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Original Research

Evaluation of some Sugar Beet Varieties using Principal Component Analysis under Levels from Mineral and Nano-Fertilizers

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ABSTRACT: Nanotechnology is a more innovative fertilizer and new approach that can increase the agricultural production and environmental safety as alternatives to traditional fertilizer. The experiment was conducted at El-Sabahia Research Station, Sugar Crops Research Institute, ARC, Alexandria, Egypt (31^{o} 12 N) during the seasons of 2019/2020 and 2020/2021. The experiments involved to study the response of three varieties of sugar beet (*Beta vulgaris* L.) to foliar application of nano-fertilizer. Field experiment this work included twenty-seven treatments, represent the combinations among three mineral fertilization (40, 60 and 80 kg N/fad and three nano-fertilization (zero, 250 and 500 ppm) and three sugar beet varieties [namely Farida, Malak and Kawmera].A Split-Split plot design with three replications was used. Three varieties were distributed in main plots; mineral fertilization was arranged in sub-plots where sub-sub plots the nano fertilization as foliar application. The results showed that applying mineral fertilizer at the rate of 80 kg N/fed had significant positive effects on Root weight, Root length, Sucrose %, Root yield, Sugar yield, however, the application of 60 kg N/fed led to a significant increase in leaf weight, leaf length, leaves yield. Malak variety surpassed the other varieties significantly in Root weight, Root length, Root diameter and Root yield. While Farida variety gave the highest values of Sucrose %, purity % and Sugar yield. Increasing nano-fertilization level to 500 ppm resulted a significant increase in leaf weight, Root length, leaf length, Root diameter, Nitrogen content in leaf, brix, Sucrose %, purity %, Sugar yield, by contrast, the application of 250 ppm led to a significant increase in Root weight and Root yield. The combination between that applying mineral fertilizer at the rate of 80 kg N/fed with nano-fertilization at the rate of 500 ppm for Malak variety gave the highest means of root yield. However, Sugar yield recorded the greatest value with the same combination (mineral fertilizer at the rate of 80 kg N/fed with nano-fertilization at the rate of 500 ppm) for Farida variety. Biplot-Principal component analysis showed that sugar yield was significantly and positively correlated with Sucrose% followed by juice purity%.Was significantly and negatively correlated with juice purity percentage. It could be recommended that, the use of nano-fertilization at rate (500ppm.)With mineral dose, (80 kg N/fad) application on some sugar beet led to increase yield and quality comparison with minerals fertilizers alone.

Keywords: Nano fertilization, mineral fertilization, biplot, principal component analysis

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INTRODUCTION

Sugar beet (Beta vulgaris L) comes in the first place as one of the most important cash crops in A.R.E, which reduces the gap between sugar's production and consumption. It can withstand various weather conditions, as it can be cultivated in a variety of environments; furthermore, it is a promising winter crop suitable for reclaimed soil to meet the increasing demand for sugar while also decreasing water use under its conditions. The government seeks, as a top priority goal, to improve sugar beet yield and quality to provide sugar production to gradually decrease the gap between sugar consumption and production under suitable conditions

(FAO, 2019). Many modern technologies entered several fields of our life, including industrial products, pharmaceuticals, and plant production. Nanotechnology, in particular, has a significant impact on crop output thank to its higher absorption and high reactivity (Dewdar, Abbas, El-Hassanin, Abd El-Aleem, and Sciences, 2018). Throughout the past years, Chemical fertilizers have grown to be one of the key elements of modern agriculture because they boost crop production and enrich the soil with minerals that may otherwise be depleted by intense land usage. However, repeated excessive use and misuse of chemical fertilizers year after year lead to several risks to environment and human health that should be monitored, controlled, and assessed to minimize them and prevent a complete retro-gradation of arable lands.

Nitric acid, ammonium nitrate, synthetic ammonia or ureas are frequently used to provide plants with the nitrogen their need (Zulfiqar *et al*., 2019), (Fatima and Anees, 2021). Regrettably, 100–782 kg of urea are used every 100 m^2 to fertilize the soils. Although fertilizers are necessary for agriculture to feed the expanding population, their excessive usage results in environmental damage (Srivastav, 2020), (Mahapatra *et al*., 2022). Only 20 to 50 percent of fertilizers provided are utilized effectively; the remaining 50 to 80 percent are lost over time due to leaching, emissions, or absorption into the soil by microorganisms, leading to ecological issues including decreased soil fertility and financial losses.

Recent years have seen the introduction nano-fertilizers which is considered one of the sustainable innovations for raising crop productivity in the developing countries (Veronica *et al*., 2015). Nanoparticles are atomic or molecular aggregates whose size ranges between 1–100 nm (Ball, 2002; Wiesner *et al*., 2006). The chemical and biological activities of most substances increase at the nanoscale (Mazaherinia *et al*., 2010). Nanotechnology can be used in crop production to boost growth and increase yield (Reynolds, 2002). Nano-fertilizers can be used in place of conventional fertilizer application techniques to gradually and deliberately release nutrients into plants in a controlled way (Naderi and Abedi, 2012).

Because of their higher absorbance and high reactivity, nanoparticles can be applied to plants to aid in their growth and development (Liu and Lal, 2015). Nano-fertilizers provide a number of advantages over traditional fertilizers for the sustainable and environmentally friendly development of crops. These basically consist of the following: (i) increased nutrient absorption and effective usage without larger losses; (ii) a considerable decrease in the danger of environmental contamination as a result of the decreased nutrient losses; (iii) nano-fertilizers significantly faster diffusion rate and solubility compared to typical synthetic fertilizers; (iv) the regulated release of nutrients in nano-fertilizers as opposed to chemical fertilizers, where it is highly spontaneous and quick (Tarafdar *et al*., 2020; Thavaseelan and Priyadarshana, 2021).

