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PRODUCȚIA ȘI CALITATEA FRUCTELOR LA SOIUL DE PIERSIC 'TROPIC BEAUTY' (*PRUNUS PERSICA* L.) ÎN FUNCȚIE DE DISTANȚA DINTRE RÂNDURI ȘI DE RATA DE FERTILIZARE NPS

YIELD AND FRUIT QUALITY OF PEACH (*PRUNUS PERSICA* L.) VAR. 'TROPIC BEAUTY' AS AFFECTED BY INTRA-ROW SPACING AND NPS FERTILIZER RATE

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Abstract

Peaches have been cultivated for a long time in Ethiopia using conventional agronomic and production technologies. Therefore, the study's objective was to assess the intra-row spacing and NPS fertilizer rate effect on peaches' yield and fruit quality performance. Thus, the study was set up in a factorial randomized complete block design with three replications, with three levels of intra-row spacing (4m, 5m, and 6m) and four levels of NPS fertilizer rates (0kg/ha, 100kg/ha, 150kg/ha and 200kg/ha) with constant inter-row spacing of 4m. Marketable and total yield, yield efficiency, average fruit weight, and crop load as well as fruit physicochemical quality parameters have been assessed. Most of the parameters evaluated have been affected by the interaction of intra-row spacing and NPS fertilizer rate. The overall result showed that intra-row spacing of 5 m and 150 kg/ha NPS fertilizer produced the highest yield with 20.38 tons/ha. It showed optimum results in fruit physicochemical quality properties, and delivered a maximum net return of (3,618,280 ETB), according to the results of the economic analysis as well. Therefore, planting peaches using 5 m intra-row (between plants) spacing with 150 kg/ha of NPS fertilizer application could be recommended under similar growing conditions.

Cuvinte cheie: îngrășământ, distanța, calitate, producție.
Key words: fertilizer; spacing, quality, yield

1. Introduction

The peach fruit is a relatively low source of calories as it comprises 87% water. On the other hand, it is rich in minerals and vitamins. The abundant antioxidant chemicals found in peaches are primarily responsible for their health advantages. Cardiovascular advantages, anti-cancer activity, eye health, bodily detoxification, dental health, weight loss, anti-diabetes activity, and antioxidant activity are a few health benefits (Hussain et al., 2021). For farmers, each serves a variety of purposes, including assuring food and nutrition security and diversifying their crop yields (Linger, 2014). It has a significant potential for mitigating climate change and preserving natural resources because it is environmentally benign and simple to integrate into the Highlands' agro-forestry program (Thorlakson and Neufeldt, 2012).

Agronomic management, which raises productivity per unit area is one of the primary methods of increasing fruit yield per hectare and ensuring net income, profitability, and great economic efficiency. The main objective of fruit cultivation is to obtain the highest possible production of superior-quality fruits at the lowest feasible cost (Westwood, 1995). Hence, fruit tree production requires specific practices to increase productivity and fruit quality (El-Razek et al., 2012).

Fertilizer recommendations have been practiced for peach cultivation in temperate regions that may not reflect current cultivation practices (Casamali et al., 2021). This requires optimization of fertilizer management for the successful production of peaches. Because there are reasons concerning over-fertilization and its effect on the balance between vegetative and reproductive growth, environmental pollution due to fertilizer runoff, and inefficient use of financial resources (Albornoz, 2016), however, its application effect on peach yield and quality is dependent on climatic factors and management practices as well as the interaction of multiple factors such as genotype and rootstock that can differ according to different growing areas (Gullo et al., 2014). Overall, in most cases, fertilizer application is necessary to preserve fruit quality and yield, and excessive fertilization is commonly used to achieve maximum yield and profit (Cai et al., 2023).

The number of individual plants per unit of ground area is referred to as plant density. The capacity of the plant canopy to gather environmental resources such as radiation energy, water, and inorganic nutrients can be enhanced in an optimal plant population (Shi et al., 2016). Greater productivity is encouraged by high plant densities while larger fruits may generally be harvested at lower densities (Qiu et al., 2013), which drives up prices in the fresh fruit market. Mostly, a high planting density is utilized for greater yields without raising production costs (Horschutz et al., 2012) since yield and yield-related traits are significantly influenced by the plant population (Chaudhuri and Baruah, 2010). According to (Chaudhuri and Baruah, 2010), the marketable yield was found to improve dramatically with increased plant population density per unit area. Contrarily, low plant population densities resulted in more leaf surfaces being exposed to sunlight and a greater amount of assimilates accumulated in various plant organs due to increased bunch weight.

Significant studies on planting density and rate of fertilizer treatments have been done on peaches in major growing areas worldwide. Irrespective of a long peach cultivation history in Ethiopia, conventional orchard management practices have been undertaken and limited research efforts were done. Due to that sufficient production technologies and information, particularly on the impacts of fruit tree density and rate of fertilizer on the yield and quality of fruit crops are lacking. Because of that, this study was designed to evaluate the effect of intra-row spacing and NPS fertilizer rate on the yield and fruit quality performance of peaches.

