Impact of NPK Fertilization on Growth and Yield of Sugarcane (*Saccharum officinarum* L.) under Different Planting Methods

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Abstract | The use of inorganic fertilizers in Pakistan is imbalanced and inappropriate. It is very important to use proper doses of balanced fertilizers to exploit the maximum yield potential of cane crop. This study focused on hypothesis that application of suitable planting methods and NPK level play a major role in improving sugarcane yield and quality. Experiment was performed under field conditions at Sugarcane Research Institute, Tandojam, Sindh, Pakistan (located at 25° 25.19' N 68° 32.07' E) during 2016-17, repeated in 2017-18 and data was averaged. The sugarcane variety PSTJ-41 was used for this study. The experiment was laid out in split plot design. Main-plot consisted of planting methods i.e. single set (parallel to furrow), double sett (parallel to furrow), single set (across furrow) whereas, sub-plot comprised of NPK levels i.e. 166-084-165 kg ha⁻¹ (25 % < recommended), 225-112-220 kg ha⁻¹ (recommended), 281-140-275 kg ha⁻¹ (25%>recommended). Results exhibited significant effects of planting methods and NPK application on most studied parameters. In case of planting methods, substantially higher seed germination (%), crop growth rate (g m⁻² day⁻¹), leaf area index (%), cane length (cm), internodes cane⁻¹, cane yield (t ha⁻¹), brix (%) and commercial cane sugar (%)were recorded under double sett (parallel to furrow). As regards NPK levels, 281-140-275 kg ha⁻¹ (25%-recommended) produced significantly increased in growth and yield characters particularly, cane yield (t ha⁻¹) and brix (%). The findings of the study further suggested that interaction of double sett (parallel to furrow) with NPK levels 281-140-275 kg ha⁻¹ (25%>recommended) resulted in highest performance of crop especially yield and quality traits.

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Introduction

Sugarcane (*Saccharum officinarum* L.) is world's largest crop in terms of total production and one of the Pakistan's major cash crop (Khan et al., 2018). Sugarcane is the world's largest crop by production quantity, with 1.8 billion tons produced in 2017, with Brazilian counting for 40% of the world total. In 2012, the Food and Agriculture Organization estimated it was cultivated on about 26 million hectares (64 million acres), in more than 90 countries (Wikipedia, 2020). Pakistan is the fifth largest sugarcane producer...
in the world with an annual production of 63,800 thousand metric tons (TMTs), after Brazil, India, China and Thailand (Anonymous, 2019). Sugarcane is categorized as high fertilizer consumption crop that requires a lot amount of nutrients to have good growth and high yield (Cantarella and Rossetto, 2010). The sugar industry is the country's second largest agro industry after textile. Sugarcane produces essential products such as sugar, ethanol, and bagasse (Jorrat et al., 2018). The reasons for low yield include traditional planting methods, expensive inputs, heavy weed infestation, improper land preparation, less than acceptable seed size, imbalanced application of fertilizer, scarcity of irrigation water, illiteracy and low income. Moreover, expensive inputs, poor fertilizer application method, natural calamities (Baloch et al., 2002), late harvesting (Malik and Gurmani, 2005), poor management of ratoon and plantation geometry are a few of the causes of low yield of sugarcane (Majid, 2007). An even handed fertilization not only ensures the most favorable crop production but also gives the farmers the chance to pay back and is the best choice for alleviating the dangerous effect of nutrient losses on the environment. Nitrogen (N), phosphorus (P) and potassium (K) are macro nutrients which have important role in supporting growth and yield of sugarcane (Costa et al., 2016). For high yield and good juice quality, K fertilizers are required in amounts equal to or greater than N and P. In most sugarcane producing countries of the world, NPK ratios of 2:1:3 or 2:1:2 or 3:1:5 are commonly used (Wood, 1990). Integrated use of organic and inorganic fertilizer not only preserves soil and crop production, but also protects soil quality and avoids several deficiencies in soil nutrients (Umesh et al., 2018). Nutrient application varies with soil types, seasons and conditions (Ghaffar et al., 2011; Sarwar et al., 2012). The application of chemical fertilizers has vital importance in sugarcane crop (Arain et al., 2017). Higher productivity of the cane and sugar depends on the interactive effects of genetic potential of the cultivars and proper crop husbandry practices including application of fertilizer at appropriate rate and time (Ghaffar, 2009). Use of balanced fertilizer contributes to enhance crop yield, the increase may varies from 30 to 60 percent. One kg of fertilizer nutrient produces about 114 kg of stripped sugarcane (Ghaffar et al., 2010). Khan et al. (2005) recommended 128–63–70 kg of NPK ha⁻¹ as a standard dose of sugar cane fertilizer. Rising Nitrogen (N) rates up to 225 kg ha⁻¹ significantly improved the yield of commercial 

