plant height was recorded with recommend dose of fertilizer with fresh water (176 cm) (Table 1).The improvement in plant height due to SSNM approach was due to adequate supply of nutrients to crop which helped in increasing various metabolic processes and optimum growth and reduction in the plant height can be attributed to inadequate supply of nutrients during the crop growth and development. The results are in conformity with the findings of Umesh (2008).

TABLE 1

Effect of different nutrient approaches under treated sugar mill effluent on growth of maize

Treatments	Plant height (cm)	Number of leaves per plant	Leaf area (cm^2) per plant	Total dry matter production (g)	SPAD value at 60 DAS
T_1: Fresh water +RDF	176.0	8.8	6876	282.8	40.7
T_2: Fresh water +STCR targeted yield 120q	187.1	11.0	8057	321.2	47.0
T_3: Fresh water + Soil test based (LMH)	182.1	9.4	7302	300.5	42.3
T_4: Fresh water + SSNM targeted yield 120q	191.0	11.2	8529	330.0	49.7
T_5: TSME+ RDF	185.1	9.1	7669	299.5	46.1
T_6: TSME+ STCR targeted yield 120q	200.0	11.5	8544	338.5	51.3
T_7: TSME+ Soil test based (LMH)	189.1	9.9	7965	311.8	47.0
T_8: TSME+ SSNM targeted yield 120q	203.3	11.5	8645	345.1	56.0
T_9: TSME + Gypsum + RDF	191.2	11.0	8058	317.7	51.0
T_{10}: TSME + Gypsum + STCR targeted yield 120q	209.3	12.2	8834	357.5	57.1
T_{11}: TSME +Gypsum + Soil test based (LMH)	193.9	11.4	8741	322.6	52.3
T_{12}: TSME +Gypsum + SSNM targeted yield 120q	216.1	12.8	9091	366.3	61.6
S.Em±	2.36	0.26	129.7	6.64	1.8
CD @ 5%	7.10	0.8	389.0	19.92	5.3

The number of leaves per plant (12.8), leaf area per plant (9091 cm^2), and total dry matter production (366.3 g) of maize was significantly higher with application of nutrients based on SSNM for a target yield of 120 q ha^{-1}along with TSME + gypsum and it was at par with STCR target yield of 120 q ha^{-1}along with TSME + gypsum (209.3 cm, 12.2, 8834 cm^2, 357.5 g and 57.1, respectively) (Table 1). Target yield approaches recorded significantly higher harvest index than other treatments. The higher dry matter was mainly due to more leaf area exposed to sunlight with which rapid photosynthetic rate helped accumulation of higher dry matter in plant. Similar results were reported by Arun kumar *et al.* (2007). The maximum number of green leaves per plant was observed with application of nutrients based on SSNM for a target yield of 120 q ha^{-1}along with TSME + gypsum.

Significantly higher yield parameters were obtained under TSME with gypsum + SSNM for targeted yield of 120 q ha^{-1} due to significantly higher yield attributing characters *viz.,* number of cobs $plant^{-1}$ (2.04), cob length (22.33 cm), cob girth (8.29 cm), number of kernels row^{-1} (33.4) and number of kernels cob^{-1} (594.6) that observed in this treatments compared to all the other treatments (Table 2). This might be due to greater availability and steady release of nutrients from the treated sugar mill effluent and readily available nutrients from inorganic fertilizers which enhanced the yield of the crop. These results are in conformity with the findings of Beg *et al.* (2010) who reported that sewage, paper mill and sugar mill effluents has resulted in increased grain yield of barley, wheat, oat, rice and fodder yield of *Pennisetum purpureum, Pennisetum americanum* and NB-2 and seed yield of brassica, respectively over recommended practice of fresh water irrigation. These findings are in accordance with those of Biradar *et al.* (2006) who observed that application of nutrient on the basis of SSNM principles resulted in significantly higher grain yields over farmer practice and recommended dose

TABLE 2

Effect of different nutrient approaches under treated sugar mill effluent on yield attributes of maize