2. Material and methods

2.1. Experimental site description

The trial was conducted at Holetta Agricultural Research Center (9° 00’ N latitude, 38° 30' E longitude, and 2400 masl. elevation), which is found in the central highlands of Ethiopia. The average annual rainfall in the area was 1236.9 mm and the relative humidity of 68.4 percent. The average annual minimum and maximum temperatures were 7.3 and 23.5 °C, respectively (Fig. 1).

2.2. Treatment Setup

Peach seedlings variety Tropic Beauty was established in 2017 using a randomized complete block design arranged in a factorial experiment replicated three times. The treatments included three levels of intra-row spacing with 4 m, 5 m, and 6 m and four different rates of NPS fertilizer (0 kg/ha, 100 kg/ha, 150 kg/ha, and 200 kg/ha) at a constant inter-row spacing of 4 m. All the field management practices like irrigation, weeding, disease and pest management, pruning, and training were equally performed.

2.3. Data Collection

Pre-fertilizer application soil sample was taken at 0-30cm depth from each replication from all plots. Then the collected samples were composited into one sample for each replication. The bulked samples were dried and ground to pass a 2 mm sieve for soil physical and chemical quality laboratory analysis.

Post-fertilizer application soil samples were collected following the same procedure. Four soil samples were taken per tree from each plot and bulked and labeled into one sample per plot. Thereafter, each sample was air-dried and taken to the laboratory for soil Physico-chemical quality analysis. The pH was measured with the 1:2.5 H_2O methods whereas phosphorous and total nitrogen were analyzed following the methods of Bray II (Khalid et al., 1977) and Kjeldhal (Bremner and Mulvaney, 1982) respectively. Soil textural (sand, silt, and clay) analysis was done following the hydrometric method.

Data on yield and yield components such as marketable and total fruit yield, crop density, and yield efficiency were collected in each cropping season. Besides, both physical fruit qualities (average fruit weight, fruit length, fruit diameter, and fruit shape index) and chemical fruit qualities of total soluble solid (TSS) and pH were recorded.

2.4. Statistical Data Analysis

The data were subjected to analysis of variance (ANOVA) using SAS version 9.3 (SAS, 2017) and interpretations were made following the procedure of (Gomez and Gomez, 1984). The mean separation was done using the Least Significance Difference test at a 5% level of significance.

2.5. Partial Economic Analysis

Economic analysis was performed to investigate the economic feasibility of the treatments by using partial analyses. This analysis was done based on the CIMMYT approach. The average open market price (Birr kg^{-1}) for peach fruits, the official prices of fertilizers, and labor costs to apply fertilizer were used for analysis.

3. Results and Discussions

3.1. Soil analysis

The experimental site had a proportion of 7.75% sand, 27.25% silt, and 65% clay which is classified as clay according to the soil texture triangle (Table1). The soil pH on the other hand was 6.4 which was acidic (Tekalign, 1991) supported this result as soils having pH values in the range of 6.73 to 7.3 are considered neutral soils. The soil sample also comprised 0.155% total N and thus could be rated as low (Landon, 1991). The experimental soil also contained an available P of 7.596 ppm which can be grouped as a low level of available P (Olsen et al., 1954).

Post-fertilizer application soil chemical characteristics result was presented in Table 2. The result showed that the soil pH after fertilizer application was decreased for most of the treatments except for a slight decrement in intra-row spacing of 5 m with no NPS fertilizer, intra-row spacing of 6 m with no NPS fertilizer and intra-row spacing of 4 m with 150 kg/ha NPS fertilizer. This implies that fertilizer application had increased soil acidity. However, the pH of all treatments was not beyond the normal pH range required for peach production, which is 6-7 (Kamas et al. 2013). Whereas, available phosphorous showed an increment in all treatments except for those treated with zero NPS fertilizer rates. When an increased amount of NPS fertilizer is applied, the availability of phosphorous also increases but it might hurt its effectiveness if its amount is beyond the required level (Taylor and Issell, 1971). The post-fertilizer application total nitrogen had increased for all treatments except the intra-row spacing of 4 m with 200 kg/ha NPS fertilizer treatment.

