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RESEARCH ARTICLE

The application of biofertilizers improves sugar beet biofortification in clay loam soils and reduces sugar losses in beet sugar processing

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Abstract

The scarcity of water resources in arid and semi-arid regions necessitates the search for drought-resistant varieties, as well as using of some treatments that reduce the impact of water stress. The present work was conducted in Upper Egypt at Sohag Governorate to study the response of four sugar beet varieties, i.e., Poseidon, Nancy, Gazelle and Lilly, to some biofertilizers under normal and drought stress.

The field experiment was carried out in a Randomized Complete Blocks Design (RCBD) using a split-split plot arrangement with three replications. The biofertilizer treatments were; control, Vinasses at 5%, yeast at 5% and Vinasses + yeast at 5%. Supplying sugar beet varieties with the optimal irrigation compared with deficit irrigation (drought stress) significantly affected the quality indicators. The results illustrated the marked superiority of the Poseidon beet variety over the other ones in all quality parameters determined. The results indicated that the addition of the biofertilizer yeast or Vinasses or both gave the lowest values for K, Na, (α-n), SL and SLY in both seasons. Biofertilizer, i.e., yeast and Vinasses mitigated the drought stress on sugar beet varieties. The application of Vinasses and yeast to the Poseidon sugar beet variety under water stress gave the best results for quality traits of sugar beet. The application of yeast and Vinasses is an effective tool in reducing the negative effects of water stress on the quality of sugar beet varieties.

Keywords: Beta vulgaris; Deficit irrigation; Yeast extract; Vinasses; Sugar loss.

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Introduction

Sugar beet (*Beta vulgaris*) is one of the most important sugar crops in the world and is considered the first sugar crop in Egypt and (www.fao.org 2020; Abou-Elwafa et al. 2006). The lack of water resources is considered one of the most important challenges facing the expansion of agriculture, and therefore it is necessary to search for varieties that are tolerant to water stress, as well as choosing treatments that reduce the impact of water stress (Yonts, 2006; Almaroai and Eissa 2020; Abou-Elwafa et al. 2020). Seeking for effective and easy–to–implement tactics to mitigate the negative impacts on crop growth as a result of water shortage will remain the main objective in irrigation water rationalization programs.

Water supply treatments significantly affected the alpha amino-N and alkalinity in sugar beet (Hosseinpour et al. 2006). Hussein et al. (2015) revealed that the highest growth parameters were obtained by irrigation with 75 % of ETc, while the lowest values were gained under the highest water stress (50 % of the ETc). Makhlouf and Abd El-All (2017) revealed that applying water at 100% ETc significantly increased K and α-amino N contents in root in both seasons. El-Sayed et al. (2018) found that increasing water stress level from 30 up to 70% from field capacity.

Juice quality significantly increased as water stress increased up to 70%, while juice impurities and sucrose loss to molasses% (SLM) decreased. Ozbay and Yildirm (2018) showed that the irrigation method has significant effects on root and sugar yields of sugar beet. Eman and Soha (2020) found that increasing irrigation interval from 3 up to 7 days caused significant increases in the sugar lost to molasses. Yassin et al. (2021) indicated that reducing water supply reduced alpha-amino N, Na% in the second season, and K present and sugar lost to molasses.

In Egypt, several investigators showed that the quality characters also are very important to gain maximum income from cultivation of sugar beet, e.g., Sharaf (2012), Ferweez et al. (2011), Ferweez and Abd El-Monem (2018). Quality of sugar beet depends on optimum supply with bio fertilizer as yeast which, containing vitamins, gibberellic acid, cytokines and amino acid in addition to mineral elements, e.g., Fe, K, Na, Ca, and Mg, which have direct effect on cell divisions and photosynthesis (Shalaby and EL-Nady 2008; Sharaf, 2012; Ferweez et al. 2011; Ferweez and Abd El-Monem 2018). Significant differences in α-N, K, Na contents and recoverable sugar yields (ton/fed) of sugar beet were found a results of soil application of yeast treatments (Alice et al. 2019; Sarhan et al. 2020). Alice et al. (2019) indicates that either humic acid or yeast have promoting effect on all studied characters, but yeast application was more effective than humic acid. Sarhan et al. (2020) showed that delaying spraying sugar beet plants with yeast extract and boron resulted in gradual and significant decrease in the values of sodium, potassium and α-amino nitrogen percentages of sugar beet juice. The present investigation was carried out to find out the optimum irrigation, varieties and biofertilizer treatments to obtain the highest quality of sugar beet grown in clay loam soils. The study is also aims to investigate the role of biofertilizer in mitigating the adverse effect of drought on the quality of sugar beet.