The variation among genotypes can be explained using the principle components analysis (PCA) that may transform several possibly correlated variables into a miller number of variables. This approach is highly useful for determining which agronomic traits of crop contribute most to yield, subsequently; these agronomic traits should be emphasized in breeding and selection programs. Although there are significant disparities between the groupings, there are similarities between the individuals within each group (Einstein, 1996, Meaherb et al., 2021; Fahamy et al 2021).

PCA is a vital and well-liked multivariate method. The PCA has been used in some research to evaluate the traits of different sugar beetroot cultivars. Jia et al. (2015) used correlation PCA methods for the concentrations of eleven elements, including potassium and salt, to undertake thorough quality evaluations on thirty-four sugar beetroot types from five different producing sites. The PCA method has also been used to analyse and thoroughly evaluate the amino acid composition of the roots of fourteen different sugar beetroot types. Despite the fact that several studies have focused on PCA analysis of agronomic aspects of sugar beetroot cultivars recently. Thus, the objectives of this inquiry were:

i)To study the effects of foliar Nano-Fertilization on the production and quality of various sugar beet genotypes in Egypt;

ii)To classify sugar beet varieties based on PCA to identify the traits that are most appropriate for the test environments.

MATERIALS AND METHODS

The field experiment was conducted at El-Sabahia Research Station, Sugar Crops Research Institute, ARC, Alexandria, Egypt (31° 12 N) during the seasons of 2019/2020 and 2020/2021. The experiment involved to study the response of three varieties of sugar beet (*Beta vulgaris* L.) to foliar application of nano- fertilizers mixtures with mineral fertilizer. Field experiment this included twenty-seven treatments, represent the combinations among three mineral fertilization (40, 60 and 80 kg N/fed, and three nano fertilization (zero, 250 and 500 ppm) and three sugar beet varieties [namely Farida, Malak and Kawmera]. A Split-Split plot design with three replications was used. The nano fertilization as foliar application in main plots; three varieties were distributed in sub-plots where sub-sub plots mineral fertilization was arranged.

Table 1: Physical and chemical soil characteristics of the experimental soil in Sabahia research station 2019/020 and 2020/021 seasons.

Soil properties	Seasons	
	2019/2020	2020/2021
A: Mechanical analysis		
Sand	14.70	14.50
Silt	40.80	41.00
Clay	44.30	44.50
Soil texture	Clay Loam	Clay Loam
B: Chemical properties:		
PH (1:1)	7.65	7.55
EC(1:1)	3.55	3.35
1-Soluble cations (1:2)	1.40	1.45
K^{+}	1.40	1.45
Ca^{++}	14.20	15.35
Mg^{++}	11.15	11.35
Na^{+}	13.65	13.85
2- Soluble anions (1:2)		
$Co^{-}3$+ $HCO^{-}3$	2.80	2.85
CL-	19.60	19.80
SO-4	12.60	12.50
Calcium carbonate %		
Total nitrogen %	1.10	1.20
Available p.(mg/kg)	3.50	3.50
Organic matter	1.08	1.50

Each sub-plot area included 5 ridges, 60 cm apart and 3.5 m length, causing in an area of 10.5 m^2 (1/400 fed.) Sugar beet was planted at the 1st week of October at two seasons (2019/2020 and 2020/2021). Thinning was done at four true leaves to get one plant/hill (35000 plans/fed.). Phosphorus fertilizer as calcium super phosphate (15% P_2O_5) was applied once during seedbed preparation, however potassium fertilization as potassium sulphate (48% K_2O) was added at the rate of 48 kg K_2O/fed, in the two at seedbed preparation. Soil moisture characteristics are showed in (Table **1**). Each sub-plot area was 10.5 m^2 (1/400 fed.) m^2 including 5 ridges, 60 cm apart and 3.5 m length. Sugar beet varieties were harvested manually after 210 days from planting. During the growing season frequently, agricultural practices for varieties were applied according to the recommendations of Sugar Crops Research Institute in Egypt.

A sample of ten plants randomly were taken from each plot in root weight/plant (Kg), Root fresh weight (g/plant) Extracted sugar % = (Pol %- 0.29) - 0.343*(K+ Na) - α-amino N * (0.0939) and sucrose% percentage (Pol%) was estimated in fresh samples of roots, using Saccharometer according to the method described in A.O.A.C. (2005). Juice quality index (QI %) was calculated according to Cooke and Scott (1993) using the following equation:

Quality index% = extracted sugar (%) / POL× 100.

root yield (ton/fed), tops yield (ton/fed) Sugar yield (t/fed) was calculated according to the following equation: Sugar equation: sugar yield (t/fed) = root yield (t/fed) x extracted sugar%. The recorded data were statistically analyzed according to Keshavarz *et al*. (2001).

Least significant difference test at 5% level of probability was used to compare means.

Principal component analysis (PCA)

PCA method defined by Harman (1976) was followed in the extraction of the components.