3.2. Yield parameters

The analysis of variance result showed that the marketable and total yield of the peach has been significantly ($p<0.05$) affected by the interaction of intra-row spacing and NPS fertilizer (Table 3). There were linear yield increments observed for three successive cropping seasons in most of the treatments except intra-row spacing of 5 m with 100 kg/ha NPS fertilizer and intra-row spacing of 6 m with 100 kg/ha NPS fertilizer treatments. In 2020 the lowest yield was exhibited from treatment of 5 m intra-row spacing with 150 kg/ha NPS fertilizer but it showed great progress in the second and third cropping seasons. Among all treatments, the highest cumulative marketable yield was obtained from treatment 5 m intra-row spacing with 150 kg/ha NPS fertilizer yielded 19.34 tons/ha. Only 33% of the treatments gave more than the mean marketable yield. (Richard and Donald, 2000) Also, it was reported that planting density significantly affected the marketable yield of peach trees. Generally, marketable yield increased with respective production seasons this might be due to the foliar carbohydrate accumulated from the previous year (Parent et al., 2021). The total yield of peach fruits also showed a similar trend in terms of increment regardless of intra-row spacing of 6 m with 150kg/ha NPS, intra-row spacing of 5m with 100 kg/ha NPS, and intra-row spacing of 6 m with 100 kg/ha NPS fertilizer treatments. The highest yield of 20.38 tons/ha was obtained from 5 m intra-row spacing with 150 kg/ha NPS fertilizer treatment and the lowest with 9.40 tons/ha was from intra-row spacing of 6 m with 100 kg/ha NPS fertilizer treatment. Generally, about 66.7 % of the treatments were set below the grand mean yield. A similar linear increment in the total yield of high-density peach orchards was observed by (Layne et al., 1996). These results might be because higher spacing exhibited sufficient availability of resources and ultimately resulted in higher synthesis of photo-assimilates and more partitioning to the food reserves (Srivastava et al., 2017). Fertilizer application can increase the yield of peaches by 26.5% (Cai et al., 2023).

The yield efficiency and crop load of peach trees received a statistically significant ($p<0.05$) variability due to the intra-row spacing and NPS fertilizer rate (Table 4). The yield efficiency was decreased in most of the treatments except for treatment 5 m x 150 kg/ha. Accordingly, the highest mean yield efficiency was obtained from intra-row spacing of 4 m without NPS fertilizer treatment which might be because of the number of plants per a given area. Overall, of the total treatments, only 25% was recorded as the highest yield efficiency as compared to the mean. Yield efficiency, which is the weight of fruit per trunk cross-sectional area, directly relates yield with vegetative growth. The two major factors affecting yield (light interception and crop load) allow a more general predictive relationship to be established for any growing area (Reginato et al., 2007). Crop load, which is the number of fruits per trunk cross-sectional area (Lombard et al., 1988), was highest at the treatment of 4 m intra-roe spacing without NPS fertilizer in 2020 and 2022 cropping seasons with respective values of 452 and 102 fruit/cm^2. According to (Maboko et al., 2011) closer spacing results in a higher number of marketable fruits. In 2021 however, the highest crop load of 102 fruit/cm^{2}was recorded at the intra-row spacing of 5 m without NPS fertilizer treatment. Conversely, the crop load combined over the years was statistically higher at the treatments without NPS fertilizer. About 33% of the treatments showed the highest crop load as compared to the mean. Many studies have shown a linear correlation between crop load and yield efficiency (Johnson and Handley, 1989).

3.3. Physicochemical Properties

The average fruit weight was significantly (p<0.05) affected by the interaction between intra-row spacing and NPS fertilizer rate (Table 5). Accordingly, there were non-significant variations in average fruit weight between treatments during the first cropping season. However, fruit weights have become increased along with tree age particularly in 200 kg/ha NPS fertilizer-treated ones with all intra-row spacing. This might be due to the large amount of available nutrients. The combined analysis over three years result indicated that the heaviest fruits were obtained from treatment of 5 m intra-row spacing with 200 kg/ha NPS fertilizer with 96.63 grams though it was significantly at par with six of the treatments. About 66.7% of the treatments showed the heaviest fruits as compared to the mean. The application of fertilizers significantly affected the physical parameters and increased the average fruit weight of peach fruits (Bussi et al., 1994). Tree density also significantly influences the average fruit weight of peaches (Richard and Donald, 2000).

The physical quality properties of peach combined over three years were statistically affected by the interaction of intra-row spacing and NPS fertilizer rate (Table 5). The highest fruit length and breadth were obtained from treatment of 4 m intra-row spacing with 100 kg/ha NPS fertilizer with respective values of 5.27 cm and 5.65 cm. About 58% of the treatments recorded more fruit length as compared to the mean. Whereas, 42% of the treatments showed more fruit diameter as compared to the mean. Fertilization might be responsible for the highest fruit length, and improved fruit diameter (Bybordi, 2013). Agreeably, a significant increment in the physical parameters of cherry, peach, plum, and nectarine was observed (Ahmed et al., 2010, Banyal et al., 2014, Verma et al., 2017 and Singh et al., 2015). Both fruit length and breadth contributed to the shape of the fruit since the shape index is calculated by dividing the length by breadth. Therefore, this result indicated that the fruit shape indexes were less than one, which indicated that the fruits were more likely to have round shapes. This showed that spacing as well as fertilizer rate could not be able to influence the shape of peach fruit but rather variety might be the reason. But as compared to the mean 75% of the treatments showed more fruit shape index.

