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Effect of Blended Fertilizer and Levels of Phosphorus on Yield and Juice Quality of Sugarcane at Fincha Sugar Estate, Ethiopia

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Abstract: High yield production and juice quality is essential in commercial sugarcane (*Saccharum officinarum* L.) production. And this is possible is partly influenced by fertilizers. However, especially the effect of phosphorus and blended fertilizers was not known at study area. Field experiment was conducted at Fincha Sugar Estate, Ethiopia in 2018-2019 aiming to determine the effect of blended fertilizers and levels of phosphorus on yield and juice quality of sugarcane. The treatments were arranged in factorial combinations of three blended fertilizers (NPS, NPSB, and NPSBZn) and five phosphorus levels (0, 57, 76, 114, and 152 kg ha^{-1}) and the experiment was laid out in randomized complete block (RCB) design with three replications. Data on sugarcane yield and juice quality parameters (Brix%, pol%, purity) and sugar yield were collected and analyzed. The result revealed that the main effect and interaction effects of blended fertilizers at different levels of phosphorus were highly significantly ($p<0.001$) for all parameters studied except for cane yield and Brix%. Accordingly, maximum cane yield was recorded in blended fertilizer NPSBZn at levels of phosphorus 152 and 114 kg ha^{-1} producing 242.5 and 233 t ha^{-1}, respectively. Thus, cane yield ranged from 106.04 to 242.5 t ha^{-1} depending on blended fertilizers and levels of phosphorus. The juice quality Brix%, pol%, purity and sugar yields of NPSBZn at a level of 114 kg ha^{-1} phosphorus was superior. Therefore, the finding show the application of blended fertilizer NPSBZn with a level of 114 kg ha^{-1} phosphorus was resulted in high cane yield and juice quality of sugarcane.

Keywords: Sugarcane, Cane Yield, Juice Quality, Sugar Yield

1. Introduction

Sugarcane (*Saccharum officinurum* L.) is originated from complex hybridization of *Saccharum officinarum*, *Saccharum Spontaneum*, *Saccharum Barberi, Saccharum Sinense*, and related species [17]. Hence, it is a highly polyploidy, heterozygous, and genetically complex crop belongs to family *Gramineae* (Poaceae). *Saccharum officinarum* or the noble cane accumulated very high levels of sucrose in the stem. It was usually vegetatively propagated from auxiliary buds on the stem (or stalk) cuttings. The first, “plant” crop was generally harvested from 14 to 16 months after planting; thereafter, "ratoon" crops may be harvested at shorter to equal periods [18]. Sugarcane is an economically important agricultural crop in many tropical and subtropical countries for the production of sugar and biofuels [31]. It was the most efficient photosynthesizer C4 plant in the plant kingdom. Sugarcane was unique in the sense that the storage of sucrose in the parenchymatous tissue of internodes has taken at higher concentrations. About 70% of the world sugar was produced from sugarcane and the rest was from sugar beet [14]. The mature stalks of sugarcane have contained juice with sucrose content as low as 8-9% and as high as 18-19% [36].

Sugarcane production area and productivity differ widely from country to country. Brazil has the highest area (9.08 million ha), Australia has the highest productivity (85.1 tons/ha), from 17 top sugarcane producing countries [8]. And it has been indicated that Ethiopia has 700,000 ha of land suitable for sugarcane cultivation which shows the capacity to produce over one billion liters of bio-ethanol [13]. (Girma, 2012). The current total area developed for the production of sugarcane in Ethiopia was only about 33.37% of the total identified suitable areas [7] (ESISC, 2008). In Ethiopia, currently, there were eight large-scale sugar factories among including Fincha Sugar Estate. The present level of national production from the eight-sugar estates was about 305,956.7 tons of white sugar per annum [33]. This shows high sugarcane production potential of the environment but not efficiently utilized and the annual demand was not yet satisfied. Expanding the area of production was not the only means to meet the national demand for sugar as well as earn foreign currency.

There are many biotic and abiotic factors limiting sugarcane production. However, among abiotic factors, the application level and types of fertilizer was a key factor in sugar production agro-industry [33]. Significantly higher cane and sucrose yield was achieved by the application of the correct fertilizer rates in sugarcane crop production. Nitrogen (N) and phosphorus (P) are the major nutrients required for higher and sustained sugarcane growth, yield, and quality [24]. Application of P, especially on P deficient soils were promoted root growth, stimulated tillering, and influences favorable better growth and thereby better yield and juice quality [3]. The wide variation in soil fertility was a major limitation to obtain higher yield goals which could be improved by balancing N, P, S and micronutrients [31].