Sugarcane growth and yield under various planting methods

Materials and Methods

Soil selection and experimental details

A field experiment was carried out at Sugarcane Research Institute, Tandojam, Sindh, Pakistan during autumn 2016-17 and 2017-18. The soil of experimental area is clay loam, which according to USDA system belongs to Order Aridisols and Subgroup Typic Camborthids. The experimental field was ploughed two times with disc harrow, irrigated, dried to workable condition, leveled and finally seedbed was prepared by plowing with cultivator. The plot size was 13 m x 2.3 m (30 m²). The sugarcane candidate variety PSTJ-41 was planted. The planting materials used were the stem cuttings known as “sett”. The experiment
was laid out under split plot design (randomizing the planting methods in main plots and NPK levels in sub plots) having three replications. The crop was planted on 22nd September 2016 and 25th September 2017. The field area was well managed prior to planting. The planting methods included single sett (parallel to furrow), double sett (parallel to furrow), single sett (across the furrow), while NPK levels comprised of NPK: 166-084-165 kg ha⁻¹ (25% <recommended), 225-112-220 kg ha⁻¹ (recommended) and 281-140-275 kg ha⁻¹ (25% >recommended). The recommended NPK fertilizers were applied in the form of Urea, DAP (diammonium phosphate) and SOP (sulphate of potash). All P and K, and 1/3rd of N were applied at the time of planting. The remaining two splits of N were applied at 1st earthing-up (3 1/2 months after sowing) on 7th January, 2017 and 9th January 2018. In the same way second, split dose was applied in next earthing-up (about 45 days after initial earthing up) on 23rd February, 2017 and 24th February 2018.

Cultural management
All routine cultural practices like weeding, hoeing and herbicide application were kept normal and uniform for all the treatments. The propagatory material was taken from upper 2/3rd portion of stalk of eight months old cane. Cane setts were soaked in Topsin-M at 150 g 100⁻¹ L water to protect them from many cane diseases like sugarcane smut. Dry method of planting was adopted for growing canes with ear-to-ear planting pattern. The cane setts were sown in furrows at 6-8 inches depth and covered with 5-6 cm soils. Immediately following coverings, the sets water was let into furrows. Irrigation was applied keeping in view the soil condition and crop need as farmer practice. In summer (April-August) irrigation was applied at the interval of 7-10 days while in winter (November-March) at the interval of 10-15 days. In all 28 irrigations were applied during the growing season (12 months). Earthing-up (putting soil on root zone) and tying of sugarcane were done after 105 days of plantation to protect the cane stalks from lodging against the possibility of strong wind. The herbicide (CLIO Combo pack at 3.75 kg ha⁻¹ was applied one month after planting when sufficient moisture was present in the soil. The insecticide Lorsban at 5 L ha⁻¹ was applied at 1st irrigation to control termites. Trichogramma cards were stapled against the borers. Insecticide Furadan 3G (Carbofuran) was broadcasted at 30 kg ha⁻¹ in case borers were not controlled by Trichogramma cards.

Crop observations and measurement
The agronomic and physiological observations were recorded for parameters of economic importance such as seed germination (%), crop growth rate (g m⁻²)
day⁻¹), leaf area index, cane length (cm), internodes cane⁻¹, brix (%), commercial cane sugar (%), cane yield (t ha⁻¹). The germination percentage was calculated after 45 days of sowing by using the formula:

\[
\text{Germination percentage} = \left( \frac{\text{No. of germinated buds}}{\text{Total number of buds}} \right) \times 100.
\]

Crop growth rate (g m⁻² day⁻¹) was recorded two times at the peak of vegetative growth. First time at the Tillering phase (130 days after planting) and second time at initial Grand Growth Phase (180 days after planting). The formula used was: \((W2 - W1) ÷ (T2 - T1)\). The leaf area index was measured at peak vegetative growth stage (Grand Growth Phase) from randomly selected plants by the formula:

\[
\text{Leaf area plant}^{-1} \text{(cm}^2\text{)} ÷ \text{Ground area plant}^{-1} \text{(cm}^2\text{)}
\]

Cane length (cm) was measured with the assistance of measuring tape in centimeters from the surface of soil to the tips of the flag leaf. Within the harvest, internodes cane⁻¹ was counted, internodes of randomly selected canes from each treatment were reckoned. Thereafter, there average was taken. For Brix (%) cane juice sample was collected in a 500 ml beaker and then a drop of juice was taken from the beaker with the help of pipette and putted on the digital Refractometer’s prism, then Brix% readings were verified. Commercial cane sugar (%) was premeditated by using the formula stated by Meade and Chen (1977).