Materials and methods

Field experiments

The current experiment took place in Shandaweel Agricultural Research Station, Sohag Governorate, Egypt, (Lat of 24.54o N and Long of 32.94o E) over the two winter seasons of 2019/2020 and 2020/2021. Sugar beet seeds were sown in hills 20 cm apart using dry sowing method on one side of a ridge of 0.6 m. The experiment included two irrigation levels (normal and drought) four sugar beet verities, and four biofertilizer treatments. The normal irrigation included 12 irrigations given at an average interval of 15 days, while the drought-stress irrigation included 7 irrigations given at an average interval of 26 days. The irrigation treatments were allocated in the main plots, and the varieties were randomly distributed in the sub plots, while the four biofertilizers treatments were distributed in the sub-sub plots. The biofertilizer treatments were control, Vinasses at 5%, yeast at 5% and Vinasses + yeast at 5% of each. Vinasses was brought from Egyptian Sugar & Integrated Industries Co., Egypt. Abu Qurqas Sugar Factories, Minya Governorate. Yeast, Saccharomyces cerevisae strain, obtained from the Egyptian Sugar and its Integrated Industries Company, Hawamdia, Egypt. Yeast was activated by adding treacle at 20% to the prepared solutions of yeast. Yeast solution was left stand at 38o C for one day before applying. The biofertilizer treatments were added by foliar spraying at age of 50 and 70 days from sowing date. The field experimental was carried out in a Randomized Complete Blocks Design (RCBD) using a split-split plot arrangement with three replications. The experiment included thirty-two treatments comprising. The experimental unit area was 10.5 m2 (1/400 feddan including 5 rows of 0.6 m apart and 3.5 m in length). At land preparation, 30 kg of P2O5 in the form of calcium super-phosphate (15% P2O5) were applied. Plants were thinned at 4 leaf stage (30 days from sowing) to one plant per hill. The nitrogen fertilization was applied in the form of urea (46% N) at a rate of 80 kg/fed at two equal doses, one after thinning and before the irrigation, the other one month later. Potassium sulphate (48% K2O) was applied as a side-dressing in two equal doses, the first one after thinning (35 days after sowing) and the other before the third irrigation (70 days after sowing). All agronomic practices in sugar beet field were done as usual. Soil samples were taken randomly from the experimental site from the soil surface (30 cm) before soil preparation to measure the chemical and physical soil properties as shown in Table 1.

Table 1. Basic soil physical and chemical properties.

Properties	2020	2021
Fine sand (%)	21	37
Coarse sand (%)	1.5	1.1
Silt (%)	42	32
Clay (%)	35.5	30
Texture	Clay loam	Clay loam
Field capacity	32.8	33.0
Witling point	16.91	16.91
Bulk density	1.22	1.23
Organic matter (%)	1.16	1.17
Available-N (ppm)	25.20	26.32
$CaCO_3$%	1.37	1.48
pH (1:1)	7.3	7.2
$EC_{1:5}$ (dS/m)	0.25	0.26

Soil analysis

Soil samples were air-dried and ground to pass through a 2-mmsieve. Selected chemical properties of the soils were determined according to the procedures referred by Jackson (1973). The soil texture was determined in the soil sample by the pipit and sieving method. The pH of the soil was determined by mixing 50 g of soil with 100 mL distilled water by pH meter (JENWAY Model 3510). The electrical conductivity (EC) of 1:5 soil to water extract was determined to assess the soil salinity. The salinity of the extract was measured by (JENWAY Model 4520 Conductivity meter). Organic matter content was determined by the Walkley–Black method. Total calcium carbonate was determined by using a Collins calcimeter.

The available nitrogen was extracted from a 10 g soil sample with 40 mL KCL_2 and shaking for 1 min, then nitrogen (NH_4 and NO_3) in the extract was measured by Kjeldahl distillation method. The pressure plate method was used to calculate the field capacity and permanent wilting point. The bulk density was measured by soil ring.

Quality properties

At harvest (after 195 days from sowing), five plants were taken randomly from the guarded ridges of each plot to determine the following characteristics:

1-Sugar lost (SL%) to molasses = 0.14 (Na+K) + 0.25 (α–amino N) + 0.5 (Deviller, 1988).