Preparation of NH_4NO_3 (NPs)

The fertilizer used in this experiment (NH_4NO_3) was ground by a regular grinder several times for an hour, then passed through a 250 millimetre sieve and then grinded several more times until it reached the very small size. Then it ground by nano grinder (Malvern instrument) to obtained nano size of powder to reach the nano size (Figure 1). Different Ammonium nitrate fertilizer concentrations (50 and 100 ppm) were used under this study,

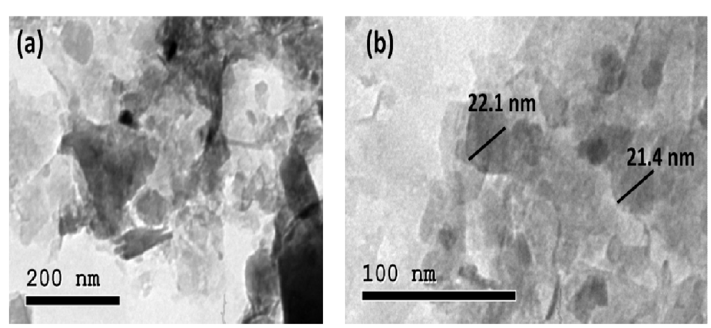

Figure 1: The HR-TEM images of the (a) Low resolution and (b) High resolution.

Table 2: Effect of nitrogen fertilizers and nano concentration on some sugar beet varieties and their interaction on growth parameters (Root length, Root diameter and Root Weight of sugarbeet plants by combined analysis between two seasons of 2019/2020 and 2020/2021.

Varieties (V)	Nitrogen fertilizer (Kg N/ fed)	Root length (cm)				Root diameter (cm)				Root weight (g/ plant)			
		Nano concentrations (Na)				Nano concentrations (Na)				Nano concentrations (Na)			
		Na_1	Na_2	Na_3	Mean	Na_1	Na_2	Na_3	Mean	Na_1	Na_2	Na_3	Mean
	40	26.8	28.2	30.7	28.5	24.6	26.6	30.3	27.2	1050.0	1093.7	1183.3	1109.0
Farida	60	26.7	31.3	33.3	30.4	30.3	36.1	38.8	35.0	1229.2	1300.0	1406.7	1311.9
	80	28.7	30.8	35.4	31.6	27.8	29.8	41.2	32.9	1213.7	1247.5	1330.8	1264.0
Mean		27.4	30.1	33.1	30.2 b	27.6	30.8	36.7	31.7 b	1164.3	1213.7	1306.9	1228.3 b
	40	32.4	34.0	36.6	34.3	32.8	34.5	41.0	36.1	1179.2	1302.5	1445.0	1308.9
Malak	60	30.1	32.8	34.8	32.6	28.8	34.5	36.2	33.1	1183.3	1245.8	1454.3	1294.5
	80	28.3	30.5	32.6	30.5	32.2	34.3	37.8	34.7	1037.5	1280.8	1377.5	1231.9
Mean		30.3	32.4	34.6	32.5 a	31.2	34.4	38.3	34.6 a	1133.3	1276.4	1425.6	1278.4 a
	40	23.5	25.6	29.3	26.1	28.6	32.0	37.5	32.7	1214.2	1352.5	1418.2	1328.3
Kawmera	60	26.1	30.1	32.0	29.4	28.1	30.1	33.5	30.6	1141.7	1230.0	1337.7	1236.4
	80	28.7	29.4	31.5	29.9	28.0	31.6	37.3	32.3	1052.5	1162.5	1305.8	1173.6
Mean		26.1	28.4	30.9	28.5 c	28.2	31.2	36.1	31.8 b	1136.1	1248.3	1353.9	1246.1 b
	40	27.6	29.3	32.2	29.7 a	28.7	31.0	36.2	32.0 a	1147.8	1249.6	1348.8	1248.7 ab
N × Na	60	27.6	31.4	33.3	30.8 a	29.0	33.6	36.1	32.9 a	1184.7	1258.6	1399.6	1281.0 a
	80	28.6	30.2	33.2	30.7 a	29.3	31.9	38.7	33.3 a	1101.2	1230.3	1338.1	1223.2 b
Mean		27.9 c	30.3 b	32.9 a	30.4	29.0 c	32.2 b	37.0 a	32.7	1144.6 c	1246 b	1362.1 a	1251.0
$L.S.D_{0.05}$													
Varieties (V)		0.6				1.2				22.3			
Nitrogen fertilizer (N)		NS				NS				38.6			
Nano concentrations (Na)		0.3				0.6				16.2			
V × N		1.8				3.9				66.9			
V × Na		0.6				1.1				28.0			
N × Na		0.6				1.1				28.0			
V × N × Na		1.0				1.9				48.5			

Characterization of NH_4NO_3 Nanoparticles

The high-resolution transmission electron microscope (HR-TEM) (JEM-2100) was used to study the morphology of the prepared nano fertilizer under an acceleration voltage of 200 kV.

Growth characters

Root length, diameter and weight

Table 2 presents the effect of three levels of nitrogen fertilizer and three nano concentrations on root length, diameter and weight of three sugar beet varieties (Farida, Malak and Kawmera) during two successive seasons. Malak variety recorded the highest values in root length, diameter and weight, while Farida had the lowest values. There was a significant effect of nano concentrations on root length, diameter and weight, the highest values recorded at 500 ppm/fed.

The interaction between varieties and nitrogen fertilizers, nano concentrations and all three factors together were significant for root length, diameter and weight. The highest values of these characters were obtained with treatments that included variety Malak,60-80 Kg N/fed and 500 ppm/fed of nano concentrations, while the lowest values were achieved with variety Kawmera, 40 Kg N/fed and zero nano concentration.

Several studies, including Liu and Lal, (2015) and Naderi and Abedi, (2012), have reported that the use of nano-fertilizers resulted in significant improvements in various plant growth traits, such as root length, root diameter, root fresh weight, and top fresh weight, compared to control treatments.