Therefore, lack of blended fertilizer type and optimum rate of phosphorus is the major problem in limiting sugarcane yield and juice quality at Fincha Sugar Estate farm. However, the phosphorus rate and blended fertilizer at Finchaa sugar estate area has not been studied so that this research was meant to fill this gap to improve sugarcane yield and quality. Thus, this study was initiated with the aim of investigating the optimum level of Phosphorus and blended fertilizer on growth, yield, and juice quality of sugarcane.

2. Materials and Methods

2.1. Description of Experimental Site

The experiment was conducted at Finchaa Sugar Factory in the Nile basin, Oromia Regional State in Horro Guduru Wollega Administrative Zone at a distance of around 350 km Northwest of Addis Ababa. It is located at 90 47 '00.35" N latitude and 370 26'13.39" E, longitude and surrounded by steep escarpment along its southern, eastern and western sides, which rises approximately 1446 m above sea level by (using GPS instrument). The Factory has a semi-arid climate with an average maximum and minimum monthly temperatures of 30.6ºC and 14.5ºC, respectively. The valley has uni-modal rainfall distribution pattern with alternate wet and dry seasons with the major rain falling between June to September which has an average annual rainfall of 1309 mm [1]. The valley is positioned between 1350 to 1650 m above sea level and gently undulating with general slope of 1 to 8%. The soil type at the experimental site is Luvisol which occupies 73% of the valley‘s area[38]. Finchaa Sugar Estate is one of the sugar estates in Ethiopia which covers an area of 19,590.74 ha land with sugarcane crops[33].

2.2. Experimental Material

Sugarcane cultivar N-14 was used for the experiment based on its desirable agronomic and industrial characteristics and with its high percentage area (47.75%) coverage from the total area of 19,590.74 ha established in the Finchaa sugar estate. The variety N-14 which was originated in Natal South Africa and introduced from India. It has high stalk mass, tall stalk height, intermediate smut resistance, rapid stalk elongation, rapid canopy formation, profuse flowering, high resistance to lodging, medium stalk population, high cane yield and a higher percent of sucrose as compared to the other varieties growing at the estate (https://www.sasa.org.za). It is a widely adaptable variety in the sugar estate. The cane variety obtained from seed cane fields of the estate. Healthy three eyes budded setts with an average of 25-30 cm length and uniform diameter was prepared from the middle portion of the seed cane stalk.

Blended Fertilizers: Various types of blended fertilizer as a source of phosphorus like NPS (Nitrogen, phosphorus, and sulphur), NPSB (Nitrogen, phosphorus, sulphur, and Boron), NPSBZn (Nitrogen, phosphorus, sulphur, Boron, and Zinc) with a rate of (0, 57, 76, 114&152) kg P_2O_5.

Treatments and Experimental Design: The treatment consisted of two factors namely different blended fertilizers (NPS, NPSB, and NPSBZn) and phosphorus levels (0, 57, 76, 114, and 152 kg/ha). The experiment was laid out as a randomized complete block design (RCBD) in a 3x5 factorial arrangement (Table 1) with three replications. Each experimental plot had four furrows of 5m length and 1.45m width. The middle two furrows used to collect data and the remaining two furrows used as border rows. The total net area of each plot has 4 rows (5.8m) x 5 m (29m^2). The space between plots and blocks was 1m and 2.9m, respectively. Border space of 3-meter width had left to facilitate observation and serve as the demarcation between the experimental site and commercial field. The treatment combination also based on currently used a rate of 114 kg of P_2O_5 per hectare NPS in the estate and treatments were assigned to each plot randomly.

Table 1. *Treatment combinations of the experiment.*

Treatments	Treatments combination
1	NPS 0 kg P_2O_5 (Control)
2	NPS with 57 kg P_2O_5
3	NPS with 76 kg P_2O_5
4	NPS with 114 kg P_2O_5
5	NPS with 152 kg P_2O_5

Treatments	Treatments combination
6	NPSB with 0 kg P_2O_5 (Control)
7	NPSB with 57 kg P_2O_5
8	NPSB with 76 kg P_2O_5
9	NPSB with 114 kg P_2O_5
10	NPSBZn with 152 kg P_2O_5
11	NPSBZn with 0 kg P_2O_5 (Control)
12	NPSBZn with 57 kg P_2O_5
13	NPSBZn with 76 kg P_2O_5
14	NPSBZn with 114 kg P_2O_5
15	NPSBZn with 152 kg P_2O_5

The percent (%) of P_2O_5 in NPS, NPSB, and NPSBZn was 38, 37.4, and 35.7, respectively.

