EFFECT OF ZEOLITE ON SUGARCANE GROWTH, YIELD AND JUICE QUALITY OF SUGARCANE IN WATER STRESS CONDITION

ABSTRACT

Soil moisture and nitrogen (N) are two of the most important factors affecting the production of crop. Zeolites, which are environmental friendly, ubiquitous, and inexpensive, have been extensively used in agricultural activities. These minerals are considered as soil soil conditioners to improve soil properties. In order to study the effect of zeolite on sugarcane Zeolite @ 75 and 100 kg/ha was applying at the time of planting with fertilizer dose with 100, 75 & 50% irrigation in a randomized block design was carried out with three replications in 2017-18 to 2020-21. The cane yield, CCS% no. of milliable cane, milliable cane height, girth, internode, soil macronutrients, uptake of nutrients, water use efficiency and economic profitability was highest in treatment receiving the application of RDF + 100 kg/ha zeolite + 100% irrigation followed by treatment with RDF + 100 kg/ha zeolite + 75% irrigation. Therefore, zeolite application improves both sugarcane growth and water use efficiency (WUE).

Keywords: Zeolite, soil properties, sugarcane growth, yield

INTRODUCTION

Sugarcane is the most important cash crop of Maharashtra. Sugarcane being a long duration and huge biomass producing crop removes substantial amount of plant nutrients from the soil. Higher sugarcane production needs higher amount of plant nutrients. Soil is one of the most important environmental factors and is considered the main source in providing essential sugarcane nutrients, water reserves and a medium for sugarcane growth.

Soil nutrient lost mainly through the runoff many nutrients are dissolving in rain water or lost. The rate of soil loss is 16.4tonnes/hectare every year, (CSWCTRI), Dehradun. Mainly N, Ca, P, Mg, K and organic matter can be lost from agriculture land through soil erosion. Manure and fertilizer can help to protect against nutrient loss low through erosion or runoff. In Maharashtra about 7 lakh ha. soils are degraded due to salinity and alkalinity. Therefore, in this type of soil, fertilizer use efficiency decrease and decrease the sugarcane yield.

Water is one of the most limiting factors in crop production worldwide (Sankar *et. al.,* 2007, AL-Busaidi*et. al.,* 2011). It is also one of the main factors affecting plant growth and development as well as morphological and physiological adaption to environmental condition. It has been reported that crop yield, especially in arid and semi-arid regions, strongly correlates water availability and seasonal changes (Cousins and Witkowski, 2012) Ghanbari and Ariafar, (2013) indicates that natural zeolite may represent an important alternative to reduce the effect of drought in arid and semi-arid regions. Zeolite are natural or artificial crystalline aluminosilicates exhibiting an open, highly porous structure containing cations balancing high electrostatic charge of the framework of silica and alumina tetrahedral units. The internal surface area of the zeolite framework can reach as many as several hundred square meters per gram (Yates *et. al.,* 1968). Zeolite as nutrient additives helps in enhancing nutrient use efficiency (Kavvadias *et. al.,* 2019) and water use efficiency (Ozbahce*et. al.,* 2014) by improving the physical and chemical properties of soil. Its use in agriculture is called as rock farming.

Utilization of zeolites in agriculture is possible because of their special cation exchange properties, molecular sieving and desorption (Hecl and Toth, 2009). It is believed that because zeolites have the ability to lose and gain water reversibly, without the change of crystal structure, they could be used as fertilizers, stabilizers and chelators. As an example, a study has shown that zeolites enable both inorganic and organic fertilizers to slowly release their nutrients (Perez-Caballero *et al.,* 2008).

Hence, the present study was undertaken to study the effect of zeolite application with recommended dose of nitrogen, phosphorus and potassium on water stress condition, soil nutrients, yield and quality parameters of sugarcane in suru season.

MATERIALS AND METHODOLOGY

Characterization of zeolite

The zeolite used in this study was procured from Tanniishk minerals and exporter, Sirohi (Rajasthan) India. The properties of zeolite were analysed using standard methods viz., pH (Jackson, 1973), EC (Jackson, 1973) CEC (Jackson, 1973), Ca (Piper, 1966), Mg (Piper, 1966), S (Piper, 1966), N (Piper, 1966), P (Piper, 1966), K (Piper, 1966), Fe, Mn, Zn, and Cu (Lindsay&Norvell, 1978) and physical properties like maximum water holding capacity (Keen and Roczkowski, 1921), porosity (Gupta and Dhakshinamurthi, 1980).