Moreover, the positive effects of nano-fertilizers were further enhanced when used in combination with conventional fertilizers, even at lower application rates. These results suggest that nano-fertilizers can either provide essential nutrients to the plant or facilitate the uptake and transport of available nutrients, leading to better crop growth.

Yield characters

Root and sugar yields (Ton/fad)

The data presented in (Table 3) shows that the root and sugar yields of varieties (Farida, Malak, and Kawmera) were significantly affected by three levels of nitrogen fertilizer (40, 60, and 80 kg N/fed) and three nano concentrations (zero, 250, and 500 ppm/fed) during the two seasons. Malak variety had the highest root yield, while Farida had the highest sugar yield. The highest values of root and sugar yield were obtained with the treatment of 80 Kg N/fed and 500ppm nano/fed., for all cultivars.

The interaction between the varieties and levels of nitrogen fertilizer was significant, while the interaction between varieties and nano concentrations and the interaction between nitrogen fertilizer and nano concentrations had no significant effect on root and sugar yield. The interaction between varieties, levels of nitrogen

Table 3: Effect of nitrogen fertilizer and nano concentrations on some sugarbeet varieties and their interaction on yield components by combined analysis between two seasons of 2019/2020 and 2020/ 2021.

Varieties (V)	Nitrogen fertilizer (Kg N/ fed)	Root yield (tons/ fed)				Sugar yield (tons/ fed)			
		Nano concentrations (Na) (ppm/ fed)				Nano concentrations (Na)			
		without	250	500	Mean	without	250	500	Mean
	40	25.425	26.405	25.708	25.846	4.550	4.990	5.773	5.104
Farida	60	25.325	26.933	29.017	27.092	4.718	5.270	6.215	5.401
	80	26.000	27.625	28.517	27.381	5.030	5.528	6.083	5.547
Mean		25.583	26.988	27.747	26.773 b	4.766	5.263	6.024	5.351 a
	40	24.842	26.125	26.917	25.961	4.258	4.958	5.478	4.898
Malak	60	26.525	27.450	27.958	27.311	4.338	4.852	5.533	4.908
	80	28.167	29.125	29.518	28.937	4.508	5.078	5.782	5.123
Mean		26.511	27.567	28.131	27.403 a	4.368	4.963	5.598	4.976 b
	40	24.250	24.958	26.417	25.208	4.205	4.675	5.520	4.800
Kawmera	60	24.458	25.167	26.042	25.222	3.907	4.693	5.207	4.602
	80	24.708	25.883	26.575	25.722	4.442	4.925	5.317	4.894
Mean		24.472	25.336	26.344	25.384 c	4.184	4.764	5.348	4.766 c
	40	24.839	25.829	26.347	25.672 c	4.338	4.874	5.591	4.934 b
N × Na	60	25.436	26.517	27.672	26.542 b	4.321	4.938	5.652	4.970 b
	80	26.292	27.544	28.203	27.346 a	4.660	5.177	5.727	5.188 a
Mean		25.522 c	26.630 b	27.408 a	26.520	4.40 c	4.997 b	5.656 a	5.031
$L.S.D_{0.05}$									
Varieties (V)		0.532				0.057			
Nitrogen fertilizer (N)		0.400				0.114			
Nano concentrations (Na)		0.305				0.051			
V × N		0.693				0.196			
V × Na		NS				NS			
N × Na		NS				0.089			
V × N × Na		0.916				0.154			

Table 4: Effect of nitrogen fertilizers and nano concentration on some sugar beet varieties and their interaction on some quality parameters of sugar beet plant by combined analysis between two seasons of 2019/2020 and 2020/2021

Varieties (V)	Nitrogen fertilizer (Kg N/ fed)	Total soluble solids percentage (T.S.S%)				Sucrose percentage (Su%)				Purity percentage (Pu%)			
		Nano concentrations (Na)				Nano concentrations (Na)				Nano concentrations (Na)			
		Na_1	Na_2	Na_3	Mean	Na_1	Na_2	Na_3	Mean	Na_1	Na_2	Na_3	Mean
	40	22.8	23.8	25.3	24.0	18.7	19.7	20.3	19.6	81.8	82.4	80.2	81.5
Farida	60	24.3	25.3	26.5	25.3	19.8	18.7	21.0	19.8	81.5	73.9	79.3	78.3
	80	24.4	25.0	26.3	25.3	19.5	20.0	21.2	20.2	79.8	80.0	80.4	80.1
Mean		23.8	24.7	26.1	24.9 a	19.3	19.4	20.8	19.9 a	81.1	78.8	80.0	79.9 a
	40	21.8	24.4	25.0	23.8	16.6	19.3	19.7	18.5	76.0	78.8	78.6	77.8
Malak	60	21.5	22.4	23.5	22.5	17.3	18.2	19.5	18.3	80.5	81.0	83.0	81.5
	80	21.5	22.8	25.2	23.2	16.0	17.3	19.4	17.6	74.4	75.8	77.1	75.8
Mean		21.6	23.2	24.6	23.1 c	16.6	18.3	19.5	18.1 c	77.0	78.6	79.6	78.4 a
	40	22.0	23.7	24.5	23.4	17.5	18.5	19.8	18.6	79.6	78.2	80.6	79.4
kawmera	60	21.8	24.1	25.3	23.8	16.2	18.8	20.3	18.4	74.1	77.9	80.0	77.3
	80	22.7	24.0	25.5	24.1	18.00	19.3	20.0	19.1	79.4	80.6	78.4	79.5
Mean		22.2	23.9	25.1	23.7 b	17.2	18.9	20.0	18.7 b	77.7	78.9	79.7	78.7 a
	40	2.2	24.0	24.9	23.7 b	17.6	19.1	19.9	18.9 a	79.1	79.8	79.8	79.6 a
N × Na	60	22.5	23.9	25.1	23.9 b	17.8	18.5	20.3	18.8 a	78.7	77.6	80.8	79.0 a
	80	22.9	23.9	25.7	24.2 a	17.8	18.9	20.2	19.0 a	77.9	78.8	78.6	78.4 a
Mean		22.5 c	23.9 b	25.2 a	23.9	17.7 c	18.9 b	20.1 a	18.9	78.6 a	78.7 a	79.7 a	79.0
$L.S.D_{0.05}$													
Varieties (V)		0.3				0.4				NS			
Nitrogen fertilizer (N)		0.3				NS				NS			
Nano concentrations (Na)		0.2				0.2				NS			
V × N		0.4				0.8				2.5			
V × Na		0.3				0.4				1.9			
N × Na		0.3				0.4				NS			
V × N × Na		0.5				0.7				3.3			