2.3. Soil Analysis

An initial soil sample at a depth of 0-30 cm was taken from five randomly selected spots diagonally across the experimental field using auger before planting. Similarly, surface soil (0-30 cm depth) samples were collected from every replication of each treatment and bulked to yield a total of 15 composite surface soil samples which is one composite soil sample per treatment after harvesting from the experimental plots. Then the collected soil samples were air-dried, grounded, sieved, and analyzed in the soil laboratory of FSRC for selected physicochemical properties mainly organic matter, total N, soil pH, available phosphorus, cation exchangeable capacity (CEC) and textural analysis using standard laboratory procedures.

Organic matter content was determined by the oxidation of organic carbon with acid potassium di-chromate ($K_2Cr_2O_7$) medium using the Walkley and Black method as described by Dewis and Freitas [6]. Total nitrogen was analyzed by the Micro-Kjeldahl method [15]. The pH of the soil was determined in 1:2.5 (weight/ volume) soil to water dilution ratio using a glass electrode attached to digital pH meter [21]. Cation exchange capacity was measured after saturating the soil with 1N ammonium acetate (NH4OAC) and displacing it with 1N NaOAC [5] Available phosphorus was determined using the Olsen method [23]. The analysis result on soil properties was summarized and presented in Table 2 and Table 3.

2.4. Crop Management Procedures

Land preparation: The land was conventionally prepared to a fine seedbed with a tractor and the fields were plowed four times and the individual plot was prepared manually.

Seed Cane Preparation: Ten months old, healthy, and three budded of N-14 variety seed cane setts were prepared from the seed cane field of the estate. The setts are prepared uniformly before planting. To protect the setts from various diseases cane knife was immersed in the solution (Ethanol (50%) with a rate of one liter of ethanol in one liter of water) for five minutes after each cutting of stool and chopping of one stalk. To protect the chopped setts from soil-borne diseases and pests after planting, the chopped seed material completely immersed in a fungicide called Bumper (propiconazole) 25 EC with a rate of 1ml per 1liter of water for five minutes using a steel wire basket after treatment [10].

Setts planting: The treated setts were planted in the furrow with 5 cm overlapping of setts arrangement on the pre-irrigated experimental field and applied with different sources (NPS, NPSB& NPSBZn) of phosphorus fertilizer with different rates of (0, 57, 76, 114 and 152kg/ha) P_2O_5, then again sprayed with a solution of two liters of dursban mixed with 200 liters of water as a per hectare rate basis at the time of planting to protect termite attack and covered with 5 cm layer of soil. The number of setts planted on 5 m length of furrow determined on the field at the time of planting based on an average length of setts. Urea fertilizer applied at the age of two months after planting consider with the amount that previously applied at the time of planting.

2.5. Data Collected

Cane Yield: Weight of cane /plot obtained using a crane, balance plus weight of sample stalks/plot collected for analysis and stalk parameter recording. This data was calculated by the weight of cane stalk multiplied by total stalk number present on a plot basis (14 months crop age).

Brix: The total soluble solids in the cane juice and it was expressed in Brix degree. This data was recorded by taking 10 cane stalks per plot and crushed the stalks with jefeco grinder. After that disntegrate1000gm of bagasse with 5000ml of water for 20 minutes and analysis it continuously.

Finally, the Brix% was measured using hydrometer by making necessary corrections with reference to temperature to obtain true Brix%. This measurement gives the concentration of all soluble compounds in juice, and not only sucrose. It was recorded in 14 months after planting (14-month crop age).

Pol cane /Sucrose: Pol is the actual cane sugar present in the juice. This data was recorded by taking 10 cane stalks per plot and crushed the stalks with jefeco grinder. After that disntegrate1000gm of bagasse with 5000ml of water for 20 minutes and analysis it continuously. Finally, measure the pol% using Polarimeter by making necessary corrections regarding temperature to obtain true pol%. This measurement gives the concentration of only sucrose.

Cane purity: It is a solution containing sucrose is the proportion by weight of sucrose to all dissolved solids, expressed as a percentage. It was recorded in 14 months after planting (14-month crop age):

$$\%\text{Purity} = \frac{\text{Pol x100}}{\text{Brix}}$$

Sugar yield: commercial sugar yield (Qt/ha) was calculated as the product of cane yield per hectare and recoverable sucrose percent accordingly. The average recoverable sucrose percent in Fincha is 11.55%. Then sugar yield per hectare was calculated as follows. Sy (t / ha)=Cy (t / ha) x Rs (%), Where: Sy=Sugar yield, Rs=Recoverable cane sucrose, Cy=Cane yield per hectare

2.6. Data Analysis

Data were subjected to analysis of variance (ANOVA) and analyzed by using the SAS software version 9.2 with the Proc GLM procedure [29]. Differences between means were separated using the LSD procedure at 5% and 1% level of significance.