Treatments	No. of cobs/plant	Cob length (cm)	Cob girth (cm)	No. of Kernels/row	No. of Kernels/cob
T_1: Fresh water +RDF	1.17	12.55	6.21	23.5	289.4
T_2: Fresh water +STCR targeted yield 120q	1.58	14.59	6.66	26.7	406.4
T_3: Fresh water + Soil test based (LMH)	1.36	13.18	6.40	25.3	337.2
T_4: Fresh water + SSNM targeted yield 120q	1.74	15.07	7.08	27.1	411.8
T_5: TSME+ RDF	1.64	14.85	7.20	26.8	337.2
T_6: TSME+ STCR targeted yield 120q	1.75	18.07	7.78	28.3	446.4
T_7: TSME+ Soil test based (LMH)	1.57	16.33	7.76	27.8	391.4
T_8: TSME+ SSNM targeted yield 120q	1.89	18.92	8.13	29.0	489.5
T_9: TSME + Gypsum + RDF	1.81	19.66	7.35	30.0	475.7
T_{10}: TSME + Gypsum + STCR targeted yield 120q	2.00	21.37	8.10	32.9	568.0
T_{11}: TSME +Gypsum + Soil test based (LMH)	1.83	19.33	7.63	30.7	497.5
T_{12}: TSME +Gypsum + SSNM targeted yield 120q	2.04	22.33	8.29	33.4	594.6
S.Em±	0.03	0.30	0.09	1.13	11.03
CD @ 5%	0.09	1.00	0.26	3.40	33.10

of fertilizers. These results are also in conformity with the findings of Kumar *et al.* (2012). The number of grains per cob differed significantly due to application of nutrients through SSNM followed by STCR approach over absolute control and farmers practice. This could be ascribed to significant difference in the number of grains per cob of maize obtained by higher amounts of nutrients supplied through targeted yield approaches.

In the present study, maize grain yield differed significantly with the use of treated sugar mill effluent (TSME), soil amendment and different nutrient management approaches. TSME with gypsum + SSNM for targeted yield of 120 q ha^{-1} significantly recorded higher seed yield (124.4 q ha^{-1}) and was on par with TSME with gypsum + STCR for targeted yield of 120 q ha^{-1} (123.2 q ha^{-1}) compared to recommended dose of fertilizer (RDF) with fresh water (81.4 q ha^{-1}) (Table 3). Significant increase in the yield and yield components with the application of nutrients through SSNM/STCR was due to supply of balanced nutrients that in turn contributed to better translocation of photosynthates from source to sink and higher growth parameter such as like higher number of leaves and dry matter production and its accumulation in different parts of plant and yield attributing characters. Further, higher yield can be attributed to the ability of targeted yield approaches to satisfy the nutrient demand of crop more efficiently and the increase in yield was due to use of treated sugar mill effluent. Since, TSME is rich source of macronutrients. The results clearly indicates that, application of fertilizers based on site specific nutrient management amended with gypsum along with treated sugar mill effluent gave higher productivity compared

TABLE 3

Effect of different nutrient approaches under treated sugar mill effluent on yield of maize

Treatments	Grain yield (qha^{-1})	Stover yield (qha^{-1})	Harvest index
T_1: Fresh water +RDF	81.4	138.2	0.36
T_2: Fresh water +STCR targeted yield 120q	119.6	175.6	0.40
T_3: Fresh water + Soil test based (LMH)	87.6	145.4	0.37
T_4: Fresh water + SSNM targeted yield 120q	120.4	179.5	0.40
T_5: TSME+ RDF	86.4	145.6	0.36
T_6: TSME+ STCR targeted yield 120q	122.1	182.6	0.40
T_7: TSME+ Soil test based (LMH)	91.4	150.6	0.36
T_8: TSME+ SSNM targeted yield 120q	122.9	189.2	0.39
T_9: TSME + Gypsum + RDF	88.7	159.0	0.35
T_{10}: TSME + Gypsum + STCR targeted yield 120q	123.2	191.4	0.40
T_{11}: TSME +Gypsum + Soil test based (LMH)	92.7	160.5	0.36
T_{12}: TSME +Gypsum + SSNM targeted yield 120q	124.4	193.0	0.40
S.Em±	0.43	0.37	0.01
CD @ 5%	1.30	2.1	0.02

to soil test based fertilizer application and RDF with fresh water.