\[
\text{CCS\%} = \frac{3 \times P}{{2} \left(1 - \frac{F + \%}{100}\right) - \frac{B}{{2} \left(1 - \frac{F + 3}{100}\right)}
\]

**Harvesting**

Harvesting was done when crop was physiologically mature i.e. ripening phase completed and brix was above 20%. The crop was harvested manually on 28th December, 2017 and 31st December, 2018, respectively. The entire plot was manually harvested, leaves were removed, canes were cut from the top, spring balance weighed the cane per plot and then the yield of cane ha⁻¹ was calculated. The pooled data for both years of each parameter (2016-17 and 2017-18) is given below in respective tables.

**Physico-chemical analysis of soil**

Soil of the experimental area was analyzed before sowing and after harvesting (Table 1). Soil samples were taken with the help of soil auger at a depth of 45 cm from five locations of total experimental area before sowing and after harvesting of the crop. The soil samples were air-dried, ground, sieved (2 mm) and placed in plastic containers. The samples were analyzed for various physical and chemical properties following the procedures of Ryan et al. (2001). Soil texture was measured by Bouyoucos hydrometer method. Electrical conductivity (EC) and soil pH was measured in 1:2 soil water extract using EC and pH meters, correspondingly. Walkley Black method was followed for the determination of organic matter content. Total N was calculated. However, soil was extracted for determining extractable P and K using Ammonium bicarbonate di-ethylene triamine penta acetic acid (AB-DTPA).

**Table 1: Average physico-chemical properties of experimental soils (2016-17 and 2017-18).**

| Soil parameter          | Values |
|-------------------------|--------|
| Soil texture            |        |
| Sand (%)                | 19.5   |
| Silt (%)                | 42.0   |
| Clay (%)                | 38.5   |
| Textural class          |        |
| Silty clay loam         |        |
| Soil chemical analysis  |        |
| EC (dS m⁻¹)             | 0.23   |
| Soil pH                 | 8.20   |
| Organic matter (%)      | 0.83   |
| Total N (%)             | 0.09   |
| Available P (mg kg⁻¹)   | 8.80   |
| Extractable K (mg kg⁻¹) | 0.88   |

**Statistical analysis**

The data were statistically analyzed following ANOVA technique using software Statistix version 8.1 (Statistix, 2006). The least significant difference (LSD) test was used at alpha 0.05 for comparing differences of treatments.

**Meteorological data**

The meteorological data of Tandojam during experimental seasons of both years (2016-17 and 2017-18) was obtained from Meteorological Station, Tandojam. The details of meteorological data on weekly basis regarding i.e. min and max: temperature(C) and Rainfall (mm) are presented in Figures 4 and 5.

**Results and Discussion**

**Seed germination (%)**

It is obvious from the statistical analysis of data that non-significant (\(p>0.05\)) effect was caused by planting methods on germination (%) whereas,
significant \((p<0.05)\) by NPK levels. However, interactive effects were also non-significant (Table 2). Double sett (parallel to furrow) gave the highest seed germination (%), followed by single sett (parallel to furrow) having statistical equality with each other while lowest germination (%) was noticed in single sett (across furrow). NPK levels 281-140-275 kg ha\(^{-1}\) resulted in greatest germination (%) seconded by 225-112-220 kg ha\(^{-1}\) NPK levels. Although, lowest seed germination (%) was recorded under 166-084-165 kg ha\(^{-1}\) NPK levels. The interaction of double sett (parallel to furrow) × 281-140-275 kg ha\(^{-1}\) NPK levels produced enhanced seed germination (%) followed by single sett (parallel to furrow) × 281-140-275 kg ha\(^{-1}\) NPK levels, whereas diminished results were recorded in single sett (across furrow) × 166-084-165 kg ha\(^{-1}\) NPK levels. This may possibly be accredited to fundamental role of NPK in growth and development of sugarcane plants. Many studies have been carried out on the NPK requirement of sugarcane (Cheema et al., 2010) which showed increase in germination rate by applying of NPK fertilizers.

