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Investigating the effect of liquid diammonium phosphate fertilizer application on growth characteristics and yield of sugarcane (*Saccharum officinarum L.*)

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ABSTRACT

A field experiment was conducted in the Shoaibieh region, Imam Khomeini Sugarcane Cultivation and Industry, a subsidiary of Khuzestan Sugarcane and Related Industries Development Company, one of the leading cultivations and industries with the highest production efficiency in the field of sugar production in Iran, in 1402. This experiment was conducted with 9 treatments including different amounts of liquid diammonium phosphate fertilizer at levels of 0, 20 and 30 liters per hectare with three replications in a randomized complete block design and with the aim of investigating the effect of liquid diammonium phosphate fertilizer application on quantitative and qualitative criteria of ratoon or regrowth sugarcane. The measured traits in this study included stem height, stem diameter, number of stems per hectare, yield (tons per hectare of stems), percentage of syrup purity (%PTY), percentage of sugar extraction %R.S. Analysis of variance showed that among the phosphorus fertilizer treatments applied, the 30-liter treatment had the highest yield, which reached 2.99 tons per hectare. In contrast, the control treatment with 0 liters of fertilizer had the lowest yield of 91.6 tons per hectare. The application of 30 liters per hectare increased the yield by 7.6 tons per hectare, indicating an 8% improvement in yield compared to the control treatment. Also, the highest percentage of sugar extraction was observed in the 30-liter treatment with 12.77%, which surpassed the control treatment with 12.46%. The results showed that due to the low phosphorus content of the field soil, adding liquid diammonium phosphate fertilizer and providing available phosphorus at the stage had a significant increase in the quantitative and qualitative characteristics of the sugarcane crop and was economically viable in terms of sugar production costs.

Keywords: Sugarcane ratoon, variety CP69-1062, liquid diammonium phosphate fertilizer, sugarcane yield, percentage of syrup purity (%PTY), percentage of sugar extraction (%R.S).

INTRODUCTION

Phosphorus is a chemical element with the symbol P and atomic number 15. The element phosphorus exists in three major forms: white phosphorus, red phosphorus, and black phosphorus. However, because it is highly reactive, phosphorus is never found as a free element on Earth. Its concentration in the Earth's crust is about one gram per kilogram. In minerals, phosphorus generally appears as phosphate.

Etesami (2019) Phosphorus is the most limiting nutrient after nitrogen, and the main source of phosphorus is concentrated phosphoric acid for agricultural fertilizers, which contains 70-75% phosphorus pentoxide P_2O_5. This led to a large increase in phosphate (PO_4^{-3}) production in the second half of the 20th century. The use of phosphate fertilizers in agriculture is essential because phosphorus is essential for all living organisms. This substance plays a role in energy transfer, root and

stem resistance, photosynthesis, plant root expansion, seed and flower formation, and other important factors affecting overall plant health and genetics.

Sugarcane is a perennial plant of the cereal family with the scientific name Saccharum officinarum, which is cultivated in a concentrated manner on a large area of about one hundred and twenty thousand hectares of land in Khuzestan province for the purpose of producing sugar from its stems, and approximately 57% of the country's demand for sugar is produced in this region. The current increase in the world population has created an increasing demand for agricultural products, thus creating great challenges in terms of how to feed such a large population (Mahohi *et al.*, 2023). The sugarcane farming system is divided into two categories of plantations or Plant and regrowth plantations or Ratoon. The plantations that are cultivated in the first year are called plantations or Plant and the subsequent ages are called plantations or Ratoon. Typically, phosphorus fertilizers are used only in one stage during the cultivation period and regrowth ages (Zhao *et al.*, 2014). Phosphorus (P) is an essential element for plant growth and development, which can directly affect crop yields (George *et al.*, 2016). This element is required for cell division, which is responsible for the longitudinal growth of roots and stems, or sugarcane plant growth. Sufficient phosphorus increases plant yield and proper growth and development, and its deficiency leads to a decrease in root mass and, as a result, a decrease in water and nutrient absorption (Arruda *et al.*, 2016).