The data pertaining to total nitrogen, phosphorus and potassium uptake by maize differed significantly due to different nutrient management approaches and soil amended with gypsum under treated sugar mill effluent irrigation compared to RDF irrigated with fresh water (Table 4). Significantly higher total nitrogen, phosphorus and potassium uptake was noticed by the maize crop in the treatment receiving fertilizer recommendation based on SSNM concept for targeted yield of 120 q ha^{-1} with TSME irrigation recorded significantly higher yield (338.0, 71.3 and 223.0 kg ha^{-1}) and it was on par with STCR through fertilizers for targeted yield of 120 q ha^{-1} (321.0, 66.2 and 219.0 kg ha^{-1}) amended with gypsum under TSME. It was followed by soil test based fertilizer recommendation under TSME with gypsum (259.5, 56.6 and 176.5 kg ha^{-1}). Significantly lower total nitrogen uptake was observed in RDF with fresh water (202.1, 38.7 and 139.1 kg ha^{-1}). Site specific fertilizer recommendation could primarily be attributed to a balanced application of nutrients in relation to targeted yield. This clearly explains how SSNM helped in promoting balanced use and uptake of all the essential nutrients required for targeted yield thereby improving yields and optimizing nutrient use in the groundnut crop. Anand *et al.,* 2017, who also repoted that, the performance of RDF with fresh water is significantly lower compared to SSNM treatments. Increased total phosphorus uptake was with application of sugar mill effluent which could be attributed to conversion of fixed phosphorus into readily available form by organic acids released during decomposition of sugar mill effluent and consequent improvement in the available P in soil. The results corroborate with the findings of Kumar and Chopra (2013) who found that 40 per cent of sugar mill effluent irrigation caused better crop growth parameters in sorghum. It was ascribed to

TABLE 4

Effect of different nutrient approaches under treated sugar mill effluent on nutrient uptake of maize

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1: Fresh water +RDF	199.0	33.1	122.6
T_2: Fresh water +STCR targeted yield 120q	279.0	51.2	195.0
T_3: Fresh water + Soil test based (LMH)	225.1	41.2	141.7
T_4: Fresh water + SSNM targeted yield 120q	298.2	58.7	203.0
T_5: TSME+ RDF	221.3	37.4	141.0
T_6: TSME+ STCR targeted yield 120q	301.2	61.2	206.0
T_7: TSME+ Soil test based (LMH)	246.2	47.3	156.0
T_8: TSME+ SSNM targeted yield 120q	319.2	65.4	217.0
T_9: TSME + Gypsum + RDF	232.0	41.2	151.0
T_{10}: TSME + Gypsum + STCR targeted yield 120q	321.0	66.2	219.0
T_{11}: TSME +Gypsum + Soil test based (LMH)	256.0	52.4	164.0
T_{12}: TSME +Gypsum + SSNM targeted yield 120q	338.0	71.3	223.0
S.Em±	6.20	1.72	1.89
CD @ 5%	18.6	5.16	5.66

maximum uptake of nitrogen, phosphorus and potassium by plants. Site specific nutrient management recorded higher uptake of potassium by maize as compared to recommended dose of fertilizer. Sufficient quantity of nutrient applied under site specific nutrient management might have helped in higher amount of nutrient uptake by the crop in accordance with the potential of the crop and genotype whereas imbalanced and under nutrition of the crops under farmers practice resulted in lower nutrient uptake (Biradar *et al*., 2012).

The present study concluded that, treatment receiving fertilizer recommendation based on SSNM/STCR for targeted yield of 120 q ha^{-1} amended with gypsum under treated sugar mill effluent irrigation increased growth, yield and yield components of maize due to available nutrients to the maize crop. Higher growth rate and yield of maize was obtained in irrigation with treated sugar mill effluent compared to irrigation with fresh water due to rich nutrients and organic matter.

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