**Leaf area index**

Leaf area index responded significantly \((p<0.05)\) to planting methods, NPK levels and their interaction (planting methods × NPK levels) (Table 3). Double sett (parallel to furrow) gave vibrant leaf area index followed by single sett (parallel to furrow) having statistical impartiality with each other while lowest leaf area index was noticed in single sett (across furrow). In case of NPK levels, 281-140-275 kg ha\(^{-1}\) NPK levels intensely improved the leaf area index followed by 225-112-220 kg ha\(^{-1}\) NPK levels, whereas 166-084-165 kg ha\(^{-1}\) NPK levels registered least leaf area index. The interaction of double sett (parallel to furrow) × 281-140-275 kg ha\(^{-1}\) NPK levels produced superior leaf area chased by single sett (parallel to furrow) × 281-140-275 kg ha\(^{-1}\) NPK levels whereas shortest crop growth rate was recorded in single sett (across furrow) × 166-084-165 kg ha\(^{-1}\) NPK. The results showed that there was noticeable increase in the crop growth rate in double sett (parallel to furrow) and in NPK levels: 281-140-275 kg ha\(^{-1}\). Similarly, Bashir and Saeed (2000) reported that physiological and quantitative traits of sugarcane are significantly affected by the planting methods.

**Cane length (cm)**

Cane length (cm) were affected non-significantly \((p>0.05)\) by planting methods and significantly \((p<0.05)\) by NPK levels but their interaction was...
found to be non-significant ($p>0.05$) (Table 3). Double sett (parallel to furrow) gave highest cane length followed by single sett (parallel to furrow) having statistical equality with each other while lowest millable canes was observed in single sett (across furrow). 281-140-275 kg ha$^{-1}$ NPK levels resulted in greatest cane length followed by 225-112-220 kg ha$^{-1}$ and 166-084-165 kg ha$^{-1}$ NPK levels. The interaction of double sett (parallel to furrow) × 281-140-275 kg ha$^{-1}$ NPK levels produced improved cane length (cm) lead by single sett (parallel to furrow) × 281-140-275 kg ha$^{-1}$ NPK levels, whereas reduced results were recorded in single sett (across furrow) × 166-084-165 kg ha$^{-1}$ NPK levels. As recorded by Srivastava et al. (2008) who conducted an experiment on productivity and profitability of sugarcane in relation to organic nutrition under various cropping systems they found highest number of millable canes (82.7 and 95.2 thousands ha$^{-1}$) and cane length (220.8 and 182.5 cm) were recorded with sulphitation press mud (SPM) 10 t ha$^{-1}$ + farmyard manure (FYM) 10 t ha$^{-1}$ in autumn and spring planted crops, respectively.

**Internodes cane$^{-1}$**

Internodes cane$^{-1}$ responded non-significantly ($p>0.05$) to planting methods and significantly ($p<0.05$) to NPK levels, and their interaction (planting methods × NPK levels) affected non-significantly ($p>0.05$) (Table 4). Double sett (parallel to furrow) gave dynamic internodes cane$^{-1}$ followed by single sett (parallel to furrow) having statistical equality with each other while lowest internodes cane$^{-1}$ was seen in single sett (across furrow). In case of NPK levels, 281-140-275 kg h$^{-1}$ NPK levels resulted in greatest internodes cane$^{-1}$ seconded by 225-112-220 kg ha$^{-1}$ NPK levels and 166-084-165 kg ha$^{-1}$ NPK levels. The interaction of double sett (parallel to furrow) × 281-140-275 kg ha$^{-1}$ NPK exposed improved internodes cane$^{-1}$ headed by single sett (parallel to furrow) × 281-140-275 kg ha$^{-1}$ NPK levels, whereas moderate

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**Table 2: Seed germination (%) and crop growth rate (g m$^{-2}$ day$^{-1}$) of sugarcane as affected by planting methods and NPK levels.**

| Planting methods                  | Seed germination (%) | Crop growth rate (g m$^{-2}$ day$^{-1}$) |
|----------------------------------|----------------------|-----------------------------------------|
|                                  | NPK levels (kg ha$^{-1}$) | Mean |
|                                  | 166-084-165 | 225-112-220 | 281-140-275 | Mean |
| Single sett (parallel to furrow) | 71.3        | 74.7        | 80.0        | 75.3  | 5.7    | 7.4    | 9.0    | 7.4 B |
| Double sett (parallel to furrow) | 71.7        | 76.7        | 83.3        | 77.2  | 6.2    | 7.8    | 9.3    | 7.8 A |
| Single sett (across furrow)      | 66.3        | 72.7        | 76.7        | 71.9  | 5.3    | 6.8    | 8.9    | 7.0 C |
| Mean                             | 69.8 B      | 74.7 AB     | 80.0 A      | -     | 5.7 C  | 7.3 B  | 9.1 A  | -     |
| Variables                        | S. E        | P-value     | LSD (5%)    | S. E  | P-value | LSD (5%) |        |        |
| Planting methods (M)             | 8.5426      | 0.0969      | -           | 0.1277 | 0.0085 | 0.3544 |        |        |
| NPK levels (F)                   | 15.001      | 0.0148      | 32.683      | 0.1969 | 0.0000 | 0.4290 |        |        |
| M × F                            | 22.869      | 0.9293      | -           | 0.3063 | 0.7214 | -      |        |        |