Mahouhi *et al*. (2023) examined the phosphorus status of soil and plants at different ages of sugarcane and reported that a significant portion of the phosphorus consumed is fixed in the soil in the first year of cultivation, and with increasing plant age, the availability of phosphorus in the soil and its concentration in the plant, and subsequently, sugarcane yield, decrease. The root system of sugarcane plants will grow poorly at low concentrations of available phosphorus in the soil, and the growth of secondary adventitious roots is limited due to the reduction in the contact area of the root with the soil and its solution. Poor root growth means insufficient access to air (for respiration), water, and nutrients for full plant growth. Phosphorus deficiency reduces tillering and reduces the length and diameter of the sugarcane internode (Zhao *et al.*, 2020). Studies have shown that in calcareous soils, the demand for phosphorus increases, which is met through the use of phosphate fertilizers (Ahmad, *et al.*, 2022). Therefore, given that most of the soils of sugarcane farms in Khuzestan Province in Iran are calcareous and have little organic matter, which leads to a decrease in phosphorus availability and also the efficiency of phosphorus fertilizer use in these soils, and on the other hand, phosphorus fertilizer is only used in the first year of sugarcane cultivation, the need to conduct research and use phosphorus fertilizers, especially liquid fertilizers, in ratoon sugarcane farms to increase the quantitative and qualitative yield of the crop becomes important. Studies have shown that in calcareous soils, the demand for phosphorus increases, which is met through the use of phosphate fertilizers (Mohammad *et al.*, 2008). Soil calcium carbonate can affect the availability of phosphorus in the soil by increasing or decreasing the availability of phosphorus in the soil. The specific effect depends on several factors such as soil pH, the form of phosphorus available, and the ability of the plant to absorb phosphorus. In general, high levels of lime can increase phosphorus availability in acidic soils, while in alkaline soils it can reduce phosphorus availability. Therefore, given that most of the soils of sugarcane farms in Khuzestan Province are calcareous and have little organic matter. The availability of nutrients, including phosphorus, as well as the efficiency of phosphorus fertilizer use in these soils is low. In calcareous soils, a significant portion of phosphorus fertilizers, after entering the soil, become insoluble and are unavailable to plants. The amount of calcium carbonate in the soil of Imam Khomeini Agricultural and Industrial Farms is also above 45 percent, the necessity of using phosphorus fertilizers, especially liquid fertilizers, in replanted sugarcane farms becomes important to increase quantitative and qualitative yield.

MATERIALS AND METHODS

This research was conducted in the Shoaibieh region, Imam Khomeini Sugarcane Farm and Industry, a subsidiary of Khuzestan Sugarcane and Related Industries Development Company, one of the leading farms and industries with the highest production efficiency in the field of sugar production in Iran, in 1402 with the aim of investigating the effect of liquid diammonium phosphate fertilizer application on the quantitative and qualitative yield

components of sugarcane in the form of single-plots split in the form of complete randomized blocks in a 25-hectare farm of seventh-year Raton sugarcane farms with the CP69-1062 variety. This farm and industry is located in Khuzestan province and in the Shoaibieh lands, between the Shatit (a branch of the Karun) and Dez rivers, 30 km south of the city of Shushtar (Fig. 1). The sugarcane cultivation method in this farm and industry is in the form of a double-row and ridge (cultivation line) with dimensions of 1.83 x 250 meters. The experimental factors included three different levels of liquid diammonium phosphate fertilizer (0, 20, and 30 liters) with three replications, and each experimental plot or treatment consisted of 7 rows and ridges with an area of 0.3 hectares (Fig. 2).

To provide the fertilizer required for the project, products manufactured by Sivan Company, which contain 15 percent absorbable phosphorus in the form of (P_2O_5), were used.

Soil sampling was performed after the first irrigation of subsoil ratooning and before fertilization in March 2023 from a depth of 0-30 cm. After air drying, grinding, and passing through a 2 mm sieve, it was transferred to the laboratory for analysis (Table 1). Based on soil analysis, the amount of phosphorus in the soil is in the critical range and is deficient in meeting the phosphorus needs of the sugarcane plant.

The treatment in this plan was applied by the fertilizer-irrigation method and in the pre-till stage, the first stage of sugarcane growth, to meet the plant's phosphorus needs, simultaneously with irrigation in March 2023 with amounts of 0, 20, and 30 liters. The treatments are:

T1 = 0 lit of Liquid di-ammonium phosphate

T2 = 20 lit of Liquid di-ammonium phosphate

T3 = 30 lit of Liquid di-ammonium phosphate

In addition, the company's conventional fertilization (350 kg of urea fertilizer in installments) was used in four stages in all treatments.