2- Sodium meq /100 gm beet (Na), was estimated as meq /100 gm beet according to the procedure described by the sugar company using Auto Analyzer (Cooke and Scott, 1993).

3- Potassium meq/100 gm beet (K) was estimated as meq /100 gm beet according to the procedure described by the sugar company using Auto Analyzer (Cooke and Scott, 1993).

4- Alpha amino nitrogen meq /100 gm beet (α-amino N) was estimated as meq /100 gm beet according to the procedure described by the sugar company using Auto Analyzer (Cooke and Scott, 1993).

5- Sugar loss yield (SLY) = Root yield x sugar losses %

6- Relative sugar loss yield (RSLY)% was calculated according to Alotaibi et al. (2021) as follows:

$$RSLY = \frac{\text{Sugar loss yield (SLY)}}{\text{Sugar loss yield (SLY)} + \text{Recoverable sugar yield}} \times 100$$

Statistical analysis

Analysis of variance (ANOVA) and least significant difference (LSD) were carried out using the Proc glm of SAS 130 package version 9.2. The proper statistical of all data was carried out according to Gomez and Gomez (1984).

Results and Discussion

Effect of irrigation treatments

Sugar lost to molasses (SL), impurities (K, Na and α-N), sugar loss yield (SLY) and relative sugar loss yield (RSLY) are indicator for quality of sugar beet roots. Data listed in Table (2) showed that the drought stress led to significant effects in the values of potassium content and SLY %, meanwhile the difference between the drought stress and optimum irrigation did not reach the level of significance on SL% and sodium contents, in both seasons, as well as α-amino N and RSLY% in the 2nd season. The optimum irrigation gave the highest value of α-amino and SLY% in the 1st season, meantime the same water regime gave the maximum value of potassium content and SLY% in the 2nd season. These findings are harmony with these obtained by Jahedi et al. (2012), Eman and Soha (2020) and Yassin et al. (2021). Water is an essential factor for the turgidity of leaf cells, the lengthening of stalk cells as well as photosynthesis process (Almaroai and Eissa, 2020). Shortage of soil moisture reduces the crop yield and adversely affects the quality (Almaroai and Eissa, 2020). These results are in line with Makhlouf and Abd El-All (2017) revealed that applying water at 100% ETc significantly increased K and α-amino N contents in root in both seasons. Moreover, El-Sayed et al. (2018) found that increasing water stress decreased juice impurities and (SLY).

Table 2. Impact of irrigation treatments on sugar beet quality parameters in 2019/2020 and 2020/2021 seasons.

Irrigation treatment	SL	Na	K	α-amino N	SLY	RSLY
2019/2020						
Optimum irrigation	2.30	1.79	4.01	3.95	0.69	14.77
Drought stress	2.31	1.74	4.08	3.77	0.63	15.02
$LSD_{0.05}$	NS	NS	**	**	**	**
2020/2021						
Optimum irrigation	2.23	1.72	4.44	3.46	0.69	14.70
Drought stress	2.16	1.77	4.24	3.27	0.62	14.87
$LSD_{0.05}$	NS	NS	**	NS	**	NS

Variations among sugar beet varieties in the quality parameters

Data in Table 3 indicated that the evaluated sugar beet varieties varied substantially in quality traits in both seasons. The results illustrated the marked superiority of Poseidon beet variety over the other ones in all quality parameters determined. On the contrary, except for Na in the first season, Gazelle variety recorded the lowed mean values of the studied traits. The monogerm sugar beet variety, i.e., Poseidon, produced the highest values of most studied traits. The superiority of a specific sugar beet variety in particular of traits under specific agricultural conditions could be attributed to its genetic make-up which enables it to respond differently to the changed environmental conditions, available nutrients and light interception, and thus affects its photosynthetic capacity and partitioning of photoassimilates. These findings are in agreement with those reported by Mohamed et al. (2012), Sadeket al. (2019), El-Mansuobet al. (2020) and Yassinet al. (2022).

Table 3. Variations among sugar beet varieties in quality parameters in 2019/2020 and 2020/2021 seasons.