**Table 3: Leaf area index and cane length (cm) of sugarcane as affected by planting methods and NPK levels.**

| Planting methods                  | Leaf area index | Cane length (cm) |
|----------------------------------|-----------------|-----------------|
|                                  | NPK levels (kg ha$^{-1}$) | Mean |
|                                  | 166-084-165 | 225-112-220 | 281-140-275 | Mean |
| Single sett (parallel to furrow) | 6.0 g        | 11.1 de       | 14.9 b      | 10.7 B | 220.0 | 243.3 | 266.7 | 243.3 |
| Double sett (parallel to furrow) | 9.6 f        | 12.0 d        | 17.2 a      | 12.9 A | 236.7 | 249.7 | 300.0 | 262.1 |
| Single sett (across furrow)      | 5.8 g        | 10.5 ef       | 13.2 c      | 9.8 C  | 213.7 | 240.0 | 260.0 | 237.9 |
| Mean                             | 7.1 C        | 11.2 B        | 15.1 A      | -     | 223.5 B | 244.3 AB | 275.6 A | -     |
| Variables                        | S. E         | P-value       | LSD (5%)    | S. E  | P-value | LSD (5%) |        |        |
| Planting methods (M)             | 0.1280       | 0.0000        | 0.3553      | 8.5426 | 0.0969 | -     |        |        |
| NPK levels (F)                   | 0.2764       | 0.0000        | 0.6022      | 15.001 | 0.0148 | 32.683 |        |        |
| M × F                            | 0.4113       | 0.0056        | 1.0430      | 22.869 | 0.9293 | -     |        |        |
results were recorded in single sett (across furrow) × 166-084-165 kg ha⁻¹ NPK. The above results are in conformity with Dev et al. (2011) recorded that application of 210 Kg N ha⁻¹ linearly and significantly increase number of tiller (5.48 %), number of millable cane (1.12 %), weight of millable cane (5.85 %), cane length, number of internodes cane (7.59 %) and cane yield (5.93%).

Cane yield (t ha⁻¹)
Cane yield was non-significant (p>0.05) regarding planting methods, significant (p<0.05) by NPK levels, however, interactive effects (planting methods × NPK levels) were non-significant (Table 4). Double sett (parallel to furrow) gave utmost cane yield followed by single sett (parallel to furrow) having statistical impartiality with each other while lowest cane yield was noticed in single sett (across furrow). 281-140-275 kg ha⁻¹ NPK levels resulted in greatest cane yield followed by 225-112-220 kg ha⁻¹ NPK levels and 166-084-165 kg ha⁻¹ NPK levels. The interaction of double sett (parallel to furrow) × 281-140-275 NPK levels produced improved cane yield lead by single sett (parallel to furrow) × 281-140-275 NPK levels whereas reduced results were recorded in single sett (across furrow) × 166-084-165 NPK levels that contrasted considerably from all other treatments. These results concur with those of Soomro et al. (2014) who observed that % brix, pol, purity, commercial cane sugar, NPK uptake and accumulation in sugarcane were higher when three-fourth of recommended rate of NPK fertilizer (169-84-261) were applied along with + 20 tons press mud ha⁻¹.

Commercial cane sugar (CCS %)
The assessment of data showed that commercial cane sugar (%) were non-significantly (p>0.05) affected by planting methods and significantly (p<0.05) by NPK levels whereas, their interaction was non-significant (Table 4). Double sett (parallel to furrow) gave highest commercial cane sugar (%) followed by single sett (parallel to furrow) having statistical equality with each other while lowest commercial

| Table 4: Internodes cane⁻¹ and cane yield (t ha⁻¹) of sugarcane as affected by planting methods and NPK levels. |
|-----------------|-----------------|----------------|-----------------|-----------------|
| **Planting methods** | Internodes cane⁻¹ | Cane yield (t ha⁻¹) |
|                 | NPK levels (kg ha⁻¹) | 166-084-165 | 225-112-220 | 281-140-275 | Mean | 166-084-165 | 225-112-220 | 281-140-275 | Mean |
| Single sett (parallel to furrow) | 24.3 | 29.3 | 34.3 | 29.3 | 102.7 | 111.0 | 118.0 | 110.6 |
| Double sett (parallel to furrow) | 25.3 | 33.0 | 35.0 | 31.1 | 104.0 | 114.0 | 120.3 | 112.8 |
| Single sett (across furrow) | 23.3 | 28.0 | 33.3 | 28.2 | 95.0 | 110.0 | 116.0 | 107.0 |
| **Mean** | 24.3 C | 30.1 B | 34.2 A | 28.2 | 100.6 C | 111.7 B | 118.1 A | - |
| **Variables** | S. E | P-value | LSD (5%) | S. E | P-value | LSD (5%) | S. E | P-value | LSD (5%) |
| **Planting methods (M)** | 1.0244 | 0.1094 | - | 1.9584 | 0.1090 | - |
| **NPK levels (F)** | 1.0384 | 0.0000 | 2.2624 | 2.5223 | 0.0001 | 5.4957 |
| **M × F** | 1.7905 | 0.6506 | - | 4.0694 | 0.7670 | - |