3. Results and Discussion

3.1. Soil Physico-Chemical Analysis of the Experimental Site

Soil analysis before planting: The laboratory analysis result conducted at Fincha Sugar Factory Research Center soil laboratory on soil samples before planting and after crop harvesting are given in Table 2 and Table 3, respectively. The analysis indicated that the soil had medium levels of total nitrogen, available phosphorus, CEC, and low organic matter. The pH of the soil is 6.67 showing nearly neutral nature of the soil. FAO [8] reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Thus, the pH of the experimental soil is within the range for productive soils. The analytical results indicated that the textural class of the experimental site was mainly of clay soil with a proportion of 49% Clay, 41% Sand, and 10% silt (Table 2).

Table 2. *Selected physicochemical properties of soil of the study area before planting.*

Physical properties				Chemical properties				
Particle size distribution (%)			Textural Class	pH (1:2.5 H2O)	M (%)	Total N (%)	Avail P (ppm)	CEC (cmol/kg)
Sand	Silt	Clay						
21	30	49	Clay	6.67	1.95	0.19	9.91	26.45

Table 3. *Effects of blended fertilizers and phosphorus levels on some soil chemical properties after harvesting.*

Treatments	pH (1:2.5 H2O)	OM (%)	Total N (%)	Ava P (ppm)	CEC (cmol/kg)
BF					
NPS	7.09	0.97	0.091	6.76	29.62
NPSB	7.09	0.96	0.095	6.77	29.68
NPSBZn	7.08	0.96	0.091	6.78	29.60
Mean	7.09	0.96	0.092	6.77	29.63
LSD (0.05)	NS	NS	NS	NS	NS
P- Levels kg ha^{-1}					
0	**7.09**	**0.94**	**0.090**	**6.75**	**29.60**
57	7.09	0.95	0.088	6.74	29.62
76	7.09	0.97	0.094	6.77	29.65
114	7.08	0.98	0.090	6.78	29.60
152	7.11	0.95	0.091	6.80	29.68
Mean	7.09	0.96	0.092	6.77	29.63
LSD (0.05)	NS	NS	NS	NS	NS

NS=is not significantly different at 5% level of probability. LSD=Least significant difference and, P=phosphorus, BF=blended fertilizer, P=prosperous levels.

Soil analysis after harvesting: Soil pH, available P, total N, organic matter and CEC were measured to assess the post-harvest status of the soil. The blended fertilizers and levels of phosphorus exhibited non-significant effects on the above soil attributes (Table 3). Analysis of the soil samples after harvesting showed a reduction in total nitrogen, available P, and organic matter as compared to the contents before planting (Table 2, Table 3). The reason for the reduction of total soil nitrogen (from 0.092%) may be due to the removal of soil N through the vegetative growth of the crops. Other losses could be via denitrification, leaching, volatilization, and/or their combination [36]. Similarly, the available P and organic matter content of the experimental soil also declined from 9.91 ppm and 1.95% at planting to 6.77 ppm and 0.96% post-harvesting due to their utilization by the growing crop, respectively (Table 3).

Cation exchange capacity (CEC) is also an important parameter of soil because it indicates the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. According to Sahlemedihn [27], CEC by sodium acetate at pH 8.2 or ammonium acetate at pH 7.0 methods with values between 25 and 40 cmol kg^{-1} were high to medium and satisfactory for agriculture with the use of fertilizer. Accordingly, the CEC (ammonium acetate at pH 7.0) of the experimental soil is 26.45 cmol kg^{-1} (at planting) and increased to 29.63 cmol kg^{-1} (after harvesting) (Table 3).