The traits measured in this study were used to investigate the quantitative and qualitative indicators of sugarcane yield components, including stem height, stem diameter, number of stems per hectare, yield (tons per hectare of stem), percentage of syrup purity (%PTY), percentage of sugar extraction (%R.S) in the following manner (Fig. 3):

1. Sampling stations were identified at the beginning and end of the middle planting line of each treatment and 30 meters from its length (3 rows and ridges on both sides of each treatment were considered as the design margin).
2. At the sampling station location, the canes were cut and harvested at a length of 3 meters.

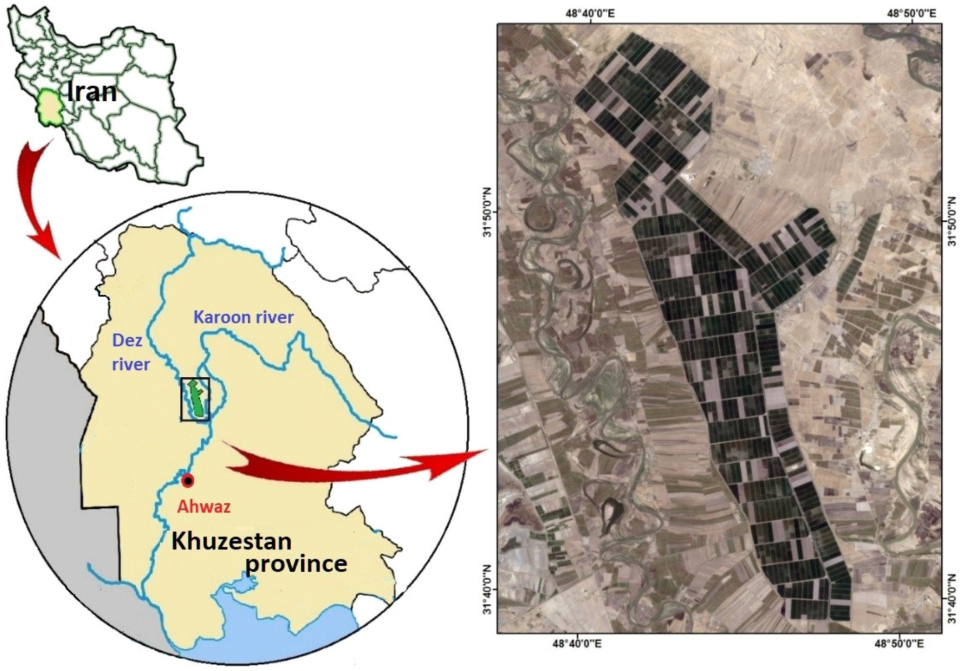

Fig. 1. Location of the study area

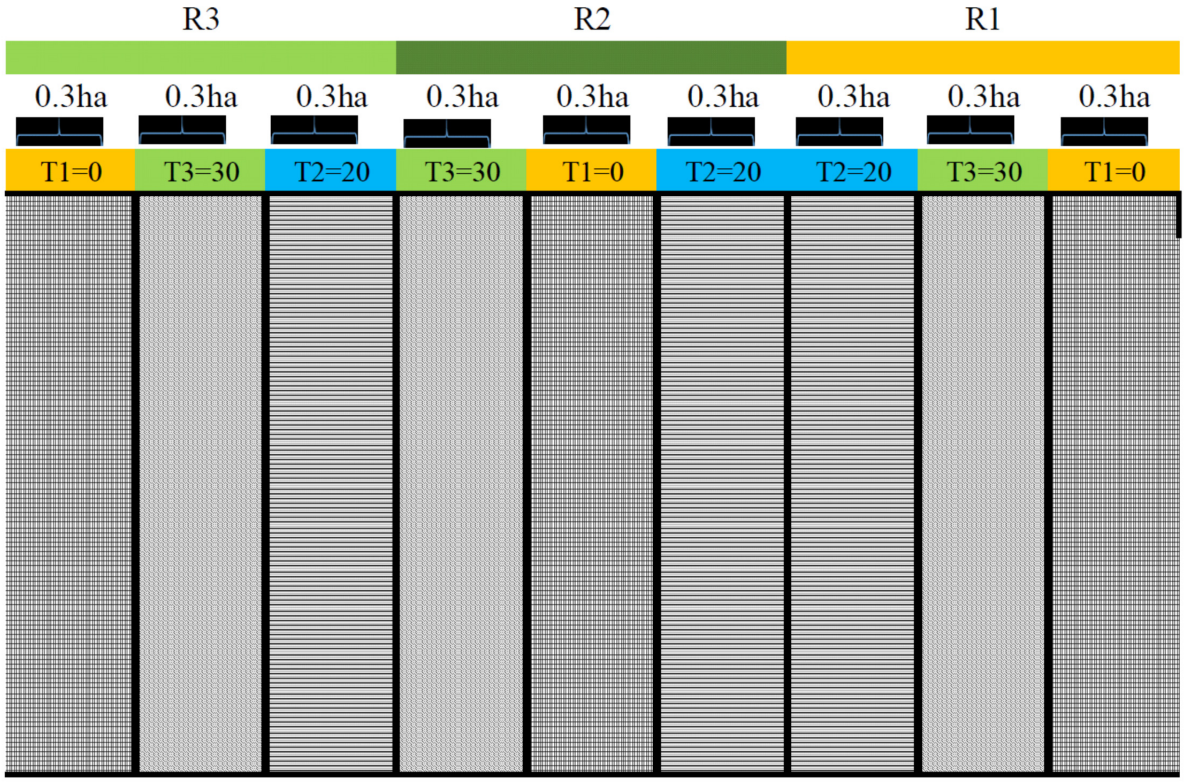

Fig. 2. Plan implementation map

Table 1. Physical and chemical characteristics of the soil of the research farm

Soil depth	Soil texture	pH	EC (ms/cm)	P (ppm)	Clay percentage	Silt percentage	Sand percentage	SAR	OM (%)
30-0	Silty clay	7.65	1.88	2.62	47%	43%	10%	3.43	0.56

3. The number of stems per hectare was calculated by counting the number of stems harvested from the second stage.
4. Stems were randomly separated from the reeds cut in the previous step to obtain stem height and diameter.

After measuring the height and diameter of the stem, 20 stems of each treatment were extracted with a reed grinder and to obtain the quality of the reed syrup, the percentage of syrup purity (%PTY) was measured with a polarimeter and the percentage of sugar extraction (%R.S) was measured with a Brix meter in the plant chemistry laboratory. Finally, the harvest time was in November 2023, with the full area of the treatment harvested, and the yield (tons per hectare of stems) was obtained.