As presented in Table 6 below, the combined over years chemical quality parameters of peach fruits were significantly (p<0.05) affected by the interaction of intra-row spacing and NPS fertilizer rate. The highest TSS was obtained from treatment of 6 m intra-row spacing with 200 kg/ha NPS fertilizer treatment with 14.19 ^{o}Brix although was statistically at par. Whereas, the lowest was recorded from the treatment of 5 m intra-row spacing without NPS fertilizer with 10.87 ^{o}Brix. From the total treatments about 50% showed higher total soluble solids as compared to the mean. (Sarrwy et al., 2012) Confirmed that the highest soluble solids concentration (^{o}Brix) was measured from the highest plant spacing. Fertilizers had significant effects on the TSS of the fruit (Bakheit and Elsadig, 2015). On the other hand, the highest specific gravity (1.057), which is directly related to the TSS as a result the highest specific gravity, was obtained from treatment at 6 m intra-row spacing with 200 kg/ha NPS fertilizer. However, the lowest specific gravity (1.044) was recorded in the treatment of 5 m intra-row spacing without NPS fertilizer. However, the rest of the specific gravities of the treatments were between 1.044 and 1.057. About 58% of the treatments give more specific gravity above the mean. The highest e pH was also obtained from treatments of 4 m intra-row spacing without NPS fertilizer and 6 m intra-row spacing with 100 kg/ha NPS fertilizer treatments with values of 3.44 each. Whereas, the lowest pH was recorded at the treatment of 4 m intra-row spacing with 150 kg/ha NPS fertilizer with a value of 3.33. Generally, 50% of the treatments gave more pH as compared to the mean. However, all of the pH values oscillated in the normal range (3.3 to 4.05) based on the USDA standard. However, the fruit quality is more affected by annual conditions (e.g. yield, weather, harvest time) than by tree density (Widmer and Krebs, 2001) while the application of fertilizer can improve the peach fruit weight (14.5%), fruit diameter (4.2%), fruit length (4.8%), and soluble solids by 9.1% (Cai et al., 2023).

3.4. Partial economic analysis

The economic analysis of peach as affected by different fertilizer rates and intra-row spacing showed that the maximum net return (3,618,280 ETB) was obtained from the treatment of 5 m intra-row spacing with 150 kg/ha NPS fertilizer (Table 7). The highest marginal rate of return (10131.2%) was also obtained from a treatment combination of 5 m intra-row spacing with 150kg/ha NPS fertilizer. The analysis of the marginal rate of return (MRR) indicated that the application of blended NPS fertilizer on the productivity of peach fruit had an MRR of greater than 100. According to (CIMMYT, 1987), the application of fertilizer with a marginal rate of return above the minimum level (100%) is economical. Based on the present result all treatments except 5 m intra-row spacing with 150 kg/ha NPS fertilizer rate marginal rate of return (10131.2%) and 6 m intra-row spacing with 150 kg/ha NPS fertilizer rate (6015.5%) had resulted in a negative cost of production. Many producers are interested in applying fertilizers for increasing yield but it is essential to consider the profit out of it. The type and amount of fertilizer, cost of fertilizer, and price of yield are determining factors for maximizing profit (Black, 1992).

4. Conclusion

The overall outcome of this study showed that the interaction between intra-row spacing and NPS fertilizer had a substantial impact on the majority of yield and quality metrics. The treatment of 5 m intra-row spacing with 150 kg/ha NPS fertilizer produced the highest yield (20.38 tons/ha). On the other hand, 5 m intra-row spacing with 200 kg/ha NPS fertilizer gave the heaviest fruit as compared to all the other treatments. The more rounded fruit's shape suggested that variety was more responsible rather than treatments. Besides, the 5 m intra-row spacing with 150 kg/ha NPS fertilizer treatment was superior in fruit TSS as well as in cost-effectiveness. Especially, the 5 m intra-row spacing with 150 kg/ha NPS fertilizer treatment dominated most of the yield and fruit quality parameters and could be used for peach production with similar soil conditions. However, additional variables such as geographical locations, weather conditions, tree age, and variety might be addressed.

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Tables and Figures

Table 1. Pre-fertilizer application soil characteristics of the experimental field

Soil parameters	**Unit**	**Value**
Sand	%	7.75
Silt	%	27.25
Clay	%	65
pH	-	6.4
Available phosphorous	Ppm	7.596
Total nitrogen	%	0.155

Table 2. Post fertilizer application soil characteristics of experimental plots

Treatments		pH	P (ppm)	N (%)
Spacing (m)	NPS (kg/ha)			
4	0	6.21	6.530	0.157
5	0	6.50	5.996	0.169
6	0	6.46	6.528	0.161
4	100	6.20	7.730	0.170
5	100	6.27	9.997	0.175
6	100	6.15	7.995	0.164
4	150	6.45	8.130	0.159
5	150	6.38	12.125	0.179
6	150	6.20	11.989	0.170
4	200	5.92	13.722	0.155
5	200	6.28	11.194	0.158
6	200	6.02	13.727	0.161

NPS = blend of nitrogen, phosphorous, and sulfur fertilizer; P = available phosphorous; N = total nitrogen