3.2. Effect of Blended Fertilizers and Levels of Phosphorus on Cane Yield

Cane Yield: Analysis of variance showed a significant difference ($P<0.01$) for the main effects of blended fertilizer treatments and phosphorus rates for cane yield per hectare. But blended fertilizers and phosphorus rates interaction had a non-significant effect on cane yield per hectare (Table 4). NPSBZn which is highly influenced by blended fertilizer had the maximum cane yield (220.77 ton ha^{-1}) while mean cane yield per hectare for blended fertilizers showed that NPSB and NPS had the minimum cane yield (184.27 and 173.09 ton ha^{-1}), respectively (Table 5). This may be because of the blended fertilizer NPSBZn has a maximum number of tillers, millable canes, plant height, and thickness of cane stalks than the rest of blended fertilizers. So, cane yield is a function of cane weight and the number of millable canes. This finding conforms to Shrivastava [30] who reported that cane yield is a result of approximately 70% of millable canes, 27% of cane length, and 3% of cane girth. Toomsan and Limpinuntana [37] indicated that higher cane yield could be attributed to the higher number of tillers and millable cane. Jiang [16] also reported that the sugarcane yield per unit of land is composed of the millable canes and the cane weight. Zn application significantly affected the quantitative parameters of sugarcane including the yield of cane stalks [30].

Table 4. *Analysis of variance showing mean square values for yield and juice quality parameters of sugarcane as affected by blended fertilizers, level of phosphorus, and interaction of both factors at Fincha Sugar Estate in 2018/19 cropping season.*

Source of Variation	**DF**	**Mean square**				
		cane yield	**brix%**	**pol%**	**Purity%**	**Sugar yield**
Rep	2	1762.67	0.27	0.17	6.66	41.99
BF	2	9325.10**	3.77**	.69***	47.01**	364.85**
P- Levels	4	27195.23**	4.74**	9.53**	44.30**	501.88**
BF * P- Levels	8	554.41^{ns}	0.94^{ns}	1.57*	48.42***	49.15**
Error	28	533.49	0.46	0.49	7.68	7.69
CV		11.98	3.93	4.49	3.07	12.66

***,** and * significance at 0.001, 0.01 and at 0.05 level of probability, respectively, ns=non significant, CV=coefficient of variation; P=phosphorus, BF=blended fertilizer.

Table 5. *The main effect of blended fertilizers and levels of phosphorus on cane yield and Brix juice of sugarcane at Fincha Sugar Estate in 2018/19 cropping season.*

Treatment	**Cane yield (ton ha^{-1})**	**Brix (%)**
Blended Fertilizers (BF)		
NPS	184.27^{b}	17.45^{a}
NPSB	173.09^{b}	16.81^{b}
NPSBZn	220.77^{a}	17.79^{a}
SE±	5.96	0.17
LSD (0.05)	17.27	0.51
P-Levels (Kg ha^{-1})		
0	106.04^{d}	16.22^{c}
57	175.75^{c}	17.15^{b}
76	206.26^{b}	17.47^{ab}
114	233.00^{a}	18.10^{a}
152	242.51^{a}	17.81^{ab}
SE±	7.69	0.22
Mean	192.71	17.35
LSD (0.05)	22.30	0.19
CV%	11.98	3.93

Means followed by the same letters are not significantly different at 5% level of significance according to the LSD test. CV=coefficient of variation, LSD=Least significant difference, and SE=Standard of error, P=phosphorus.

Mean values for phosphorus rates showed that cane yield per hectare increased with each increment of phosphorus rates from the control to the highest rate but the two higher P rates are statistically at par (Table 5). The increased cane yield at the highest level of phosphorus was probably due to the availability of more nutrients, which helped for the occurrence of maximum cane weight and the number of millable canes. This result was in line with Bokhtail and Sakurai [4] who reported that the application of P, especially on P deficient soils stimulates tillering, and influences favorable better growth and thereby better cane yield. Maximum cane yield (242.51 and 233 ton ha^{-1}) was recorded at P rate of 152 and 114 kg ha^{-1}, respectively, while minimum cane weight (106.04 ton ha^{-1}) was recorded in the control (0 kg ha^{-1}) (Table 5) indicating that P rates of 152 and 114 kg ha^{-1} were not statistically significant to influence cane weight but P rates of 152 kg ha^{-1} were showed better influence than 114 kg ha^{-1} of P rates. This finding was lined with Omollo and Abayo [24] who reported that the levels of P increases significantly increased cane weight, plant height, and cane yield.