Statistical methods

Analysis of variance and comparison of data means with the least significant difference (LSD) test were performed using statistical analysis software (SAS) and graphs were drawn using Excel. At this stage, using descriptive statistics, the mean and standard deviation of sugarcane yield components in both sections, control and treatment, were calculated and compared.

Data analysis methods

Data analysis was performed using software (SAS) and graphs were drawn using Excel. Examination of Table 2 of the analysis of variance data showed that there was a significant difference between sugarcane yield components.

RESULTS AND DISCUSSION

Comparison of the averages (Table 3) and examination of the graphs drawn in Fig. 4 showed that there is a difference between the treatments of liquid diammonium phosphate fertilizer application, and this difference indicates the effect of phosphorus

Fig. 3. Review of quantitative and qualitative indicators of sugarcane production

Table 2. Analysis of variance of mean squares of the studied traits

Sources of changes	Degree free	Mean squares of traits					
		Number of stems (per hectare)	Stem yield (tons per hectare)	Stem diameter	Stem height	%PTY	%R.S
Repetition	2	23589485.4	2.08	0.0047	101.61	0.093	0.0021
Treatment	2	^{ns} 96417698.1	**43.31	*0.0693	*1294.81	**11.57	**0.069
Error	4	19689538.1	1.37	0.0084	175.66	0.101	0.0043
C.V		0.52	0.34	6.14	4.70	1.23	3.06
R^2		0.89	0.98	0.80	0.81	0.94	0.75

**,*, ns are non-significant and significant at the statistical error probability levels of five and one percent, respectively.