Site and Experimental details

Field experiment on effect of zeolite on sugarcane growth, yield and juice quality of sugarcane in water stress condition was conducted during 2017-18 to 2020-21 at Vasantdada Sugar Institute, Manjari (Bk.), Pune (MH).The soil of the experimental site was medium black soil, low in organic carbon (0.66%) and available N, medium in available P and high available K (Table 2). The experiment was laid out in randomized block design with three replication and variety VSI 08005. Zeolite @ 75 and 100 kg/ha was applying at the time of planting with fertilizer dose (Table 1).

Prepared irrigation schedule (Table 3) on the basis of season and days of interval for irrigation to sugarcane. Initial and post-harvest soil samples (0-22 cm) were collected from experimental plots, and were ground to pass through a 2 mm sieve. The soil samples were analyzed for determination of soil pH and electrical conductivity 1:2.5 soil: water suspensions. Organic C (Walkley and Black method), Available N (Potassium permanganate ($KMnO_4$) method), Available P determined by 0.5 M sodium bicarbonate ($NaHCO_3$, pH 8.5) and Available K determined by 1N ammonium acetate (NH_4OAC), following Jackson (1973).

The field observations of biometric, growth and yield parameters were taken at different stages of the crop and at harvest. Sugarcane juice quality for brix and pol percentage was analyzed by using ICUMSA methods. The field and laboratory analysis data was statistically analyzed by methods of Gomez and Gomez (1984).

ZEOLITE CHARACTERIZATION

The data on the characteristics of zeolite used in the experiment are presented in Table 4. The zeolite characterized for physical properties maximum water holding capacity and porosity of zeolite was 88.65% and 69.68% respectively. The zeolite had pH of 7.52 that is slightly alkaline in nature and electrical conductivity 0.59 dS^{-1}. The nitrogen, phosphorous and potassium content of zeolite were 0.16, 0.19, and 0.81 percent respectively. The higher water holding capacity (88.65%) was found might be due to lower bulk density. Similar, results were observed by Shivakumara*et al*., 2019. The secondary nutrients like Calcium, Magnesium and Sulphur content of zeolite were 2.17, 0.20, and 0.23 percent respectively. The micronutrients like Fe, Mn, Cu and Zn were 36.90, 11.88, 15.42, 32.40 mg kg^{-1} respectively. Among the micronutrients, Fe recorded higher concentration compared to other treatments might be due to the nature of origin of zeolite mineral, since zeolites were generally originated from volcanic ash that contains higher concentration of acidic minerals containing iron (Mohammadi&Shadparvar, 2013).

RESULTS AND DISCUSSION

Cane yield:

Data of cane yield influenced by zeolite on sugarcane was presented in Table 5. Maximum cane yield (119.68 t ha^{-1}) obtained where applied 100% recommended dose of fertilizer and 100 kg zeolite with 100% irrigation followed by (117.89 t ha^{-1}) where applied 100% recommended dose of fertilizer and 100 kg/ha zeolite with 75% irrigation (Table 4). In organic and organic fertilizer along with zeolite showed higher fertilizer use efficiency because of less leaching of these nutrients and helps to retain nutrients in root zone by enhancing nutrients absorption. Therefore, higher productivity of the cane and sugar depends on the proper management of the crop including application of chemical fertilizer with zeolite at appropriate rate and time. Similar results by Ahmad, 2010 and Zheng *et al*., (2018).

Commercial Cane Sugar Yield:

The data on Commercial Cane Sugar Yield showed that there was significant increase in CCS yield (18.9 t ha^{-1}) whereas applied RDF along with zeolite @100 kg ha^{-1} and 100% irrigation followed by 18.5 t ha^{-1} where soil application of 100 kg ha^{-1} zeolite with 75% irrigation was found significantly superior over recommended dose of fertilizer (16.6 t ha^{-1}) (Table 6). Rabai *et al.,* 2013 reported that zeolites used as a slow plant –nutrient fertilizer and soil conditioner and can also be used to retain water and nitrogen in near-surface soil layer.