3.3. Effect of Blended Fertilizers and Levels of Phosphorus on Sugarcane Juice Quality

Brix of Juice (%): Analysis of variance showed significant differences ($P<0.01$) for the main effect of blended fertilizer treatments at various rates of phosphorus for brix of juice (Table 4). But the interaction effect of blended fertilizers and phosphorus rates was non-significant for brix of juice. Mean Brix percentage for blended fertilizers showed that NPS had the minimum Brix of juice (16.81%) while NPSBZn and NPSB which are highly influenced blended fertilizer had the maximum Brix percentage (17.79% and 17.45%), respectively (Table 5). This is because of micronutrients significantly affected the juice quality directly. This result was in line with Ghaffar et al. [12] report on Zn and B application in addition to NPS to sugarcane fields significantly affected the sugarcane juice including brix, pol, and purity. Franco et al. [11] also reported that the beneficial effect of Zn should be highlighted because its application significantly increased the values of brix percentage. So, brix (total soluble solids in a juice) is one of the qualitative parameters used for maturity judgment in sugar cane production [28].

Mean brix percentage for phosphorus rates showed that increased with each increment of phosphorus rates from the control to the highest rate up to a maximum point of phosphorus rates (114 kg ha^{-1}) and above these rates of phosphorus the effect was immediately decreased (Table 5). The increased brix percentage at the highest level of phosphorus was probably due to the availability of more nutrients, which helped for the accumulation of maximum brix in the cane juice. This result was in line with Pannu et al. [26] who reported that P application with different rates increase and conducive for higher brix percentage and sugar accumulation in cane juice. Malie et al.[20] reported that increasing phosphorus rates especially on P deficit soils increased the percentage of brix of sugar cane juice. However, as opposed to this result, Pannu et al., [26] and Majeedamo et al. [19] expressed the adverse effect of high phosphorus rate of application on brix of cane juice. The maximum percentage of brix (18.10%) followed by (17.81% and 17.47%) was recorded at P rate of 114 kg ha^{-1}, 152 kg ha^{-1} and 76 kg ha^{-1}, respectively, while the minimum percentage of brix (16.22%) was recorded in the control (0 kg ha^{-1}). In general, in this study the percentage of brix for blended fertilizers and phosphorus rates ranged between 16.81% (NPS) and 17.79% (NPSBZn), 16.22% (0kg ha^{-1}) and 18.10% (114 kg ha^{-1}) (Table 5).

Polarization of Juice (%): Analysis of variance showed significant differences (P<0.01) among blended fertilizer treatments, phosphorus rates, and their interaction for the pol percentage of juice. The interaction effect between rates of blended fertilizers at various phosphorus rates was found to be significant (P<0.05) for pol percentage (Table 4). NPSBZn blended fertilizer rate showed maximum pol percentage (17.70% and 17.58%) at the highest rate of phosphorus (114 and 152 kg ha^{-1}) application respectively (Table 6). This may be because zinc proved to highly effective, even when applied without boron in addition to NPS. Similarly, Bokhtiar et al.[4] indicated the highest pol percentage with micronutrient application including zinc. And combined application of boron and zinc proved to be more beneficial as compared to Zn or B application alone [22]. The rest of the blended fertilizers obtained maximum pol percentage at the P rate application of 57 kg ha^{-1} (16.55%) and 114 kg ha^{-1} (15.80%) for NPSB and NPS, respectively. Blended fertilizers NPSB showed maximum pol percentage at the control treatment compared to the rest of blended fertilizer (Table 6).

Table 6. *Interaction effect of blended fertilizers and levels of phosphorus on pol percentage and purity percentage of sugarcane juice at Fincha sugar Estate in 2018/19 cropping season.*

Interaction Effect of factors	**P-Levels (Kg ha^{-1})**											
	Pol (%)						**The purity of Juice (%)**					
Blended Fertilizers	**0**	**57**	**76**	**114**	**152**	**Mean**	**0**	**57**	**76**	**114**	**152**	**Mean**
NPS	14.03^{h}	14.15^{gh}	14.99^{ef}	15.63^{cde}	16.00^{cde}	14.96	87.89^{def}	83.40^{f}	90.40^{bcd}	90.44^{bcd}	88.29^{cd}	88.08
NPSB	14.37^{gh}	16.55^{bc}	16.07^{cde}	16.20^{cde}	16.11^{cde}	15.86	87.79^{def}	94.77^{ab}	87.66^{def}	88.07^{cd}	94.39^{ab}	90.53
NPSBZn	13.66^{h}	15.46^{ef}	16.67^{bc}	17.70^{a}	17.58^{ab}	16.21	83.55^{f}	90.98^{bcd}	93.5^{ab}	97.19^{a}	94.39^{ab}	91.92
Mean	14.02	15.38	15.91	16.51	16.56		86.41	89.71	90.52	91.9	92.35	
SE$\pm$	0.18						0.71					
LSD (0.05)	0.11						0.15					
CV%	4.39						3.06					