fertilizer, and nano concentrations was significant for root and sugar yield. The present findings are in line with the results reported by Dewdar *et al*., (2018), whom found that the utilization of NPs fertilizers enhanced the growth and yield components of various crop sugar. In the same context, Graciela *et al.,* (2022) suggested that the application of NPs led to an improvement in plant growth and yield components of different crop sugar, owing to the nanoparticles' effectiveness in absorption and penetration.

Quality characters

Total soluble solids, sucrose and purity percentages

Total soluble solids, sucrose and purity percentages as affected by varieties, mineral nitrogen, Nano concentrations and their interactions in both seasons2019/020 and 2020/021. The data in (Table 4) shows that the amount of nitrogen fertilizer and nano concentration used has a significant impact on the Total

Soluble Solids (TSS), Sucrose (Su), and Purity (Pu) percentages of three varieties of sugar beet. Variety Farida had the highest TSS and Su percentages, while there was no significant difference in Pu percentage among the varieties.

The highest TSS percentage was reached with the application of 80 kg N/fed, while the highest Su percentage was obtained with the application of nano concentration Na3 (500 ppm/fed). When the interaction between varieties and nitrogen fertilizer levels was analyzed, the treatments involving the Farida variety and the application of 60-80 kg N/fed resulted in the highest values of T.S.S., Su, and Pu percentages.

In other words, the application of nano concentration Na3 (500 ppm/fed) also resulted in a slight increase in sugar yield, but the effect was not as pronounced as the effect of nitrogen fertilizer.

These results suggest that the Farida variety of sugar beet is more responsive to nitrogen fertilizer than the other two varieties, and that the application of nano concentration Na3 can also improve total soluble solids, sucrose and purity percentages. The findings are consistent with those reported by Yasser and Alaa (2021) and Veronica et al., (2015), which demonstrated that the use of nano fertilizers can improve total soluble solids, sucrose and purity percentages.

Sugar losses in molasses and sugar extracted percentage

The presented data in (Table 5) showed significant effects of three levels of nitrogen fertilizer and three nano concentrations on sugar lose in molasses and extracted sugar of three sugar beet varieties in two seasons.

Table 5: Effect of nitrogen fertilizer and nano concentrations on some sugar beet varieties and their interaction on Sugar Lose in Molasses and Extracted sugar by combined analysis between two seasons of 2019/2020 and 2020/ 2021.

Varieties (V)	Nitrogen fertilizer (Kg N/ fed)	Sugar Lose in Molasses (SLM)				Extracted sugar			
		Nano concentrations (Na)				Nano concentrations (Na)			
		Na_1	Na_2	Na_3	Mean	Na_1	Na_2	Na_3	Mean
	40	2.57	2.33	2.3	2.41	15.50	16.73	17.41	16.55
Farida	60	2.28	2.02	2.31	2.20	16.87	16.05	18.09	17.01
	80	2.79	2.36	2.70	2.62	16.11	17.04	17.87	17.00
Mean		2.55	2.24	2.44	2.41 a	16.16	16.61	17.79	16.85 a
	40	3.16	2.50	2.64	2.77	12.83	16.15	16.43	15.14
Malak	60	2.36	2.04	2.36	2.25	14.37	15.53	16.54	15.48
	80	3.02	2.24	2.21	2.49	12.38	14.50	16.61	14.50
Mean		2.84	2.26	2.40	2.50 a	13.19	15.39	16.52	15.04 c
	40	2.30	2.90	2.45	2.55	14.60	15.00	16.70	15.43
Kawamera	60	2.29	2.50	2.50	2.43	13.28	15.65	17.15	15.36
	80	2.43	2.74	1.99	2.38	14.97	16.00	17.41	16.13
Mean		2.34	2.71	2.31	2.46 a	14.28	15.55	17.09	15.64 b
	40	2.68	2.58	2.47	2.57 a	14.31	15.96	16.85	15.70 a
N × Na	60	2.31	2.19	2.39	2.30 b	14.84	15.74	17.26	15.94 a
	80	2.75	2.45	2.30	2.50 a	14.49	15.84	17.30	15.88 a
Mean		2.58 a	2.40 b	2.39 b	2.46	14.54 c	15.85 b	17.13 a	15.84
$L.S.D_{0.05}$									
Varieties (V)		NS				0.47			
Nitrogen fertilizer (N)		0.08				NS			
Nano concentrations (Na)		0.09				0.23			
V × N		0.14				0.62			
V × Na		0.16				0.40			
N × Na		0.16				0.40			
V × N × Na		0.28				0.70			

There were no significant differences between sugar beet varieties in sugar lose in molasses, but Farida variety had the highest value of extracted sugar. The application of 40 Kg N/fad resulted in the highest values of Sugar lose in molasses, while the lowest values were obtained with 80 Kg N/fad. Increasing nano concentrations significantly increased Extracted sugar, with the highest values obtained with 500 ppm/fed and without nano.