No of milliable cane (‘000 ha)

The data on no of milliable cane (‘000 ha) showed that highest plant population (66.1 thousand ha^{-1}) was recorded where applied RDF along with zeolite @ 100 kg ha^{-1} and 100% irrigation followed by (63.5 thousand ha^{-1}) where applied RDF along with zeolite @ 100 kg ha^{-1} with 75% irrigation was found significantly superior over RDF (58.0 thousand ha^{-1}) (Table 7).

Yield contributing parameter

The data on growth observation showed in Table 7. The maximum milliable cane height (243.7 cm), cane girth (9.60 cm) was significantly increased where applied RDF with 100 kg ha^{-1} zeolite and 100% irrigation followed cane height 241.6 cm and cane girth 9.45 cm where applied zeolite @ 100 kg ha^{-1} with RDF and 75% irrigation was significantly superior over recommended dose of fertilizer (cane height 223.7 cm and cane girth 8.94 cm) (Table 7). The juice quality parameter viz., CCS % showed that cane juice quality was not affected by different zeolite application with recommended dose of fertilizer.

Economics and profitability

The data presented in table 7. Showed the highest benefit cost ratio (2.99) where application of zeolite @ 100 kg ha^{-1} with 100% irrigation and RDF followed by 2.98 where application o zeolite @ 100 kg ha^{-1} with 75% irrigation with RDF (Table8).

Soil moisture

The data one week after planting showed highest soil moisture before irrigation, 5th day after irrigation and one day before next irrigation in treatment where application of RDF + 100 kg/ha zeolite along with 75% irrigation (26.43, 42.26 & 26.97 % respectively) over RDF (Figure 1).

After 120 days after planting showed the highest soil moisture before irrigation, 5th day after irrigation and one day before next irrigation in treatment T4 where application of RDF + 100 kg/ha zeolite along with 100% irrigation (28.60, 38.69, 28.84 % respectively) followed by treatment T6 where application of RDF + 100 kg/ha zeolite with 75% irrigation (28.34, 35.10 &25.18% respectively) over FDF (25.79, 28.87 & 17.22 % respectively) (Figure 1). Zeolite has a high porosity of the crystalline structure and may hold water up to 60 % of their weight (Pol *et al*., 2004). The combination of RDF & zeolite application increased soil moisture by 6 to 7 % (weight basis) on average as compared with RDF. The effects on water retention of increasing rates of zeolite were determined in figure 1. This finding reveals that more water was being retained in the pore spaces of the 100 kg/ha zeolite mixed with RDF thus improving soil potential to support crop growth. This result is similar with the findings of Ippolito *et. al.,*2011.

Soil Macronutrients

The on soil properties showed in figure 2, illustrated that soil available nitrogen showed the highest in treatment with the application of RDF + zeolite @ 100 kg/ha +100% irrigation (251.5 kg ha^{-1}) followed by T3 – RDF + zeolite @ 75 kg/ha + 100% irrigation (243.1 kg ha^{-1}), T6 – RDF + zeolite @ 100 kg/ha +

75% irrigation (244.4 kg ha^{-1}) & T8 – RDF + zeolite @ 100 kg/ha + 50% irrigation (241.6 kg ha^{-1}) treatment over RDF (220.0 kg ha^{-1}).

Highest soil available phosphorous showed in treatment T4- RDF + zeolite @ 100 kg/ha +100% irrigation (39.6 kg ha^{-1}) followed by treatment T5, T6, T7 & T8 over RDF. The soil available potassium showed highest in RDF + zeolite @ 100 kg/ha + 100% irrigation treatment (812.9 kg ha^{-1}) followed by treatment-T3 RDF + zeolite @ 75 kg/ha + 100% irrigation (801.2 kg ha^{-1}) & T6- RDF + zeolite @ 100 kg ha +75% irrigation (794.6 kg ha^{-1}). This Figure 2 showed the available N, P, & K content is higher in all the treatment where zeolite 100 kg ha^{-1} and 75 kg ha^{-1} applied with 100 and 75% irrigation. This might be due to zeolite role in improving soil fertility and increasing the availability of nutrient element or due to beneficial effect of zeolite in improving soil characteristics. These similar results were obtained by Tohidi-Moghadam *et al.,* (2009).