Table 7. *Interaction effect of blended fertilizers and levels of phosphorus on sugar yield of sugarcane at Fincha Sugar Estate in 2018/19 cropping season.*

Interaction Effect of factors	**P-Levels (Kg ha^{-1})**					
	Sugar yield (ton ha^{-1})					
Blended Fertilizers	**0**	**57**	**76**	**114**	**152**	**Mean**
NPS	10.74^{f}	16.35^{de}	21.20^{bcd}	22.06^{bc}	22.92^{bc}	18.65
NPSB	9.80^{f}	17.72^{cd}	20.79^{bcd}	25.37^{b}	23.61^{b}	19.45
NPSBZn	12.02^{ef}	23.03^{b}	24.66^{b}	40.77^{a}	41.37^{a}	27.57
Mean	10.85	19.03	22.21	28.06	29.3	
SE$\pm$	0.71					
LSD (0.05)	0.10					
CV%	14.42					

Means followed by the same letters are not significantly different at 5% level of significance according to the LSD test. CV=coefficient of variation, LSD=Least significant difference, and SE=Standard of error, P=phosphorus.

On the other hand, NPSBZn and NPS Blended fertilizers showed the lowest pol percentage for the control treatment (Table 5). In general, in this study, the percentage of pol ranged between 13.66% (NPSBZn) and 17.70% (NPSBZn) (Table 6). However, reports of Pannu et. al. [26] and Majeedamo et al.[19]contradict the present study by reporting the adverse effect of high phosphorus rate of application on the percentage of pol in cane juice.

The purity of juice (%): The result showed significant differences (P<0.01) among blended fertilizer treatments, phosphorus rates, and their interaction effect for purity of sugarcane juice (Table 4). Furthermore, NPSBZn blended fertilizer was showed maximum purity of juice (97.19%) at the highest rate of phosphorus 114 kg ha^{-1} (Table 6) indicating zinc proved to be highly effective, even when applied without boron in addition to NPS. This study conforms to Bokhtiar et al.[4]. Mariano et al. [22] also reported that the combined application of boron and zinc proved to be more beneficial as compared to Zn or B application alone. Franco et al. [11] also reported that the beneficial effect of Zn should be highlighted because its application significantly increased the values of sugar yields. The rest of the blended fertilizers obtained maximum juice purity percentage at the P rate application of 152 kg ha^{-1} (94.39%) and 57 kg ha^{-1} (94.77%) for NPS and NPSB, respectively. Blended fertilizers NPS & NPSB showed maximum juice purity (87.89% and 87.79%) at the control treatment, respectively compared to the rest one blended fertilizer. On the other hand, NPSBZn blended fertilizers were lowest for juice purity (83.55%) at the control treatment. In general, in this study, the purity juice ranged between 83.55% (NPSBZn) and 97.19% (NPSBZn) (Table 6). However, Pannu et al.[26] and Majeedamo et al. [19] report the adverse effect of high Phosphorus rate of application on the purity of juice. Farias et al.[9]also did not confirm the Zn benefits in the sugarcane technological quality including purity of juice. This deviation might be due to the different in climatic and soil conditions.

Sugar Yield: The result showed significant differences ($P<0.01$) among blended fertilizer treatments, phosphorus rates, and their interaction for sugar yield (Table 4). NPSBZn blended fertilizer was showed maximum sugar yields (41.37 and 36.77) ton ha^{-1} at the highest rate of phosphorus (152 and 114 kg ha^{-1}) application, respectively (Table 7) showing that zinc proved to be highly effective, even when applied without boron in addition to NPS. And Bokhtiar et al., [4] also obtained the highest sugar yield with micronutrient applications including zinc. Mariano et al.[22] reported that the combined application of boron and zinc proved to be more beneficial as compared to Zn or B application alone. The rest of blended fertilizers obtained maximum sugar yield at the P rate application of 152 and114 kg ha^{-1} for NPS and NPSB, respectively. Blended fertilizers NPSBZn showed maximum sugar yields at the control treatment compared to the rest of one blended fertilizer (Table 7). Similarly, Franco et al. [11] reported the beneficial effect of Zn should be highlighted because its application significantly increased the values of sugar yields.

Another report showed maximum cane yield (tons/hectare), millable cane, and cane weight (kg) were obtained at two locations from the treatment and blended fertilizer was reported to have better effect on growth and cane yield of sugarcane than straight fertilizer [2](Afghan et al., 2014). Furthermore, soil application of Zn enhanced cane yield (111.9 t ha^{-1}) and the foliar application of B resulted produced highest cane yield attributes specifically cane yield (107.4 t ha-1), brix (21.9%). And its interaction effects increased distinctively cane yield (119.0 t ha-1) and brix (24.0%), [21] (Mangrio1 et al., 2020).