Table 3. Comparison of the average effect of liquid diammonium phosphate fertilizer amount on

Treatments	Stem height	Stem diameter	Stem yield (tons per hectare)	Number of stems (per hectare)	%PTY	%R.S
Control (T1 = 0 lit)	193.17^{b}	1.82^{b}	91.61^{c}	138267^{b}	90.30^{c}	12.46c
20 liters of liquid diammonium phosphate fertilizer per hectare (T2 = 20 lit)	220.10^{ab}	1.92^{ab}	95.2^{b}	148661^{a}	91.6^{b}	12.61b
30 liters of liquid diammonium phosphate fertilizer per hectare (T3 = 30 lit)	243.03^{a}	2.12^{a}	99.2^{a}	147388^{ab}	94.2^{a}	12.77a

In each column, means that share letters do not differ significantly at the 5% probability level based on the LSD test.

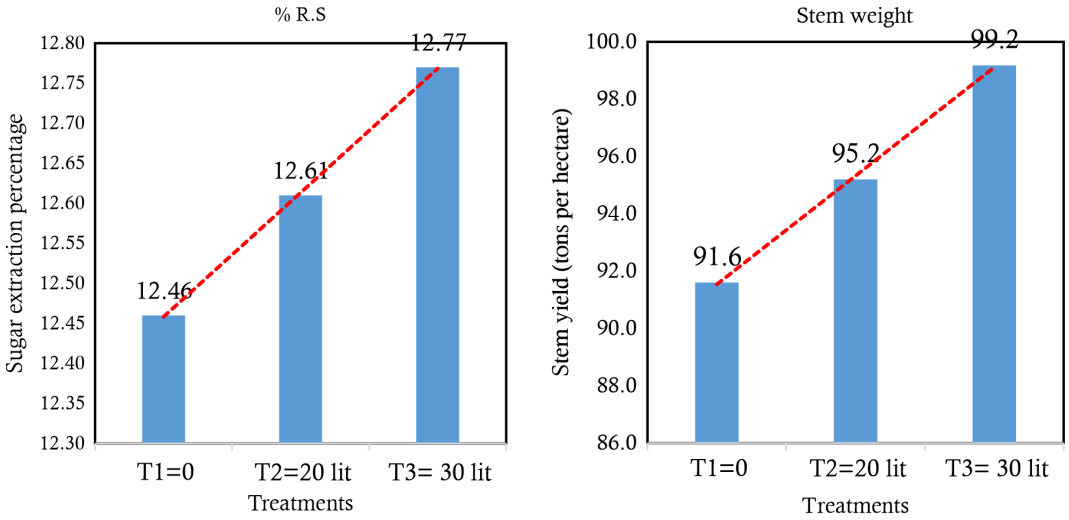

Fig. 4. Quantitative and qualitative index diagrams of sugarcane yield

on the development of the sugarcane root, which leads to better absorption of nutrients, and this increase has had a direct effect on the yield components. In a way, it has led to an increase in yield by 7.6 tons per hectare, that is, 8 percent compared to the control. Therefore, the highest yield for the 30-liter treatment is equivalent to 2.99 tons per hectare, and the lowest yield for the control treatment (0 liters) is equivalent to 6.91 tons per hectare. There is no statistically significant difference between the two 20- and 30-liter treatments.

A review of the research results showed that the application of liquid diammonium phosphate fertilizer with the trade name Phosphotech of Sivan Company had a favorable effect on sugarcane yield components and increased the quantitative and qualitative characteristics of sugarcane yield by 8 percent per hectare. This increase is due to meeting the phosphorus needs of sugarcane plants at the right time and its effective role includes stimulating good growth and development of roots, greater absorption of nutrients and photosynthesis, storage and transfer of nutrients throughout the plant and ripening of the product. Therefore, considering the findings of this research, including increased yield with increased levels of liquid diammonium phosphate fertilizer and the significance of all treatment levels in order to achieve the best application level of this fertilizer, it is recommended that this experiment be conducted with more different levels in the new crop year.

CONCLUSION

The use of liquid phosphorus fertilizers such as liquid diammonium phosphate in this project showed that, given that most of the soils of sugarcane farms in Khuzestan Province are calcareous and have little organic matter, and the availability of nutrients, including phosphorus, as well as the efficiency of using solid phosphorus fertilizers in these soils, has a significant impact on increasing the growth indicators and characteristics of sugarcane, such that it caused:

- An 8% increase in the quantity and quality of sugarcane yield
- An increase of 7.6 tons of sugarcane per hectare compared to the control treatment
- An increase of 1.25 tons of sugar per hectare compared to the control treatment
- An increase in the net profit of sugarcane yield by 11%

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