Brix (%)
Analysis of variance indicated that a significant (p<0.05) effect was induced by planting methods and NPK levels on brix (%) while, non-significant (p>0.05) by interaction (planting methods × NPK levels) (Table 5). Double sett (parallel to furrow) gave most productive brix (%) followed by single sett (parallel to furrow) having statistical parallelism with each other while lowest brix (%) noticed in single sett (across furrow). 281-140-275 kg ha⁻¹ NPK levels resulted in greatest brix (%) followed by 225-112-220 kg ha⁻¹ NPK levels and 166-084-165 kg ha⁻¹ NPK levels. The interaction of double sett (parallel to furrow) × 281-140-275 NPK levels produced improved brix (%) lead by single sett (parallel to furrow) × 281-140-275 NPK levels whereas reduced results were recorded in single sett (across furrow) × 166-084-165 NPK levels that contrasted considerably from all other treatments. These results agree to those of Ali and Afghan, 2000 where stripped cane yield was significantly increased with 200-150-150 kg NPK against 168-112-112 kg NPK per hectare. (Ali et al., 2000) also reported an increase in cane yield with maximum NPK dose (275-200-200 kg/ha).
Table 5: Effect of planting methods and NPK levels on brix (%) and commercial cane sugar (%) of sugarcane.

| Planting methods (M) | NPK levels (kg ha\(^{-1}\)) | Brix (%) | Commercial cane sugar (%) |
|----------------------|-------------------------------|----------|---------------------------|
|                      | 166-084-165                  | 255-112-220 | 281-140-275               | Mean   | 166-084-165                  | 255-112-220 | 281-140-275               | Mean   |
| Single sett (parallel to furrow) | 20.3 | 20.7 | 22.0 | 21.0 AB | 8.3 | 8.6 | 10.1 | 9.0 |
| Double sett (parallel to furrow)      | 20.3 | 21.2 | 23.5 | 21.7 A | 8.4 | 8.8 | 10.5 | 9.2 |
| Single sett (across furrow)              | 18.3 | 20.5 | 21.3 | 20.0 B | 8.0 | 8.6 | 9.4 | 8.7 |
| Mean | 19.6 B | 20.8 AB | 22.3 A | - | 8.2 B | 8.7 B | 10.0 A | - |

Variables

| Variables | S. E | P-value | LSD (5%) |
|-----------|------|---------|----------|
| Planting methods (M) | 0.4291 | 0.0481 | 1.1915 |
| NPK levels (F) | 0.9553 | 0.0539 | 2.0814 |
| M × F | 1.4175 | 0.8963 | - |

Cane sugar (%) was noticed in single sett (across furrow). 281-140-275 kg ha\(^{-1}\) NPK levels resulted in greatest commercial cane sugar (%) followed by 225-112-220 kg ha\(^{-1}\) NPK levels and 166-084-165 kg ha\(^{-1}\) NPK levels. The interaction of double sett (parallel to furrow) × 281-140-275 NPK levels produced improved commercial cane sugar (%) lead by single sett (parallel to furrow) × 281-140-275 NPK levels, whereas reduced results were recorded in single sett (across furrow) × 166-084-165 NPK levels. Aamer et al. (2017) also affirmed that planting dimensions in ratoon cane had no significant effect on length of internodes and most of the qualitative attributes. Sarwar et al. (2012) reported that inorganic fertilizer increases the sugar yield 54.92 % and juice 21.95 %. Similarly, when press mud was applied along with inorganic fertilizers, it resulted in increase in total soluble solid 7.83 %, sucrose 10.42 % purity 2.80 %, CCS 12.06 % and sugar recovery of juice 12.07 %.

Conclusions and Recommendations

The results of this study concluded that growth, yield and quality traits of sugarcane were affected significantly by planting methods, NPK levels and their interaction. However, Double sett (parallel to furrow), 281-140-275 kg ha\(^{-1}\) NPK levels and their interaction produced highest cane yield (t ha\(^{-1}\)) and brix (%).