Uptake of nutrients

The data on uptake of nutrients Table 9. Showed that nitrogen uptake highest in RDF + Zeolite @ 100 kg/ha + 100% irrigation (286.90, kg ha^{-1} respectively), followed by RDF + Zeolite @ 100 kg/ha + 75% irrigation (279.78 kg ha^{-1}). Application of zeolite reduced the leaching rate of soil N, which increased the rate of plant uptake and thus increased the efficiency of N and uptake (Hazrati *et al.,* 2022).

Phosphorous uptake highest in RDF + Zeolite @ 100 kg/ha + 100% irrigation (30.75kg ha^{-1}) followed by T3, T5, T6, T7 & T8 treatment. Absorption of phosphorous is moisture. With increasing soil moisture, phosphorous uptake by plants generally increases, the reason of which is higher solubility of phosphorous and further development of the root caused by moisture (Misra, 2003) and potassium uptake was highest in RDF + Zeolite @ 100 kg/ha + 100% irrigation over all the treatments (161.99kg ha^{-1}).

Water use efficiency

Wateruse efficiency affected by water stress and zeolite application. The highest water use efficiency was obtained in treatment RDF + Zeolite @100 kg/ha + 100 % (0.33 t/ha cm^{-1}) (Table 10).

Conversely, the lowest value was recorded absolute control. Generally, water use efficiency increased with increasing water stress intensity and zeolite applied. Water use efficiency is depending on yield and water requirement of crop. In this study, zeolite increased water use efficiency so that the highest value was obtained in RDF + Zeolite @100 kg/ha + 100 % irrigation. From the table 9 it can be concluded that under water stress, the application of zeolite could increase the WUE with the application of 100% RDF. It can be concluded that since zeolite is among the group of natural porous mineral with their crystalline structure can to open channels in their network, and allow some ions to pass through and block the passage of some other ions. Zeolite is able to absorb water up to 70% of its volume, which is due to its high porosity that originates from its crystalline structure (De Smedt *et al.,* 2017; Kennedy,2020).

CONCLUSION

Application of zeolite @ 100 kg ha^{-1} along with 75% irrigation and recommended dose of fertilizer increased cane yield by 11 t ha^{-1}, sugar yield 1.76 t ha^{-1} and also saves six irrigations. The study clearly emphasis that application of zeolite with fertilizer would be an important component for water retention and availability of nutrients.

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Table 1. Treatment details

T1	:	Absolute control
T2	:	RDF
T3	:	RDF + Zeolite @ 75 kg /ha + 100 % Irrigation (21 irrigation)
T4	:	RDF + Zeolite @ 100 kg /ha + 100 % Irrigation (21 irrigation)
T5	:	RDF + Zeolite @ 75 kg /ha + 75 % Irrigation (15 irrigation)
T6	:	RDF + Zeolite @ 100 kg /ha + 75 % Irrigation (15 irrigation)
T7	:	RDF + Zeolite @ 75 kg /ha + 50 % Irrigation (10 irrigation)
T8	:	RDF + Zeolite @ 100 kg /ha + 50 % Irrigation (10 irrigation)

Table2. Initial properties of soil

Soil properties	Values
pH	8.22
EC (dS m^{-1})	0.15
Organic carbon (%)	0.66
Available Nitrogen (kg ha^{-1})	188.20
Available Phosphorous (kg ha^{-1})	19.60
Available Potassium (kg ha^{-1})	375.20

Table 3. Irrigation Schedule on the basis of season and days of interval

Season	Irrigation Schedule		
	100 %	75 %	50 %
Rainy (Jun., July. Aug., Sep.)	25	37	50
Winter (Oct., Nov., Dec., Jan.)	20	30	40
Summer (Feb., Mar., April. May.)	12	18	24
Total irrigation	21	15	10

Table 4. Characterization of Zeolite

Parameter	Values
pH	7.32
EC (dS m^{-1})	0.59
Nitrogen (%)	0.16
Phosphorus (%)	0.19
Potassium (%)	0.81
Calcium (%)	2.17
Magnesium (%)	0.20
Sulphur (%)	0.23
Fe (mg kg^{-1})	36.90
Mn (mg kg^{-1})	11.88
Cu(mg kg^{-1})	15.42
Zn(mg kg^{-1})	32.4
CEC (cmol (p^{+}) kg)	175
MWHC	88.65
Porosity (%)	69.68