Sugar beet varieties	RY (t fed^{-1})	Pol (%)	SL (%)	Na (%)	K (%)	α-amino N (%)	SLY (t fed^{-1})	RSLY (%)
				2019/2020				
Poseidon	29.68	17.46	2.29	1.64	4.44	3.77	0.68	15.57
Nancy	29.45	16.91	2.25	1.70	4.05	3.78	0.66	15.06
Gazelle	28.16	16.50	2.30	1.72	3.81	4.12	0.65	14.59
Lilly	27.39	16.34	2.37	2.01	3.86	4.19	0.65	14.37
$LSD_{0.05}$	0.20	0.13	0.04	0.08	0.08	0.13	0.02	0.19
				2020/2021				
Poseidon	30.90	17.12	2.23	1.75	4.56	3.39	0.69	15.29
Nancy	30.60	16.89	2.18	1.74	4.56	3.18	0.66	15.11
Gazelle	29.33	15.94	2.14	1.67	4.26	3.26	0.63	14.20
Lilly	28.57	16.37	2.22	1.83	3.98	3.62	0.64	14.55
$LSD_{0.05}$	**0.19**	**0.16**	**0.05**	**NS**	**0.15**	**0.16**	**0.02**	**0.17**

Effect of biofertilizer on the studied traits

Concerning the foliar application of yeast or Vinasses on sugar beet with rates (5% g/L), the data obtained in Table 4 revealed that induced minimum values of impurities (Na and α-n), SL and SLY. Data in the same Table that application of yeast + Vinasses on sugar beet with rates (5% g/L), revealed that induced maximum values of RSLY which were 15.38 in the first season while in the second season application of yeast with rates (5% g/L), gave the highest values of RSLY which were (15.20%).

The promoting effect of biofertilizer, i.e., vinasse, yeast and Vinasses + yeast, could be due to the biologically active substance produced by these biofertilizers such as auxins, gibberellins, cytokinins, aminoacids and vitamins, the positive effect of photo-chemically and biologically treated Vinasses on quality parameters may be attributed to their stimulatory effect as an optimal un-harmful type of vinasse. These results are accordance with those of Sharaf (2012), Ferweez et al. (2011), FerweezandAbd El-Monem (2018) and Sarhan et al. (2020).

Table 4. Effect of biofertilizer on sugar beet in quality parameters in 2019/2020 and 2020/2021 seasons.

Biofertilizer	RY (t fed^{-1})	Pol (%)	SL (%)	Na (%)	K (%)	α-amino N (%)	SLY (t fed^{-1})	RSLY
				2019/2020 season				
Control	27.36	16.14	2.44	2.21	3.83	4.35	0.66	14.10
Vinasse	28.49	16.76	2.22	1.60	4.03	3.79	0.64	14.93
Yeast	29.26	17.03	2.25	1.54	4.15	3.83	0.66	15.17
Vinasses + Yeast	29.56	17.27	2.29	1.72	4.16	3.88	0.68	15.38
$LSD_{0.05}$	0.21	0.15	0.06	0.12	NS	0.24	0.02	0.15
				2020/2021 season				
Control	28.49	15.93	2.23	2.27	4.61	3.67	0.68	13.95
Vinasse	29.61	16.65	2.18	1.59	4.14	3.31	0.63	14.92
Yeast	30.43	16.96	2.14	1.62	4.26	3.38	0.66	15.20
Vinasses + Yeast	30.86	16.77	2.22	1.50	4.37	3.09	0.65	15.08
$LSD_{0.05}$	**0.23**	**0.12**	**0.07**	**0.15**	**0.17**	**0.29**	**0.02**	**0.16**

Effect of the interaction between drought stress and sugar beet varieties

Data in Table 5 pointed out that sugar lost to molasses affected significantly affected by the interaction between water stress and sugar beet varieties in the second season only. Poseidon sugar beet variety under the applying 100% of irrigation water gave the highest and significant value of sugar lost to molasses (2.30%) in the second seasons. Results also revealed that the application of drought stress and Lilly sugar beet variety gave the highest and significant value of sugar lost to molasses in the first season only which were (2.22 %). The results in the same table obtained that (K, α-N) affected significantly be the interaction between water stress and sugar beet varieties in both seasons. Planted Poseidon sugar beet variety under drought stress gave the highest and significant of K in both seasons, the same variety gave the highest α-N under optimum irrigation in the second season, in the first season Lilly Varity superiority. Results in Table 5 obtained that sugar loss yield (SLY) affected significantly by the interaction between water stress and sugar beet varieties in both seasons, while sugar loss yield (RSLY) significantly only in the first season. Planted Poseidon sugar beet variety under optimum irrigation gave the highest and significant value of SLY in both seasons. In the first season planted Poseidon sugar beet variety under drought stress gave the highest and significant value of RSLY.