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Novelty Statement

Planting of sugarcane under double sett (parallel to furrow) along with different NPK levels is a unique research under agro-climatic conditions of Sindh, Pakistan.

Author’s Contribution

MNK wrote manuscript and guided overall. NM designed and conducted experiment. AAS helped in collection of data. ZHS analyzed the data. GSM helped in writing of manuscript. NM provided research facility. ZAA reviewed article. SPT edited format of manuscript.

Conflict of interest

The authors have declared no conflict of interest.

References

Aamer, M., R. Ahmad, S.A. Anjum, M.U. Hassan, F. Rasul, W. Zhiqiang, H.Z.U. Qasim, F.A. Chaudhary and H. Guoqin. 2017. Production potential of ratoon crop of sugarcane planted under varying planting dimensions. Acad. J. Agric. Res., 5(3): 39-44.

Ali, F.G. and S. Afghan. 2000. Effect of fertilizer and seed rate towards stripped-cane yield of spring-planted sugarcane. Pak. Sugar J., 15(4): 12-16.

Ali, F.G., M.A. Iqbal, A.A. Chattha and S. Afghan. 2000. Effect of fertilizer and seed rate towards stripped-cane yield of spring-planted sugarcane. Pak. Sugar J., 15(4): 12-16.

Anonymous, 2019. Pakistan fifth largest sugarcane
producer in world. The Nation. Internet source. Abbasi, S.T., R. Nazli, B. Nawab and R.M. Tariq. 2012. Efficacy of bio-K fertilizer on the growth and sugar content of sugarcane plants. Pak. J. Bot., 44(1): 131-134.

Akhtar, M., F.G. Ali, M. Saeed and S. Afghan. 2000. Effect of moisture regimes and fertilizer levels on yield and yield parameters of spring planted sugarcane. Pak. Sugar J., 15(5): 2-6.

Arain, M.Y., K.S. Memon, M.S. Akhtar and M. Memon. 2017. Soil and plant nutrient status and spatial variability for sugarcane in lower Sindh, Pakistan. Pak. J. Bot., 49(2): 531-540.

Baloch, S.M., I.H. Shah, I. Hussain and K. Abdullah. 2002. Low Sugar Production in Pakistan Causes and Remedies. Pak. Sugar J., 17: 13-14.

Bashir, S., and M. Saeed. 2000. Biomass production and partitioning in sugarcane genotype SPSG 394 as influenced by planting pattern and seeding density. J. Agric. Res., 36(2): 129-137.

Cantarella, H. and R. Rossetto. 2010. Fertilizers for Sugarcane Bioethanol, ed L.A.B. Cortez (Sao Paulo: Blucher). pp. 954.

Cheema, I.A., M. Ayub and A. Jabbar. 2010. Bio economic efficiency of spring planted sugarcane as influenced by spatial arrangement and nutrient management. Pak. Sugar J., 17: 62-68.

Costa, A.R.F.C., M.M. Rolim, E.M. Bonfim-Silva, D.E.S. Neto, E.R.M. Pedrosa and E.F.F. Silva. 2016. Accumulation of nitrogen, phosphorus and potassium in sugarcane cultivated under different types of water management and doses of nitrogen. Aust. J. Crop Sci., 10: 362–369.

Dev, C.M., R.N. Meena, Kumar, Ashok and G. Mahajan. 2011. Earthing up and nitrogen level in sugarcane ratoon under sub tropical Indian condition. Indian J. Sug., Tech., 26(1): 1-5.

Ehsanullah, S., Anjum, Š.A. Raza, M.M. Riaz, A. Abbas, M.M. Yousif and Y. Xu. 2016. Optimizing row spacing to ameliorate the productivity of spring sugarcane (Saccarum officinarum L.). Agric. Sci., 7(08): 531-538. https://doi.org/10.4236/as.2016.78053

Wikipedia, 2020. https://en.wikipedia.org/wiki/Sugarcane#:%20text=Sugarcane%20is%20the%20world%27s%20largest,in%20more%20than%2090%20countries.

Ghaffar, A., E.N. Akbar and S.H. Khan. 2011. Influence of zinc and iron on yield and quality of sugarcane planted under various trench spacing. Pak. J. Agric. Sci., 48(3): 25-33.

Ghaffar, A., 2009. Fertilizer management strategies in spring planted sugarcane. PhD thesis, Department of Agronomy, University of Agriculture, Faisalabad, Pakistan.