Table 3. Yield performance of peach var. Tropic Beauty as affected by intra-row spacing and NPS fertilizer rate during 2020-2022

Treatments		Marketable yield (ton/ha)				Total yield (ton/ha)			
Spacing (m) (a)	NPS (kg/ha) (b)	2020	2021	2022	Combined	2020	2021	2022	Combined
4	0	8.42^{a}	8.21^{g}	23.26^{c}	13.30^{c}	9.36^{a}	8.21^{g}	23.87^{c}	13.81^{c}
5	0	7.16^{c}	12.34^{d}	24.46^{b}	14.65^{b}	7.75^{d}	12.37^{d}	24.95^{b}	15.02^{b}
6	0	6.37^{f}	7.67^{h}	16.84^{d}	10.29^{f}	6.69^{e}	7.67^{g}	17.54^{d}	10.64^{f}
4	100	8.00^{b}	12.11^{d}	15.78^{e}	11.96^{d}	8.75^{bc}	12.44^{d}	16.15^{e}	12.44^{d}
5	100	8.33^{a}	12.82^{c}	8.92^{h}	10.02^{g}	9.17^{ab}	13.07^{c}	9.12^{h}	10.45^{fg}
6	100	7.20^{c}	12.34^{d}	7.86^{i}	9.13^{h}	7.76^{d}	12.41^{d}	8.04^{i}	9.40^{h}
4	150	7.86^{b}	11.18^{e}	16.73^{d}	11.92^{d}	8.73^{bc}	11.22^{ef}	17.35^{d}	12.43^{d}
5	150	6.66^{ef}	13.98^{b}	37.39^{a}	19.34^{a}	7.33^{d}	14.00^{b}	39.81^{a}	20.38^{a}
6	150	7.13^{cd}	18.36^{a}	13.80^{f}	13.10^{c}	7.79^{d}	18.87^{a}	14.47^{f}	13.71^{c}
4	200	7.87^{b}	11.28^{e}	13.81^{f}	10.99^{e}	8.50^{c}	11.34^{e}	14.36^{f}	11.40^{e}
5	200	6.70^{e}	10.75^{f}	12.13^{g}	9.86^{g}	7.65^{d}	10.77^{f}	12.44^{g}	10.29^{g}
6	200	6.84^{de}	10.91^{ef}	15.25^{e}	11.00^{e}	7.39^{d}	10.91^{ef}	15.60^{e}	11.30^{e}
Mean		7.38	11.83	17.19	12.13	8.07	11.94	17.81	12.61
LSD (0.05)		0.32	0.39	0.54	1.01	0.49	0.55	0.57	1.01
CV (%)		2.57	1.97	1.88	8.84	3.64	2.73	1.89	8.49
Significance	a	ns	**	**	*	*	**	**	*
	b	ns	**	**	**	ns	**	**	**
	a*b	**	**	**	*	*	**	**	*

*Means with the same letter are not significantly different; LSD (0.05) =least significant difference; CV (%) =coefficient of variation; ns=non-significant; *=significant at 5% probability level; **=significant at 0.1% probability level*

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Table 4. Average fruit weight, yield efficiency, and crop density due to spacing and NPS fertilizer rate during three cropping seasons