Table 5. Impact of the interaction between irrigation treatments and sugar beet varieties on quality parameters in 2019/2020 and 2020/2021 seasons.

Irrigations	Sugar beet varieties	RY (t fed^{-1})	Pol (%)	SL (%)	Na (%)	K (%)	α-amino N (%)	SLY (t fed^{-1})	RSLY (%)
				2019/2020					
Optimum irrigation	Poseidon	30.85	17.02	2.30	1.83	4.32	3.77	0.70	15.12
	Nancy	31.42	16.93	2.26	1.82	4.02	3.78	0.71	15.07
	Gazelle	29.17	16.38	2.30	1.72	3.80	4.11	0.67	14.48
	Lilly	28.69	16.36	2.34	1.80	3.88	4.16	0.67	14.41
Drought stress	Poseidon	28.51	16.67	2.28	1.45	4.57	3.76	0.65	16.02
	Nancy	27.47	16.88	2.24	1.58	4.08	3.78	0.61	15.04
	Gazelle	27.15	16.61	2.31	1.72	3.82	4.12	0.63	14.71
	Lilly	26.19	16.33	2.41	2.22	3.84	4.23	0.63	14.32
$LSD_{0.05}$		0.06	0.18	NS	0.12	0.08	0.19	0.02	0.27
				2020/2021					
Optimum irrigation	Poseidon	32.02	17.04	2.30	1.81	4.44	3.69	0.74	15.14
	Nancy	32.58	16.76	2.19	1.69	4.67	3.18	0.71	14.98
	Gazelle	30.34	15.93	2.24	1.59	4.49	3.55	0.70	14.09
	Lilly	29.76	16.39	2.18	1.79	4.16	3.40	0.65	14.61
Drought stress	Poseidon	29.77	17.20	2.16	1.68	4.68	3.09	0.64	15.44
	Nancy	28.61	17.01	2.17	1.79	4.46	3.18	0.62	15.24
	Gazelle	28.33	15.96	2.05	1.73	4.04	2.96	0.58	14.31
	Lilly	27.38	16.35	2.26	1.87	3.81	3.85	0.62	14.49
$LSD_{0.05}$		**0.26**	**NS**	**0.07**	**NS**	**0.22**	**0.22**	**0.03**	**NS**

Effect of the interaction between drought stress and biofertilizer:

The results listed in Table 6 show that sugar lost to molasses (SL) was significantly affected by the interaction between irrigation and biofertilization in the first season only, while Sodium (Na) was affected in both seasons of the study. The results also showed that potassium and relative sugar loss yield (RSLY) were significantly affected in the first season, and described as alpha amino, and sugar loss yield (SLY) in the second season only.

Table 6. Impact of the interaction between drought stress and biofertilizer on quality parameters in 2019/2020 and 2020/2021 seasons.

Irrigations	Biofertilizers	RY (t fed^{-1})	Pol (%)	SL (%)	Na (%)	K (%)	α-amino N (%)	SLY (t fed^{-1})	RSLY (%)
					2019/2020				
Optimum irrigation	Control	28.74	16.16	2.43	2.26	3.77	4.34	0.70	14.14
	Vinasse	29.86	16.59	2.26	1.57	3.96	3.94	0.67	14.73
	Yeast	30.61	16.76	2.26	1.72	4.00	3.84	0.69	14.90
	Vinasses + Yeast	30.82	17.16	2.25	1.63	4.30	3.69	0.69	15.31
Drought stress	Control	25.98	16.10	2.44	2.16	3.90	4.36	0.63	14.06
	Vinasse	27.13	16.94	2.21	1.63	4.10	3.65	0.60	15.13
	Yeast	27.91	17.30	2.25	1.37	4.30	3.82	0.63	15.45
	Vinasses + Yeast	28.30	17.38	2.33	1.82	4.03	4.06	0.66	15.45
$LSD_{0.05}$		0.30	0.21	NS	0.17	0.12	NS	NS	0.22
					2020/2021				
Optimum irrigation	Control	29.85	15.89	2.43	2.23	4.77	3.81	0.73	13.86
	Vinasse	31.03	16.53	2.14	1.55	4.26	3.30	0.66	14.79
	Yeast	31.79	16.86	2.21	1.67	4.25	3.53	0.70	15.05
	Vinasses + Yeast	32.03	16.84	2.12	1.43	4.49	3.18	0.68	15.11
Drought stress	Control	27.13	15.96	2.33	2.31	4.44	3.52	0.63	14.03
	Vinasse	28.20	16.77	2.12	1.63	4.02	3.33	0.60	15.05
	Yeast	29.07	17.07	2.13	1.57	4.27	3.23	0.62	15.34
	Vinasses + Yeast	29.70	16.71	2.06	1.56	4.24	3.01	0.61	15.04
$LSD_{0.05}$		NS	0.17	0.12	0.21	NS	0.41	0.03	NS

