

## 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

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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-Busaidiet. *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 (Ozbahceet. *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 Roczowski, 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<sub>4</sub>) method), Available P determined by 0.5 M sodium bicarbonate (NaHCO<sub>3</sub>, pH 8.5) and Available K determined by 1N ammonium acetate (NH<sub>4</sub>OAC), 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<sup>-1</sup>. 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<sup>-1</sup> 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<sup>-1</sup>) obtained where applied 100% recommended dose of fertilizer and 100 kg zeolite with 100% irrigation followed by (117.89 t ha<sup>-1</sup>) 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<sup>-1</sup>) whereas applied RDF along with zeolite @100 kg ha<sup>-1</sup> and 100% irrigation followed by 18.5 t ha<sup>-1</sup> where soil application of 100 kg ha<sup>-1</sup> zeolite with 75% irrigation was found significantly superior over recommended dose of fertilizer (16.6 t ha<sup>-1</sup>) (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<sup>-1</sup>) was recorded where applied RDF along with zeolite @ 100 kg ha<sup>-1</sup> and 100% irrigation followed by (63.5 thousand ha<sup>-1</sup>) where applied RDF along with zeolite @ 100 kg ha<sup>-1</sup> with 75% irrigation was found significantly superior over RDF (58.0 thousand ha<sup>-1</sup>) (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<sup>-1</sup> zeolite and 100% irrigation followed cane height 241.6 cm and cane girth 9.45 cm where applied zeolite @ 100 kg ha<sup>-1</sup> 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<sup>-1</sup> with 100% irrigation and RDF followed by 2.98 where application o zeolite @ 100 kg ha<sup>-1</sup> with 75% irrigation with RDF (Table8).

### **Soil moisture**

The data one week after planting showed highest soil moisture before irrigation, 5<sup>th</sup> 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, 5<sup>th</sup> 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<sup>-1</sup>) followed by T3 – RDF + zeolite @ 75 kg/ha + 100% irrigation (243.1 kg ha<sup>-1</sup>), T6 – RDF + zeolite @ 100 kg/ha +

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

Highest soil available phosphorous showed in treatment T4- RDF + zeolite @  $100 \text{ kg/ha}$  +100% irrigation ( $39.6 \text{ kg ha}^{-1}$ ) followed by treatment T5, T6, T7 & T8 over RDF. The soil available potassium showed highest in RDF + zeolite @  $100 \text{ kg/ha}$  + 100% irrigation treatment ( $812.9 \text{ kg ha}^{-1}$ ) followed by treatment-T3 RDF + zeolite @  $75 \text{ kg/ha}$  + 100% irrigation ( $801.2 \text{ kg ha}^{-1}$ ) & T6- RDF + zeolite @  $100 \text{ kg ha}$  +75% irrigation ( $794.6 \text{ kg ha}^{-1}$ ). This Figure 2 showed the available N, P, & K content is higher in all the treatment where zeolite  $100 \text{ kg ha}^{-1}$  and  $75 \text{ kg ha}^{-1}$  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 @  $100 \text{ kg/ha}$  + 100% irrigation ( $286.90, \text{ kg ha}^{-1}$  respectively), followed by RDF + Zeolite @  $100 \text{ kg/ha}$  + 75% irrigation ( $279.78 \text{ kg ha}^{-1}$ ). 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 @  $100 \text{ kg/ha}$  + 100% irrigation ( $30.75 \text{ kg ha}^{-1}$ ) 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 @  $100 \text{ kg/ha}$  + 100% irrigation over all the treatments ( $161.99 \text{ kg ha}^{-1}$ ).

### **Water use efficiency**

Water use 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<sup>-1</sup>) (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<sup>-1</sup> along with 75% irrigation and recommended dose of fertilizer increased cane yield by 11 t ha<sup>-1</sup>, sugar yield 1.76 t ha<sup>-1</sup> 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.