Treatments		Average fruit weight (gm)				Yield efficiency (kg/cm^2)				Crop load (Number of fruits/cm^2)			
Spacing (m)	NPS (kg/ha)	2020	2021	2022	Combined	2020	2021	2022	Combined	2020	2021	2022	Combined
4	0	71.32^{a}	103.30^{ab}	95.09^{a}	89.90^{ab}	9.74^{a}	2.24^{c}	3.26^{a}	5.08^{a}	451.5^{a}	65.6^{c}	101.7^{a}	206.3^{a}
5	0	76.21^{a}	95.26^{b}	69.50^{f}	80.32^{c}	5.27^{c}	4.81^{a}	2.50^{b}	4.19^{b}	142.5^{d}	102.1^{a}	72.1^{b}	105.5^{b}
6	0	74.94^{a}	93.62^{b}	83.17^{d}	83.91^{bc}	7.97^{b}	2.09^{cd}	2.56^{b}	4.21^{b}	212.9^{b}	44.5^{de}	61.6^{c}	106.4^{b}
4	100	86.01^{a}	104.67^{ab}	77.02^{e}	89.23^{ab}	3.91^{d}	1.40^{cd}	0.61^{de}	1.97^{de}	142.9^{d}	43.6^{def}	23.7^{e}	70.1^{d}
5	100	78.88^{a}	103.37^{ab}	78.99^{e}	87.08^{bc}	4.15^{d}	1.91^{cd}	0.26^{e}	2.10^{cd}	105.4^{e}	40.8^{ef}	6.6^{h}	51.0^{f}
6	100	86.78^{a}	94.75^{b}	88.49^{b}	90.01^{ab}	3.73^{d}	3.40^{b}	0.28^{e}	2.47^{c}	92.2^{f}	71.1^{b}	6.4^{h}	56.6^{e}
4	150	73.31^{a}	100.36^{ab}	87.49^{bc}	87.06^{bc}	3.79^{d}	1.31^{cd}	0.89^{cd}	1.80^{de}	157.3^{c}	39.2^{f}	30.6^{d}	75.7^{c}
5	150	83.89^{a}	95.14^{b}	88.61^{b}	89.21^{ab}	1.76^{e}	1.95^{cd}	2.87^{ab}	2.19^{cd}	50.4^{h}	41.4^{ef}	64.9^{c}	52.2^{f}
6	150	85.49^{a}	94.82^{b}	85.61^{cd}	88.64^{b}	2.07^{e}	2.27^{bc}	0.55^{de}	1.63^{e}	48.6^{h}	48.2^{d}	12.8^{fg}	36.5^{h}
4	200	74.67^{a}	109.44^{a}	86.19^{bc}	90.10^{ab}	1.83^{e}	0.97^{d}	0.51^{de}	1.10^{f}	75.4^{g}	26.8^{g}	17.6^{f}	40.0^{g}
5	200	86.03^{a}	108.60^{a}	95.25^{a}	96.63^{a}	1.40^{e}	1.02^{d}	0.59^{de}	1.01^{f}	32.7^{i}	18.9^{h}	12.3^{g}	21.3^{i}
6	200	82.38^{a}	113.13^{a}	78.14^{e}	91.22^{ab}	2.03^{e}	1.40^{cd}	1.38^{c}	1.60^{e}	52.2^{h}	24.8^{g}	35.3^{d}	37.4^{gh}
Mean		79.99	101.98	84.46	88.61	3.97	2.06	1.36	2.45	130.3	47.3	37.1	71.6
LSD (0.05)		19.86	13.33	2.68	7.75	0.69	1.12	0.59	0.47	5.21	5.16	4.86	2.83
CV (%)		14.73	7.80	1.88	9.30	10.35	32.33	25.77	20.11	2.37	6.48	7.77	4.21
Significance	a	ns	ns	**	ns	**	**	**	**	**	**	**	**
	b	ns	**	**	*	**	**	**	**	**	**	**	**
	a*b	ns	ns	**	*	*	**	**	*	**	**	**	*

*Means with the same letter are not significantly different; LSD (0.05) =least significantly different; CV=coefficient of variation; ns=non-significant; *=significant at 5% probability level; **=significant at 0.1% probability level*