Effect of the interaction between sugar beet varieties and biofertilizer

The data listed in Table 7 indicate that the interaction between sugar beet varieties and biofertilization had a significant effect on the studied quality traits in both seasons. The data indicated that the addition of the biofertilizers vinasse, yeast, or Vinasses with the yeast gave better results in reducing sodium, potassium, and alpha-amino nitrogen, compared to the control in both seasons. Data in the same Table cleared that relative sugar loss yield (RSLY) significantly affected by the interaction between sugar beet varieties and biofertilization in both seasons. Planted Poseidon sugar beet variety with biofertilizers yeast gave the highest and significant value of RSLY (16.24 and 15.80%) in the first and second seasons.

Table 7. Impact of the interaction between sugar beet varieties and biofertilizer on quality parameters in 2019/2020 and 2020/2021 seasons.

Sugar beet varieties	Biofertilizers	RY (t fed^{-1})	Pol (%)	SL (%)	Na (%)	K (%)	α-amino N (%)	SLY (t fed^{-1})	RSLY (%)
				2019/2020					
Poseidon	Control	28.13	15.91	2.40	2.35	3.69	4.21	0.67	13.92
	Vinasse	29.45	17.96	2.24	1.21	4.56	3.72	0.66	16.13
	Yeast	30.47	18.09	2.24	1.73	4.77	3.50	0.68	16.24
	Vinasses + Yeast	30.67	17.87	2.29	1.57	4.76	3.63	0.70	15.98
Nancy	Control	28.20	16.52	2.48	2.32	3.87	4.46	0.70	14.44
	Vinasse	29.12	16.52	2.13	1.62	3.80	3.48	0.62	14.78
	Yeast	30.11	17.04	2.10	1.10	4.26	3.39	0.63	15.34
	Vinasses + Yeast	30.35	17.54	2.29	1.76	4.27	3.78	0.69	15.65
Gazelle	Control	26.71	16.37	2.32	1.81	3.88	4.07	0.62	14.45
	Vinasse	28.20	16.33	2.33	1.77	3.84	4.16	0.65	14.41
	Yeast	28.71	16.62	2.35	1.77	3.71	4.33	0.67	14.62
	Vinasses + Yeast	29.04	16.67	2.23	1.53	3.82	3.90	0.65	14.84
Lilly	Control	26.41	15.73	2.54	2.36	3.88	4.66	0.67	13.59
	Vinasse	27.23	16.24	2.25	1.79	3.91	3.80	0.61	14.39
	Yeast	27.76	16.37	2.33	1.87	3.86	4.10	0.64	14.44
	Vinasses + Yeast	28.17	17.01	2.36	2.03	3.80	4.20	0.66	15.04
$LSD_{0.05}$		NS	0.30	0.12	0.24	0.17	0.48	0.03	0.44
				2020/2021					
Poseidon	Control	29.34	16.53	2.54	2.62	4.59	4.13	0.75	14.39
	Vinasse	30.61	16.90	2.16	1.59	4.24	3.37	0.66	15.15
	Yeast	31.62	17.59	2.18	1.57	4.68	3.23	0.69	15.80
	Vinasses + Yeast	32.02	17.45	2.04	1.20	4.73	2.83	0.66	15.81
Nancy	Control	29.33	16.22	2.36	2.55	4.59	3.42	0.69	14.27
	Vinasse	30.23	17.01	2.12	1.40	4.36	3.23	0.64	15.30
	Yeast	31.28	17.58	2.23	1.47	4.78	3.41	0.70	15.75
	Vinasses + Yeast	31.54	16.74	2.02	1.53	4.53	2.66	0.64	15.13
Gazelle	Control	27.75	15.32	2.36	1.84	4.82	3.69	0.65	13.36
	Vinasse	29.35	16.03	2.20	1.75	4.20	3.49	0.65	14.23
	Yeast	29.83	16.32	2.00	1.56	3.73	3.04	0.60	14.72
	Vinasses + Yeast	30.38	16.10	2.02	1.52	4.31	2.81	0.62	14.49
Lilly	Control	27.54	15.64	2.27	2.07	4.43	3.43	0.63	13.77
	Vinasse	28.24	16.67	2.05	1.64	3.77	3.16	0.58	15.02
	Yeast	28.98	16.37	2.26	1.89	3.85	3.83	0.66	14.51
	Vinasses + Yeast	29.51	16.80	2.31	1.74	3.89	4.07	0.68	14.89
$LSD_{0.05}$		NS	0.25	0.17	0.30	0.35	0.59	0.05	0.45