## REFERENCES

- Ahmed, O. H. (2010) Selected growth variables, nutrient uptake, and yield of zeamaysl. Cultivated with cocomposted wastes. Retrieved from <http://www.upm.edu>.
- Al-Busaidi, A., Yamamoto, T., Tanigawa, T., Rahman, H.A., (2011) Use of zeolite to alleviate water stress on sub-surface drip irrigated barley under hot environments. *Irrigation Drainage* 60, 473-480.
- Cousins, S.R., Witkowski, E.T.F. (2012) African aloe ecology: A review. *J. Arid Environment* 85, 1-17.
- De Smedt, C., Steppe, K., Spanoghe, P., (2017). Beneficial effects of zeolites on plant photosynthesis. *Adv. Mater.* 2(1), 1-11. <https://doi.org/10.15761/ams.1000115>.
- Ghanbari M, Ariafar S. (2013) The effect of water deficit and zeolite application on growth traits and oil yield of medicinal peppermint (*Menthapiperita* L.) *International Journal of Medicinal and Aromatic Plants* 3(1): 33-39.15.
- Gomez, K.A. and Gomez, A.A. (1984) *Statistical Methods for Agricultural Research*. Technology and Engineering p704.
- Gupta, R.P., and Dhakshinamurthi, C. (1980). *Procedures for physical analysis of soils and collection of agrometeorological data* division of agricultural physics. IARI, New Delhi
- Hazrati, S. Khurizadeh, A.S., Sadeghi, E. (2022) Application of zeolite improves water and nitrogen use efficiency while increasing essential oil yield and quality of *Salvia officinalis* under water-deficit stress. *Saudi Journal of Biological Sciences* 29(3), 1707-1716.
- Hecl, J. and Toth, S. (2009) Effect of fertilizers and sorbents applied to the soil on heavy metal transfer from the soil. *Electron Journal of Polish Agricultural University* 12, 7-17.
- Ippolito, J.A., Tarkalson, D.D. and Lehrs, G.A. (2011) Zeolite Soil Application Method Affects Inorganic Nitrogen, Moisture, and Corn Growth. *Lippincott Williams & Wilkins* 176(3), 136-142.

- Jackson, M. L. (1979) Soil Chemical Analysis, Advanced Course, published by the author, University of Wisconsin, Madison, USA
- Jackson, M.L. (1973) Soil Chemical Analysis prentice Hall of India Pvt. Ltd. New Delhi.
- Kavvadias, V., Ioannou, Z., Katsaris, P., Kardimaki, A., Vavoulidou, E. and Theocharopoulos, S. (2019) Use of zeolites in Agriculture: Effect of addition of natural zeolite and clinoptilolite and compost on soil properties and crop development. In: *Soil amendments for sustainability challenges and perspectives*. Rakshit, A., Sarkar, B. and Abhilash, P. (Eds). CRC press, Taylor and Francis group, Boca Raton.
- Keens, B.A., and Raczowski, H. (1921). The relation between clay content and certain physical properties of soil. *Journal of Agricultural Sciences.*, 11, 441-449.
- Kennedy, (2020) Cation Exchange Modification of Clinoptilolite zeolite for Application in Nitrogen Rejection. <http://dx.doi.org/10.20381/ruor-24314>
- Lindsay, W.L. and Norvel, W.A. (1978) Development of DTPA soil test for Zn, Fe, Mn and Cu. *Soil Science Society of America*42, 421-428.
- Misra, A. (2003). Influence of water conditions on growth and mineral nutrient uptake of native plants on calcareous soil (Doctoral dissertation, Lund University).
- Mohammadi, T.A., and Shadparvar, V. (2013) Effect of some organic waste and zeolite on water holding capacity and PWP delay of soil. *Current Biotica*,6(4), 459-465.
- Ozbahce, A., Tari, A.F., Gonulal, E., Simsekli, N, Padem, H. (2014) The effect of zeolite applications on yield components and nutrient uptake of common bean under water stress. *Archives of Agronomy and Soil Sciences*, 61(5), 615-626.
- Perez-Caballero, R., Gil, J., Benitez, C., Gonzalez, J.L. (2008). The effect of adding zeolite to soils in order to improve the N-K nutrition of olive trees, preliminary results. *American Journal of Agricultural Biological Science* 2, 321-324.
- Piper, C.S. (1966) "Soil and plant analysis". Hans Publisher, Botany