There were significant interactions between the varieties and levels of nitrogen fertilizer, as well as between the varieties and nano concentrations, on Sugar Lose in Molasses and Extracted sugar. The highest values were obtained with specific treatments, such as (Malak × 40 Kg N/ fed × Zero nano/ fed) for Sugar Lose in Molasses and (Farida × 60 Kg N/ fed × 500 ppm nano/ fed) for Extracted sugar. However, the lowest values were obtained with different treatments, such as (Farida × 60 Kg N/ fed × 250 ppm. nano) for Sugar Lose in Molasses and (Malak × 40 Kg N/ fed × without nano) for Extracted sugar. These results in harmony with those obtained by Mollasadeghi *et al.* (2010), they revealed that nano-fertilizer had a positive effect on sugar beet yield and quality, with the sugar losses in molasses and sugar extracted percentage being obtained with the application of 500 ppm nano-fertilizer. Presents data (Table 6), showed the effect of nitrogen fertilizer levels and nano

Table 6: Effect of nitrogen fertilizer and nano concentrations on some sugar beet varieties and their interaction on A.C and extrability percentage by combined analysis between two seasons of 2019/2020 and 2020/ 2021.

Varieties (V)	Nitrogen fertilizer (Kg N/ fed)	A.C				Extrability%			
		Nano concentrations (Na)				Nano concentrations (Na)			
		Na1	Na2	Na3	Mean	Na1	Na2	Na3	Mean
	40	2.92	3.64	3.96	3.51	83.02	85.09	85.59	84.57
Farida	60	4.26	4.00	3.73	4.00	85.39	85.91	86.14	85.81
	80	2.61	3.67	2.78	3.02	82.47	85.19	84.42	84.03
Mean		3.26	3.77	3.49	3.51 a	83.63	85.40	85.38	84.80 a
	40	2.57	3.56	2.90	3.01	77.21	83.88	83.16	81.41
Malak	60	4.29	4.06	3.64	3.99	82.71	85.32	84.72	85.25
	80	2.41	3.33	3.14	2.96	77.29	83.57	85.58	82.15
Mean		3.09	3.65	3.22	3.32 a	79.07	84.26	84.49	82.60 c
	40	3.57	2.86	2.66	3.03	83.36	80.94	84.43	82.91
Kawmera	60	4.02	2.92	2.60	3.18	82.12	83.41	84.66	83.39
	80	2.48	2.61	4.19	3.09	83.11	82.64	87.01	84.25
Mean		3.36	2.79	3.15	3.10 b	82.86	82.33	85.36	83.52 b
	40	3.02	3.35	3.17	3.18 b	81.20	83.30	84.39	82.96 c
N × Na	60	4.19	3.66	3.32	3.72 a	83.40	84.88	85.17	84.49 a
	80	2.50	3.20	3.37	3.02 b	80.96	83.80	85.67	83.48 b
Mean		3.24 a	3.40 a	3.29 a	3.31	81.85 c	83.99 b	85.08 a	83.64
L.S.D0.05									
Varieties (V)		0.19				0.83			
Nitrogen fertilizer (N)		0.19				0.49			
Nano concentrations (Na)		NS				0.52			
V × N		0.33				0.85			
V × Na		0.25				0.91			
N × Na		0.25				0.91			
V × N × Na		0.43				1.57			

concentrations and sugar beet varieties on A.C. and Extrability % over two seasons. Results indicate that Farida variety had the highest A.C. and Extrability %, and the 60 Kg N/fed treatment generated the highest values. Nano concentrations did not affect A.C. significantly, but the 500 ppm/ fed treatment increased Extrability % significantly.

The interaction between varieties, nitrogen fertilizer levels, and nano concentrations significantly affected A.C. and Extrability %. The highest A.C. and Extrability% were obtained with the Malak variety at 60 Kg N/fed and without nano fertilizers and Farida at 60 Kg N/fed and 500 ppm nano, respectively. The lowest values were obtained with Kawmera variety at 80 Kg N/fed and without nano and Malak at 40 Kg N/fed and without nano, respectively. These results come to an agreement with those obtained by Dewdar *et al*., (2018).

Principal component analysis (PCA)

PCA of standardized data was used to show trait associations, also its use in cultivar attributes and contrast to demonstrate the genetic diversity among sugar beet cultivars. Data standardization is necessary to remove the units because different characters use different units. Scaling PC1 and PC2's principal components produced values that are symmetrically distributed between the variety and character scores (Mehareb *et al*., 2021). The first two components (PCA1 and PCA2) accounted up to 89.4% of the total variation among characters in the evaluation of diversity among sugar beet cultivars using 15 characters (Table 7 and Figure 2). The first principal component (PCA1) is more significant when considering how to interpret the rotation (farthest from zero). The first principal component (PC) accounted for 77.3% of the total phenotypic variation expressed. Characters accounting for the most of variation expressed in the PC1 were sucrose%, sugar yield, top yield and root length (Table 7). The PC2 accounted for 12.1% of the variation with root dry weight/plant, nitrogen leaf content and no of leaves/plant as the main traits in this component. For analyzing the attributes of sugar beet genotypes, there are many indicators available, and the variations in quality between genotypes have been linked to a variety of interrelated causes (Xiao *et al*., 2017 and Mehareb *et al.,* 2021). Generally speaking, variable indicators chosen using the PCA technique based on different quality attributes might not only speed up the evaluation process but also enable scientific screening of high-quality varieties and prevent resource waste. Due to this, many crops have used the PCA technique Dray and Josse, 2016, Li *et al*., 2017, and Abo Elenen *et al*., 2019 and Mehareb *et al*., 2021).