Effect of the interaction among drought stress, sugar beet varieties and biofertilizer

The 2nd order interaction, among the three factors, i.e., irrigation, sugar beet varieties and biofertilization were significant in both seasons (Table 8 and 9) on the quality characteristics of the studied. The results indicated that the addition of the yeast or vinasse, or both Vinasses and yeast together, was significant and positive in reducing the characteristics of sodium, potassium, alpha-amino nitrogen, and lost sugar in molasses. On the contrary data revealed that planted Poseidon sugar beet variety under drought stress with Vinasses or yeast bio fertilizer gave the highest values of sugar loss yield which gave 17.03% with Vinasses in the first season and 15.86% with yeast in the second season.

Table 8. Impact of the 2nd order interactions among the three studied factors on quality parameters in 2019/2020 season.

Irrigation	Sugar beet varieties	Biofertilizers	RY (t fed^{-1})	Pol (%)	SL (%)	Na (%)	K (%)	α-amino N (%)	SLY (t fed^{-1})	RSLY (%)
			2019/2020 season							
Optimum irrigation	Poseidon	Control	29.22	16.16	2.22	2.53	3.55	4.48	0.65	14.34
		Vinasse	30.67	17.14	2.32	1.43	4.34	4.06	0.71	15.22
		Yeast	31.54	17.62	2.31	1.64	4.67	3.70	0.73	15.72
		Vinasses + Yeast	31.98	17.15	2.36	1.71	4.72	3.83	0.75	15.19
	Nancy	Control	30.25	16.67	2.53	2.69	3.69	4.53	0.76	14.54
		Vinasse	31.23	16.70	2.14	1.41	3.80	3.62	0.66	14.96
		Yeast	32.23	16.62	2.12	1.49	3.84	3.48	0.68	14.90
		Vinasses + Yeast	31.97	17.75	2.27	1.70	4.75	3.47	0.73	15.88
	Gazelle	Control	28.13	16.25	2.41	1.89	3.88	4.40	0.68	14.24
		Vinasse	29.08	16.32	2.29	1.71	3.84	4.05	0.67	14.43
		Yeast	29.60	16.42	2.34	1.91	3.66	4.23	0.69	14.48
		Vinasses + Yeast	29.88	16.53	2.17	1.39	3.83	3.74	0.65	14.77
	Lilly	Control	27.37	15.58	2.56	1.95	3.94	4.95	0.70	13.42
		Vinasse	28.47	16.20	2.28	1.73	3.85	4.01	0.65	14.32
		Yeast	29.08	16.38	2.28	1.82	3.84	3.95	0.66	14.50
		Vinasses + Yeast	29.43	17.22	2.21	1.71	3.90	3.72	0.65	15.40
Drought stress	Poseidon	Control	27.03	15.67	2.58	2.16	3.83	4.95	0.70	13.49
		Vinasse	28.23	18.78	2.15	0.99	4.77	3.39	0.61	17.03
		Yeast	29.39	18.55	2.18	1.22	4.88	3.30	0.64	16.77
		Vinasses + Yeast	29.37	18.60	2.22	1.43	4.79	3.42	0.65	16.78
	Nancy	Control	26.16	16.38	2.44	1.96	4.05	4.39	0.64	14.34
		Vinasse	27.00	16.33	2.13	1.84	3.80	3.34	0.57	14.61
		Yeast	27.99	17.47	2.08	0.72	4.69	3.30	0.58	15.79
		Vinasses + Yeast	28.73	17.33	2.31	1.82	3.70	4.09	0.66	15.42
	Gazelle	Control	25.28	16.48	2.22	1.74	3.88	3.74	0.56	14.66
		Vinasse	27.31	16.35	2.36	1.83	3.85	4.26	0.64	14.39
		Yeast	27.81	16.82	2.36	1.63	3.75	4.42	0.66	14.86
		Vinasses + Yeast	28.20	16.80	2.28	1.67	3.81	4.06	0.64	14.92
	Lilly	Control	25.45	15.88	2.52	2.77	3.83	4.38	0.64	13.76
		Vinasse	25.96	16.28	2.21	1.85	3.97	3.59	0.58	14.47
		Yeast	26.45	16.35	2.37	1.91	3.87	4.25	0.63	14.38
		Vinasses + Yeast	26.91	16.80	2.52	2.34	3.71	4.69	0.68	14.68
$LSD_{0.05}$			0.61	0.43	0.17	0.34	0.24	0.68	0.05	0.44