- Polat, E. M., Karaca, M., Demir, H., Onus, A. N. (2004) Use of natural zeolite (clinoptilolite) in agriculture. *Journal of Fruit and Ornamental Plant Research*12(1), 183–189.
- Rabai, K. A., Ahmed, O. H., & Kasim, S. (2013) Use of formulated nitrogen, phosphorus, and potassium compound fertilizer using clinoptilolite zeolite in maize (*zea mays L.*) cultivation. *Emirates Journal of Food & Agriculture (EJFA)*, 25(9),713-722.doi:10.9755/ejfa.v25i9.14541.
- Snkar, B., Jaleel, C.A., Manivannan, P., Kishorekumar, A., Somasudaram, R., Panneerselvam, R., 2007. Drought-induced biochemical modification and proline metabolism in *Abelmoschus esculentus(L.)* Monech. *Acta Bot. Croat.*66, 43-56.
- Tohidi-Moghadam H.R, Shirani-Radl A.H, Nour Mohammadi G., Habibi D., ModarresSanavy S.A.M., Mashhadi-Akbar-Boojar M., and Dolatabadian A., (2009) Response of six oilseed rape genotypes to water stress and hydrogel application. *Pesquisa Agropecuária Tropical*39(3), 243-250.
- Yates, D.J.C. (1968) Studies on the surface area of the zeolites, as determined by physical adsorption and X-ray crystallography. *Can. J. Chem.* 64: 1695\_1701.doi:10.1139/v68-282.
- Zheng, H., Zhai, D., Zhao, L., Zhang, C., Yu, S., Gao, J., and Zu, C. (2018) "Insight into the Contribution of Isolated Mesopore on Diffusion in Hierarchical Zeolites: The Effect of Temperature", *Industrial and Engineering Chemistry Research* 57, 5453-546.

**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 <sup>-1</sup> )                     | 0.15   |
| Organic carbon (%)                           | 0.66   |
| Available Nitrogen (kg ha <sup>-1</sup> )    | 188.20 |
| Available Phosphorous (kg ha <sup>-1</sup> ) | 19.60  |
| Available Potassium (kg ha <sup>-1</sup> )   | 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 <sup>-1</sup> )        | 0.59   |
| Nitrogen (%)                    | 0.16   |
| Phosphorus (%)                  | 0.19   |
| Potassium (%)                   | 0.81   |
| Calcium (%)                     | 2.17   |
| Magnesium (%)                   | 0.20   |
| Sulphur (%)                     | 0.23   |
| Fe (mg kg <sup>-1</sup> )       | 36.90  |
| Mn (mg kg <sup>-1</sup> )       | 11.88  |
| Cu(mg kg <sup>-1</sup> )        | 15.42  |
| Zn(mg kg <sup>-1</sup> )        | 32.4   |
| CEC (cmol (p <sup>+</sup> ) 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 <sup>-1</sup> |        |              |             |
|--|-------------------------------|--------|--------------|-------------|
|  | 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   | 3.56                          | 3.38   | 3.83         | 2.67        |
| CD %   | 10.82                         | 10.27  | 11.62        | 8.11        |

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

| Treatment  | CCS yield (t ha <sup>-1</sup> ) |        |              |             |
|--|---------------------------------|--------|--------------|-------------|
|  | 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   | 0.50                            | 0.32   | 0.45         | 0.22        |
| CD %   | 1.52                            | 0.98   | 1.39         | 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 % Irrigation  | 55.0                           | 229.7                      | 20.0      | 8.96       | 16.4  |
| SE   | 1.80                           | 2.27                       | 1.28      | 0.26       | 0.21  |
| CD %   | 5.48                           | 6.91                       | NS        | NS         | 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      |

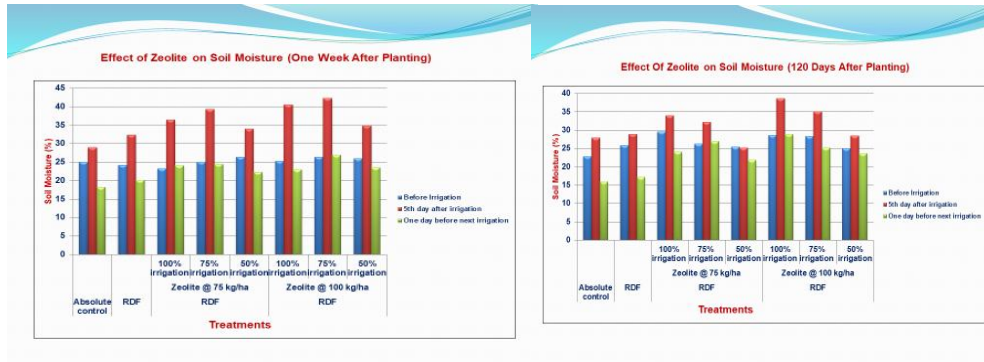
**Table 9. Effect of zeolite on uptake of plant nutrients**

| 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   | 5.61             | 2.35               | 4.29              |
| CD %   | 17.03            | 7.15               | 13.01             |

**Table 10. Effect of zeolite on water use efficiency**

| Treatment  | Cane yield t ha <sup>-1</sup> | Water requirement (ha cm) | Water use efficiency (t/ha cm <sup>-1</sup> ) |
|--|-------------------------------|---------------------------|---|
| 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