Principle components analysis study the interrelation among the traits and genotypes (Mehareb and El-Mansoub 2020, Gaballah and Mehareb 2020 and Fahmy

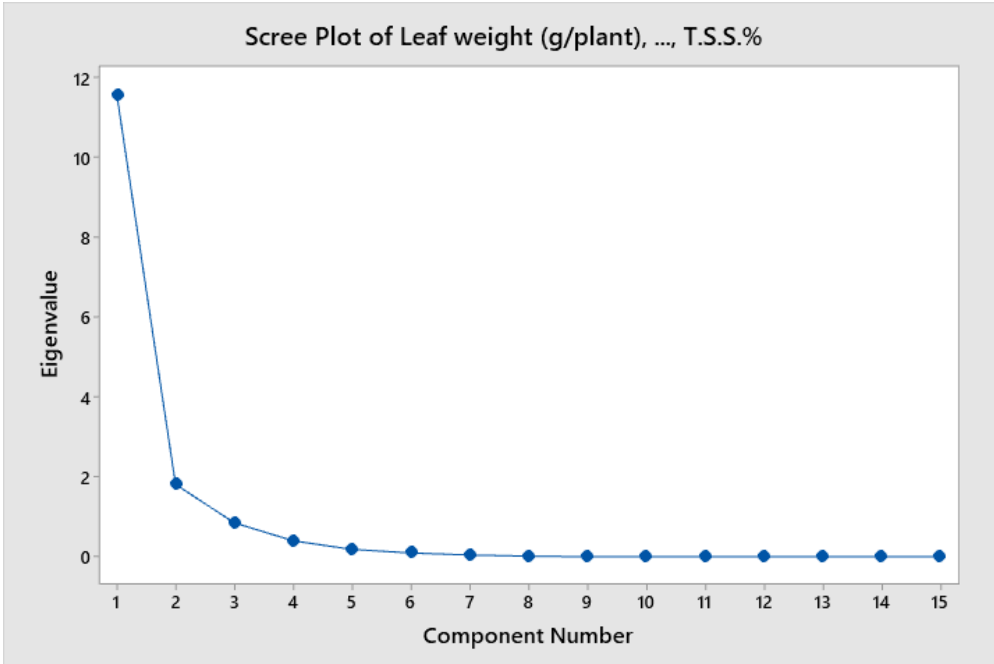

Figure 2: Scree plot of eigen-values of sugar beet yield under mineral and nano fertilization along with various growth traits and Quality parameters of three sugar beet varieties (Leaf weight (g/plant), Root weight (g/plant), Root. Length (cm.), Root diameter (cm)., Leaf. Length (cm.),), Nitrogen leaf content , Number of leaves/plant, Root dry weight/plant, Leaf dry weight/plant and T.S.S.% Sucrose%, purity%, Top yield (ton/fad),Root yield (ton/fad) and Sugar yield (ton/fad).

Table 7: Principal component analysis of measured traits in sugar beet genotypes under foliar application of nano- microelements mixtures and mineral fertilization.

Variable	PC1	PC2	PC3	Pc4
Leaf weight	**0.287**	**-0.119**	**0.099**	**-0.065**
Root. weight	**0.284**	**-0.16**	**0.021**	**0.034**
Root. Length	**0.286**	**-0.015**	**0.057**	**-0.074**
Leaf. Length	**0.24**	**-0.405**	**0.02**	**0.128**
Sucrose%	**0.292**	**-0.028**	**0.042**	**0.022**
purity%	**0.226**	**-0.311**	**0.332**	**-0.455**
Root yield	**0.24**	**0.291**	**0.028**	**-0.639**
Sugar yield	**0.29**	**0.091**	**0.046**	**-0.013**
Top yield	**0.286**	**-0.105**	**-0.013**	**0.226**
Nitrogen leaf content	**0.19**	**0.454**	**-0.449**	**0.061**
Root dimeter	**0.285**	**0.023**	**-0.105**	**0.166**
No of leaves/plant	**0.245**	**0.366**	**-0.199**	**-0.111**
Root dry weight/plant	**-0.013**	**0.501**	**0.781**	**0.215**
Leaf dry weight/plant	**0.275**	**0.037**	**0.084**	**0.446**
T.S.S.%	**0.29**	**0.027**	**-0.028**	**0.128**
Eigenvalue	**11.591**	**1.813**	**0.85**	**0.401**
Proportion	**0.773**	**0.121**	**0.057**	**0.027**
Cumulative	**77.3**	**89.4**	**95**	**97.7**

et al., 2021). PCA offered in (Figure 3) was performed for 15 characters of sugar beet, it found high positive correlation between root length and root weight, these results are similar with those obtained by Campbell and Cole (1986), Sklenar *et al*., (1997) and Dario *et al*.,(2011), that found positive correlation between root weight and root length. On the other hand, it found high positive correlation between root length and root diameter, also root diameter, root length and top yield, likewise high positive correlation between root dry weight and top yield, additionally, sucrose and purity, these results with harmony with Mehareb, and El-Mansoub (2020) and Gaballah and Mehareb 2020, Fahmy et al 2021that found high positive correlation between sucrose