On the other hand, NPS and NPSB Blended fertilizers showed the lowest sugar yields at the control treatment. In general, in this study, the yield of sugar ranged between 9.80 ton ha^{-1} (NPSB) to 41.37 ton ha^{-1} (NPSBZn) (Table 7). As opposed to this, Pannu et al.[26] and Majeedamo et al.,[19] indicating the adverse effect of high Phosphorus rate of application on cane juice quality and sugar yield. Farias et al. [9] also did not confirm the Zn benefits in the sugarcane technological quality including sugar yield.

3.4. Economic Analysis of Blended Fertilizers and Levels of PHOSPHORUS on Sugar Yield

Economic returns of sugarcane due to fertilizer application were worked out according to prices of fertilizer and sugarcane during 2018/19. It is evident from data in Table 8 that maximum Economics returns (19405.44 USD) was obtained from NPSBZn 114kg ha^{-1} followed by NPSBZn 152kg ha^{-1} and NPSB 114kg ha^{-1} with Economic returns (19347.66 USD and 12031.71 USD, respectively, as compared to control treatment.

Table 8. *Economic Analysis of Sugar yields ha^{-1} due to Blended Fertilizers and levels of Phosphorus Application at Fincha Sugar Estate in 2018/2019 cropping season.*

Blended Fertilizers	P- levels (Kg)	Sugar yields (tons)	Increased sugar (tons)	Gross income (USD)	Cost of fertilizers (USD)	Net income (USD)
NPS	0	10.74	-	5155.2	50.6	5104.6
NPS	57	16.35	5.61	7848.0	102.5	7745.5
NPS	76	21.20	10.46	10176	119.8	10056.2
NPS	114	22.06	11.32	10588.8	154.4	10434.4
NPS	152	22.92	12.18	11001.6	189.0	10812.6
NPSB	0	9.8	-	4704.0	50.6	4653.4
NPSB	57	17.72	7.92	8505.6	98.1	8407.5
NPSB	76	20.79	10.99	9979.2	114.1	9865.1
NPSB	114	25.37	15.57	12177.6	145.9	12031.7
NPSB	152	23.61	13.81	11332.8	177.3	11155.6
NPSBZn	0	12.02	-	5769.6	50.6	5719.0
NPSBZn	57	23.03	11.01	11054.4	106.9	10947.5
NPSBZn	76	24.66	12.64	11836.8	125.6	11711.2
NPSBZn	114	40.77	28.75	19569.6	163.2	19406.3
NPSBZn	152	41.37	29.35	19587.6	239.9	19347.7

N. B: Prices of NPS: 0.423 USD/kg, NPSB: 0.44USD NPSBZn: 0.44USD/kg and Urea: 0.41 USD/kg. Other costs were similarly used on each treatment.

The statistical analysis showed that the main effect and interaction effects of the main effect of blended fertilizers at different levels of phosphorus were highly significantly ($p<0.001$) for all parameters studied except for cane yield and brix% where interaction effect was not significant. Thus, the maximum cane yield was recorded in the blended fertilizer NPSBZn with 152 and 114 kg ha^{-1} levels of phosphorus. The maximum mean values of brix were recorded in NPSBZn and NPS (17.79 &17.45%), respectively. The highest mean value of brix (18.10%) was obtained from plots treated with 114 kg ha^{-1} level of phosphorus. Similarly, the highest polarization (17.70%) was obtained from NPSBZn fertilizer at the levels of 114 kg ha^{-1} phosphorus while the lowest pol (14.03 and 14.37%) was recorded from NPSB and NPSBZn at the control of 0 kg ha^{-1} phosphorus levels. While the highest cane juice purity (97.19%) was obtained from NPSBZn fertilizer at the levels of 114 kg ha^{-1} phosphorus. And the highest sugar yields 40.77 tons ha^{-1} was obtained from NPSBZn fertilizer at the levels of 114 kg ha^{-1} phosphorus while the lowest (10.74 and 9.8 tons ha^{-1}) was recorded from NPSB and NPS at the control of 0 kg ha^{-1} phosphorus levels, respectively. Generally, it can be suggested based on cane yield and juice quality and economical analysis, blended fertilizer NPSBZn and 114 kg ha-1 was the best-blended fertilizer and correct combination among the rest blended fertilizers and levels of phosphorus.

Statement of Conflict of Interest

The authors declare that there is no conflict of interest.

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