Table 5. Fruit length, fruit diameter and fruit shape index due to spacing and NPS fertilizer rate during three growing seasons

Treatments		Fruit length (cm)				Fruit diameter (cm)				Fruit Shape index			
Spacing (m) (a)	NPS (kg/ha) (b)	2020	2021	2022	Combined	2020	2021	2022	Combined	2020	2021	2022	Combined
4	0	4.95^{bc}	4.70^{bc}	5.19^{ef}	4.95^{cd}	5.35^{b}	5.12^{ab}	5.58^{d}	5.35^{c}	0.93^{abc}	0.92^{c}	0.93^{b}	0.93^{bcd}
5	0	5.16^{ab}	4.97^{abc}	5.34^{a}	5.16^{ab}	5.45^{ab}	5.22^{ab}	5.67^{c}	5.45^{abc}	0.95^{a}	0.95^{abc}	0.94^{a}	0.95^{a}
6	0	5.07^{abc}	4.92^{abc}	5.21^{de}	5.07^{bc}	5.35^{b}	4.98^{ab}	5.71^{c}	5.35^{c}	0.95^{a}	0.99^{ab}	0.91^{cd}	0.95^{a}
4	100	5.27^{a}	5.23^{a}	5.31^{ab}	5.27^{a}	5.65^{a}	5.53^{a}	5.77^{b}	5.65^{a}	0.93^{abc}	0.95^{abc}	0.92^{c}	0.93^{abc}
5	100	4.86^{c}	4.54^{c}	5.16^{f}	4.85^{d}	5.36^{b}	4.95^{b}	5.77^{b}	5.36^{c}	0.91^{bc}	0.92^{c}	0.90^{ef}	0.91^{cd}
6	100	5.04^{abc}	5.01^{ab}	5.08^{g}	5.04^{bc}	5.40^{ab}	5.39^{ab}	5.40^{e}	5.40^{bc}	0.93^{abc}	0.93^{bc}	0.94^{a}	0.93^{abc}
4	150	5.12^{ab}	5.07^{ab}	5.17^{ef}	5.12^{ab}	5.40^{ab}	5.09^{ab}	5.70^{c}	5.40^{bc}	0.95^{a}	0.99^{a}	0.91^{de}	0.95^{a}
5	150	5.10^{ab}	4.90^{abc}	5.30^{ab}	5.10^{bc}	5.42^{ab}	5.01^{ab}	5.83^{a}	5.42^{bc}	0.94^{ab}	0.98^{abc}	0.91^{d}	0.94^{ab}
6	150	5.14^{ab}	5.03^{ab}	5.25^{cd}	5.14^{ab}	5.43^{ab}	5.28^{ab}	5.59^{d}	5.43^{bc}	0.95^{a}	0.95^{abc}	0.94^{a}	0.95^{a}
4	200	5.08^{abc}	5.04^{ab}	5.12^{g}	5.08^{bc}	5.57^{ab}	5.46^{ab}	5.67^{c}	5.57^{ab}	0.91^{bc}	0.92^{c}	0.90^{ef}	0.91^{cd}
5	200	5.11^{ab}	4.94^{abc}	5.29^{bc}	5.11^{ab}	5.59^{ab}	5.36^{ab}	5.83^{a}	5.59^{ab}	0.91^{bc}	0.92^{c}	0.91^{de}	0.91^{cd}
6	200	5.12^{ab}	4.99^{ab}	5.25^{cd}	5.12^{ab}	5.47^{ab}	5.12^{ab}	5.83^{a}	5.47^{abc}	0.94^{ab}	0.98^{abc}	0.90^{ef}	0.94^{ab}
Mean		5.09	4.95	5.22	5.08	5.45	5.21	5.69	5.45	0.93	0.95	0.92	0.93
LSD (0.05)		0.23	0.45	0.04	0.16	0.29	0.58	0.04	0.21	0.03	0.06	0.01	0.02
CV (%)		2.65	5.39	0.49	3.40	3.15	6.64	0.45	4.10	1.97	4.02	0.60	2.65
Significance	a	ns	ns	**	ns	ns	ns	**	ns	ns	ns	**	ns
	b	ns	ns	**	ns	ns	ns	**	*	*	ns	**	**
	a*b	*	*	**	**	ns	ns	**	*	*	*	**	*