Table 5. Effect of zeolite on cane yield in water stress condition

Treatment	Cane yield t ha^{-1}			
	Plantcane I	Ratoon	Plantcane II	Pooled mean
T1 - Absolute control	99.97	84.77	97.90	94.21
T2 - RDF	113.03	100.34	108.47	107.28
T3 - RDF + Zeolite @ 75 kg /ha + 100 % Irrigation	120.97	108.26	114.43	114.55
T4 - RDF + Zeolite @ 100 kg /ha + 100 % Irrigation	126.03	114.67	121.33	120.68
T5 - RDF + Zeolite @ 75 kg /ha + 75 % Irrigation	118.50	104.14	112.47	111.70
T6 - RDF + Zeolite @ 100 kg /ha + 75 % Irrigation	124.33	110.82	120.17	118.44
T7 - RDF + Zeolite @ 75 kg /ha + 50 % Irrigation	115.67	101.61	110.77	109.35
T8 - RDF + Zeolite @ 100 kg /ha + 50 % Irrigation	118.47	104.43	112.50	111.80
SE CD %	3.56 10.82	3.38 10.27	3.83 11.62	2.67 8.11

Table 6. Effect of zeolite on CCS yield in water stress condition

Treatment	CCS yield (t ha^{-1})			
	Plantcane I	Ratoon	Plantcane II	Pooled mean
T1 - Absolute control	14.6	14.3	16.3	15.1
T2 - RDF	16.4	16.4	17.0	16.6
T3 - RDF + Zeolite @ 75 kg /ha + 100 % Irrigation	18.3	17.4	18.3	18.0
T4 - RDF + Zeolite @ 100 kg /ha + 100 % Irrigation	19.4	18.3	19.0	18.9
T5 - RDF + Zeolite @ 75 kg /ha + 75 % Irrigation	17.7	16.9	18.0	17.5
T6 - RDF + Zeolite @ 100 kg /ha + 75 % Irrigation	18.7	17.9	18.9	18.5
T7 - RDF + Zeolite @ 75 kg /ha + 50 % Irrigation	17.2	16.8	18.4	17.5
T8 - RDF + Zeolite @ 100 kg /ha + 50 % Irrigation	17.5	17.2	18.4	17.7
SE CD %	0.50 1.52	0.32 0.98	0.45 1.39	0.22 0.68

Table 7. Effect of zeolite on growth observation of zeolite

Treatment	No. of milliable cane ('000')ha	Milliable cane height (cm)	Internode	Girth (cm)	CCS %
T1 - Absolute control	55.7	216.3	17.3	8.52	15.6
T2 - RDF	58.0	223.7	19.0	8.94	16.2
T3 - RDF + Zeolite @ 75 kg /ha + 100 % Irrigation	62.7	237.7	20.7	9.12	16.0
T4 - RDF + Zeolite @ 100 kg /ha + 100 % Irrigation	66.1	243.7	21.0	9.60	16.4
T5 - RDF + Zeolite @ 75 kg /ha + 75 % Irrigation	57.7	234.4	21.0	9.19	16.2
T6 - RDF + Zeolite @ 100 kg /ha + 75 % Irrigation	63.5	241.6	21.3	9.45	16.4
T7 - RDF + Zeolite @ 75 kg /ha + 50 % Irrigation	54.0	226.9	20.0	8.85	16.5
T8 - RDF + Zeolite @ 100 kg /ha + 50 % rrigation	55.0	229.7	20.0	8.96	16.4
SE CD %	1.80 5.48	2.27 6.91	1.28 NS	0.26 NS	0.21 0.66

Table 8. Effect of zeolite on economic evaluation

Treatment	B:C ratio
T1 - Absolute control	2.95
T2 - RDF	2.70
T3 - RDF + Zeolite @ 75 kg /ha + 100 % Irrigation	2.85
T4 - RDF + Zeolite @ 100 kg /ha + 100 %Irrigation	2.99
T5 - RDF + Zeolite @ 75 kg /ha + 75 % Irrigation	2.81
T6 - RDF + Zeolite @ 100 kg /ha + 75 % Irrigation	2.96
T7 - RDF + Zeolite @ 75 kg /ha + 50 % Irrigation	2.78
T8 - RDF + Zeolite @ 100 kg /ha + 50 % Irrigation	2.83