Ghaffar, A., M.F. Saleem, A. Ali, A.M. Ranja. 2010. Effect of K2O levels and its application time on growth and yield of sugarcane. J. Agric. Res., 48(3): 315-325.

Jorrat, M.D.M., P.Z. Araujo and F.D. Mele. 2018. Sugarcane water footprint in the province of Tucumán, Argentina. Comparison between different management practices. J. Clean Prod., 188: 521–529. https://doi.org/10.1016/j.jclepro.2018.03.242

Khan, M.T., I.A. Khan, S. Yasmeen, N. Seema, G.S. Nizamani. 2018. Field evaluation of diverse sugarcane germplasm in agroclimatic conditions of Tandojam, Sindh. Pak. J. Bot., 50(4): 1441-1450.

Khan, I.A., A. Khatri, G.S. Nizamani, M.A. Siddiqui, S. Raza and N.A. Dahar. 2005. Effect of NPK fertilizers on the growth of sugarcane clone AEC86-347 developed at NIA, Tandojam, Pakistan. Pak. J. Bot., 37(2): 355-360.

Khan, I.A., M.A. Javed, A. Khatri, M.A. Siddiqui, M.K.R. Khan, N.A. Dahar, M.H. Khanzada and R. Khan 2002. Performance of exotic sugarcane clones at NIA, Tando Jam. Asian J. Plant Sci., 1: 238-240.

Krauss, A., 2003. Crop insurance against stress with adequate potash. AFA 9th International Annual Conference, Cairo, Egypt. January 28th -30th.

Meade, G.P. and J.C.P. Chen. 1977. Cane sugar hand book. 10th Ed. John Wiely and Sons, New York.

Rayan, J., G. Estefan and A. Rashid. 2001. Soil and plant analysis laboratory manual. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria. pp. 172.

Sandhu, M.I., 1991. Effect of fertilizer application and planting geometry on yield and sucrose content of autumn planted sugarcane. M. Sc. (Hons.) Agri. thesis, Dept. Agron., Univ. Agric., Faisalabad, Pakistan.

Sarwar, M., G. Gilani, E. Rafique, M.E. Akhtar and A.N. Chaudhry. 2012. Impact of integrated nutrient management on yield and nutrient uptake by Maize under rain fed conditions. Pak. J. Nutr., 11(1): 27-33. https://doi.org/10.3923/pjn.2012.27.33
Soomro, A.F., S.D. Tunio, M.I. Keerio and I. Rajper. 2014. Effect of inorganic NPK fertilizers under different proportions on growth, yield and juice quality of sugarcane (Saccharum officinarum L). Pure Appl. Biol., 3(1): 10-18. https://doi.org/10.19045/bspab.2014.31002

Statistix, 2006. Statistix 8 user guide, version 1.0. Analytical Software, PO Box 12185, Tallahassee FL 32317 USA. Copyright 2006 by Analytical Software.

Sreewarome, A.B., V. Toomsan, P. Limpinuntana, J.M. Rao and M. Krishnamurthi. 2005. Effect of phosphorus on physiological and agronomic parameter of sugarcane cultivars. Thiland Silver Jubilee Cong. Guatemala. 30th January to 4th February.

Srivastava, A.K. and M.K. Rai. 2008. Sugarcane production: Impact of climate change and its mitigation. Biodiv. J. Biol. Div., 13(4): 214-227. https://doi.org/10.13057/biodiv/d130408

Majid, A. 2007. Sugarcane variety composition in Pakistan. Pak. Sugar J., 22: 2-21.

Malik, N.A., 1993. Response of sugarcane cultivars to different doses of NPK fertilizer in Somalia. Pak. Sugar J. 7(1): 11.13.

Mathur, B.K., 1972. Response of NPK fertilization on sugarcane crop. Indian Sugar. 21(12): 809-815.

Miller, J.D. and R.A. Gilbert. 2006. Florida Sugarcane Handbook This document is SS-AGR-234, one of a series of the Agronomy Department, Florida Cooperative Extension Service, Institute of Food and Agriculture Science University of Florida.

Nazir, A., G.A. Jariko and M.A. Junejo. 2013. Factors affecting sugarcane production in Pakistan. Pak. J. Commer. Soc. Sci., 7(1): 128-140.

Umesh U.N., R.K. Prasad and K. Vipin. 2018. Integrated effect of organic and inorganic fertilizers on yield, quality parameter and nutrient availability of sugarcane in calcareous soil. J. Pharm. Phytol., 1: 556-560.

Wood, R.A., 1990. The role of nitrogen, phosphorus and potassium in the production of sugarcane in South Africa. Fert. Res., 26: 87-98. https://doi.org/10.1007/BF01048746