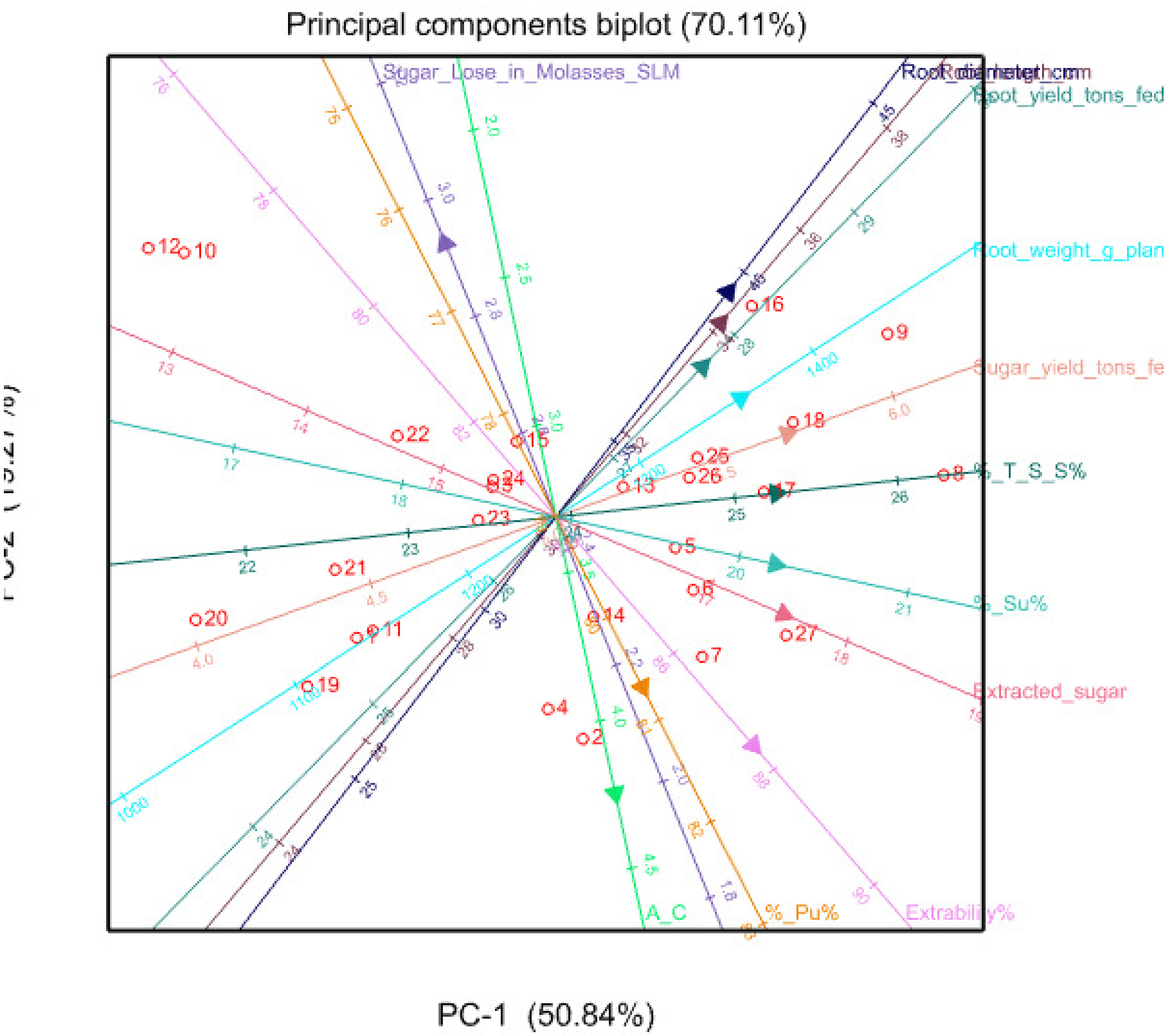

Figure 3. Biplot based on principal component analysis for traits in sugar beet varieties (V1=Farida, , V2 =Malak,V3 =Kawmera, as affected by the three mineral fertilization (N1=40, N2=60 and N3=80 kg N/fed, *i.e.* three nano fertilization (Na1=zero, Na2=250 and Na3=500 ppm) with 27 combinations; O1= (V1 , Na1N1), O2= (V1 , Na1N2)andO3=(V1 , Na1N3), O4=(V1 , Na2N1),O5=(V1 , Na2N2), O6=(V1 , Na2N3), O7= (V1 , Na3N1), O8= (V1 , Na3N2)andO9=(V1 , Na3N3), O10= (V2 , Na1N1), O11= (V2 , Na1N2)andO12=(V2 , Na1N3), O13=(V2 , Na2N1),O14=(V2 , Na2N2), O15=(V2 , Na2N3), O16= (V2 , Na3N1), O17= (V2 , Na3N2)andO18=(V2 , Na3N3), O19= (V3 , Na1N1), O20= (V3 , Na1N2)andO21=(V3 , Na1N3), O22=(V1 , Na2N1),O23=(V1 , Na2N2), O24=(V1 , Na2N3), O25= (V1 , Na3N1), O26= (V1 , Na3N2) and O27=(V1 , Na3N3).

and purity. Correspondingly, results in (Figure 3) displayed that O9= (Na3, N3) was the highest variety in Root diameter (cm) and sucrose% and the other hand, O8=(Na3, N2) was the highest variety in TSS% and sugar yield, while O16 = (Na3N1) was the highest one in root length (cm).

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