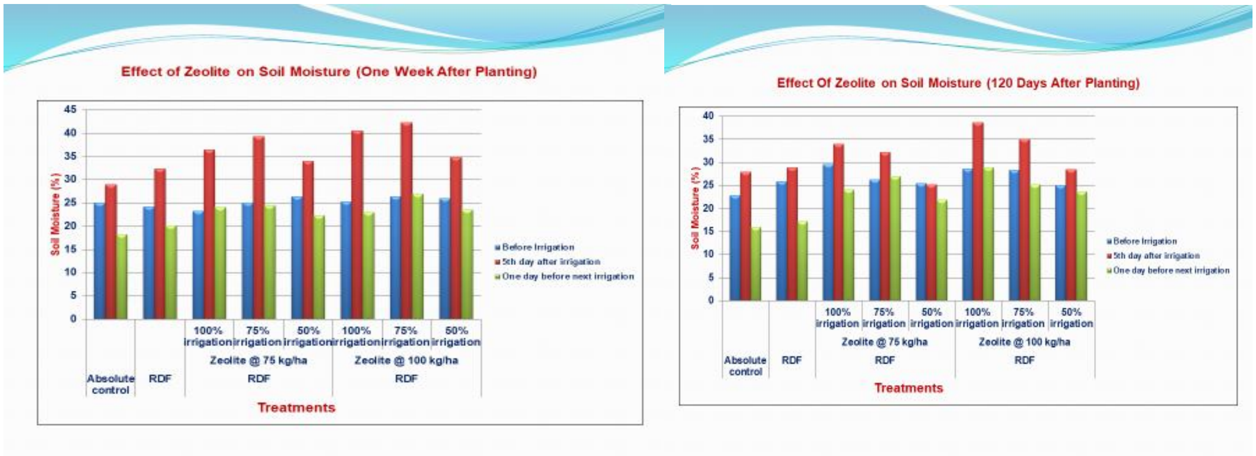
Table 9. Effect of zeolite on uptake of plant nutrients

Treatment	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
T1 - Absolute control	198.23	16.71	84.03
T2 - RDF	224.32	20.57	113.45
T3 - RDF + Zeolite @ 75 kg/ha + 100% irrigation	269.57	28.48	140.04
T4 - RDF + Zeolite @ 100 kg/ha + 100% irrigation	286.90	30.75	161.99
T5 - RDF + Zeolite @ 75 kg/ha + 75% irrigation	265.03	27.91	136.75
T6 - RDF + Zeolite @ 100 kg/ha + 75% irrigation	279.78	31.25	152.01
T7 - RDF + Zeolite @ 75 kg/ha + 50% irrigation	260.80	26.22	141.46
T8 - RDF + Zeolite @ 100 kg/ha + 50% irrigation	264.50	27.47	147.61
SE CD %	5.61 17.03	2.35 7.15	4.29 13.01

Table 10. Effect of zeolite on water use efficiency

Treatment	Cane yield t ha^{-1}	Water requirement (ha cm)	Water use efficiency (t/ha cm^{-1})
T1 - Absolute control	94.21	300	0.27
T2 - RDF	107.28	300	0.30
T3 - RDF + Zeolite @ 75 kg/ha + 100% irrigation	114.55	300	0.32
T4 - RDF + Zeolite @ 100 kg/ha + 100% irrigation	120.68	300	0.33
T5 - RDF + Zeolite @ 75 kg/ha + 75% irrigation	111.70	200	0.31
T6 - RDF + Zeolite @ 100 kg/ha + 75% irrigation	118.44	200	0.32
T7 - RDF + Zeolite @ 75 kg/ha + 50% irrigation	109.35	150	0.30
T8 - RDF + Zeolite @ 100 kg/ha + 50% irrigation	111.80	150	0.31

Figure 1. Effect of zeolite on soil moisture (%)



One week after planting 120 Days after planting

Figure 2. Effect of zeolite on soil macronutrients