*Means with the same letter are not significantly different; LSD (0.05) = least significantly difference; CV=coefficient of variation; ns=non-significant; *=significant at 5% probability level; **=significant at 0.1% probability level*

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Table 6. Total soluble solids, Specific gravity, and pH of peach fruits due to spacing and NPS fertilizer rate during three growing seasons

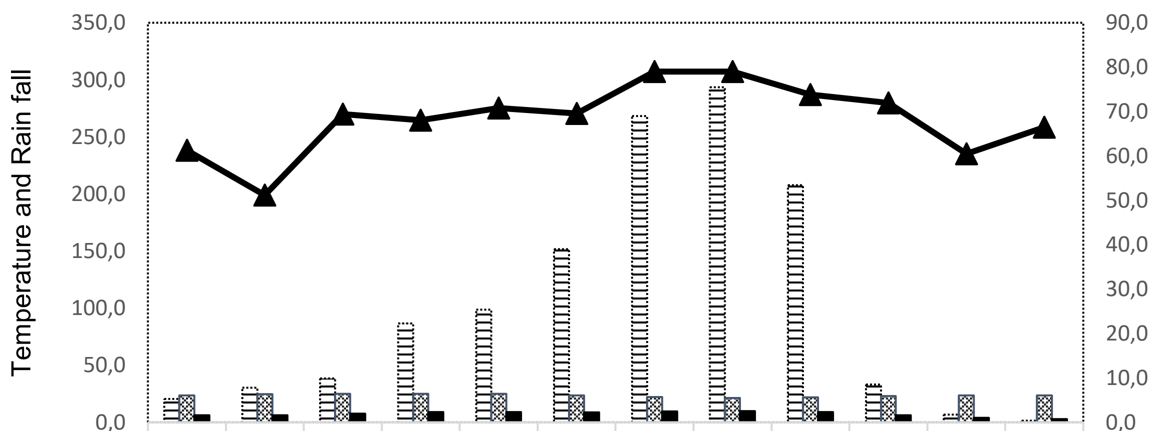
Treatments		Total soluble solid (^{o}Brix)				Specific gravity				pH			
Spacing (m) (a)	NPS (kg/ha) (b)	2020	2021	2022	Combined	2020	2021	2022	Combined	2020	2021	2022	Combined
4	0	14.73^{ab}	10.33^{fg}	13.13^{a}	12.73^{ab}	1.059^{ab}	1.041^{fg}	1.053^{a}	1.051^{abc}	3.44^{a}	3.41^{ab}	3.47^{a}	3.44^{a}
5	0	9.97^{c}	11.57^{cde}	11.07^{e}	10.87^{c}	1.040^{c}	1.046^{de}	1.044^{e}	1.044^{d}	3.38^{bc}	3.36^{a-e}	3.40^{def}	3.38^{bc}
6	0	15.47^{ab}	11.30^{def}	11.55^{d}	12.77^{ab}	1.062^{ab}	1.045^{def}	1.046^{cd}	1.051^{abc}	3.42^{ab}	3.41^{ab}	3.42^{bcd}	3.42^{ab}
4	100	15.27^{ab}	12.37^{a-d}	12.63^{b}	13.42^{ab}	1.061^{ab}	1.049^{bcd}	1.051^{b}	1.054^{abc}	3.41^{ab}	3.40^{abc}	3.41^{cde}	3.42^{ab}
5	100	16.17^{a}	11.57^{cde}	12.90^{ab}	13.54^{a}	1.064^{a}	1.046^{de}	1.051^{ab}	1.054^{ab}	3.36^{c}	3.33^{cde}	3.39^{ef}	3.36^{c}
6	100	15.10^{ab}	11.73^{cde}	11.85^{cd}	12.89^{ab}	1.060^{ab}	1.047^{cde}	1.047^{cd}	1.052^{abc}	3.44^{a}	3.44^{a}	3.45^{ab}	3.44^{a}
4	150	11.30^{bc}	12.17^{b-e}	12.53^{b}	12.00^{bc}	1.045^{bc}	1.049^{bcd}	1.051^{b}	1.048^{cd}	3.34^{c}	3.29^{e}	3.38^{f}	3.33^{d}
5	150	15.70^{ab}	12.63^{abc}	12.70^{ab}	13.68^{a}	1.063^{ab}	1.051^{abc}	1.051^{b}	1.055^{ab}	3.42^{ab}	3.39^{abc}	3.44^{ab}	3.42^{ab}
6	150	16.17^{a}	13.17^{ab}	11.54^{d}	13.62^{a}	1.065^{a}	1.053^{ab}	1.046^{de}	1.054^{ab}	3.38^{bc}	3.35^{b-d}	3.41^{cde}	3.38^{bc}
4	200	16.30^{a}	11.10^{efg}	12.07^{c}	13.16^{ab}	1.065^{a}	1.044^{efg}	1.048^{c}	1.053^{abc}	3.38^{bc}	3.31^{de}	3.44^{bc}	3.37^{c}
5	200	15.50^{ab}	10.10^{g}	12.53^{b}	12.71^{ab}	1.062^{ab}	1.040^{g}	1.051^{b}	1.051^{bc}	3.41^{ab}	3.41^{ab}	3.41^{cde}	3.42^{ab}
6	200	16.50^{a}	13.37^{a}	12.70^{ab}	14.19^{a}	1.066^{a}	1.054^{a}	1.051^{ab}	1.057^{a}	3.38^{bc}	3.37^{a-d}	3.39^{def}	3.38^{bc}
Mean		14.85	11.78	12.27	12.97	1.059	1.047	1.049	1.052	3.40	3.37	3.42	3.40
LSD (0.05)		4.58	1.07	0.46	1.52	0.018	0.004	0.002	0.006	0.05	0.08	0.03	0.03
CV (%)		18.31	5.37	2.25	12.49	1.03	0.24	0.11	0.62	0.84	1.44	0.49	0.99
Significance	a	ns	**	**	ns	ns	**	**	ns	ns	ns	*	ns
	b	ns	**	**	*	ns	**	**	*	ns	ns	ns	**
	a*b	*	**	**	*	*	**	**	*	**	*	**	**

*Means with the same letter are not significantly different; LSD (0.05) =least significantly difference; CV=coefficient of variation; ns=non-significant; *=significant at 5% probability level; **=significant at 0.1% probability level*

Table 7. Partial and dominant budget analysis of fertilizer from the combined yield of three years (2020-2022)

Treatment combination		Gross return (ETB)	Total varying cost (ETB)	Net return (ETB)	Net income over control (ETB)	Marginal rate of return (%)	Domination rank
Spacing (m)	NPS (kg/ha)						
4	0	2493125	0	2493125	0	0	-
5	0	2747500	0	2747500	0	0	-
6	0	1930000	0	1930000	0	0	-
4	100	2243125	7890	2235235	-257890	-3268.6	ND
5	100	1879375	6810	1872565	-874935	-12847.8	ND
6	100	1712500	6810	1705690	-224310	-3293.8	ND
4	150	2235625	9675	2225950	-267175	-2761.5	ND
5	150	3626875	8595	3618280	870780	10131.2	D
6	150	2455625	8595	2447030	517030	6015.5	ND
4	200	2060000	11460	2048540	-444585	-3879.5	ND
5	200	1848750	10380	1838370	-909130	-8758.5	ND
6	200	2062500	10380	2052120	122120	1176.5	ND

D = dominant; ND = not dominant



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
RF	20,4	30,3	38,3	86,6	98,8	151,7	268,4	293,5	207,6	33,1	6,7	1,4
TMAX	23,7	24,7	25,1	24,9	24,9	23,6	22,2	21,3	21,8	23,0	23,5	23,5
TMIN	6,2	6,2	7,5	8,9	9,1	8,7	9,7	9,8	9,0	6,3	4,1	2,8
RH	61,3	51,2	69,4	68,0	70,8	69,6	79,0	79,0	73,8	71,9	60,5	66,5

Fig. 1. Climatic data of Holetta Agricultural Research Center Metrology Station during 2017-2022