Table 9. Impact of the 2nd order interactions among the three studied factors on quality parameters in 2020/2021 season.

Irrigation	Sugar beet varieties	Biofertilizers	RY (t fed^{-1})	Pol (%)	SL (%)	Na (%)	K (%)	α-amino N (%)	SLY (t fed^{-1})	RSLY (%)
Optimum irrigation	Poseidon	Control	30.35	16.26	2.60	2.74	4.34	4.45	0.79	14.06
		Vinasse	31.87	16.46	2.17	1.52	3.98	3.59	0.69	14.69
		Yeast	32.72	17.62	2.28	1.64	4.75	3.54	0.75	15.74
		Vinasses + Yeast	33.16	17.80	2.13	1.32	4.69	3.16	0.71	16.06
	Nancy	Control	31.40	16.27	2.36	2.74	4.65	3.31	0.74	14.31
		Vinasse	32.33	16.79	2.09	1.22	4.25	3.28	0.67	15.10
		Yeast	33.44	17.40	2.22	1.37	4.77	3.43	0.74	15.58
		Vinasses + Yeast	33.14	16.60	2.07	1.42	5.02	2.68	0.69	14.93
	Gazelle	Control	29.14	15.06	2.45	1.59	5.15	4.02	0.71	13.01
		Vinasse	30.20	16.31	2.25	1.73	4.75	3.38	0.68	14.46
		Yeast	30.75	16.32	2.15	1.64	3.64	3.67	0.66	14.56
		Vinasses + Yeast	31.24	16.03	2.10	1.42	4.42	3.15	0.66	14.32
	Lilly	Control	28.52	15.98	2.32	1.85	4.94	3.47	0.66	14.06
		Vinasse	29.69	16.57	2.04	1.74	4.05	2.93	0.61	14.93
		Yeast	30.26	16.09	2.19	2.03	3.84	3.48	0.66	14.30
		Vinasses + Yeast	30.57	16.92	2.19	1.55	3.82	3.74	0.67	15.14
Drought stress	Poseidon	Control	28.33	16.80	2.48	2.51	4.84	3.80	0.70	14.72
		Vinasse	29.35	17.35	2.14	1.65	4.49	3.14	0.63	15.61
		Yeast	30.53	17.55	2.09	1.50	4.62	2.92	0.64	15.86
		Vinasses + Yeast	30.88	17.10	1.94	1.07	4.77	2.50	0.60	15.56
	Nancy	Control	27.25	16.17	2.35	2.37	4.52	3.53	0.64	14.23
		Vinasse	28.13	17.23	2.14	1.58	4.46	3.18	0.60	15.49
		Yeast	29.13	17.75	2.23	1.56	4.80	3.38	0.65	15.92
		Vinasses + Yeast	29.94	16.88	1.96	1.64	4.04	2.64	0.59	15.32
	Gazelle	Control	26.37	15.58	2.26	2.09	4.48	3.36	0.59	13.72
		Vinasse	28.50	15.75	2.16	1.76	3.64	3.60	0.61	13.99
		Yeast	28.91	16.32	.185	1.47	3.83	2.42	0.54	14.88
		Vinasses + Yeast	29.52	16.18	1.93	1.61	4.20	2.47	0.57	14.65
	Lilly	Control	26.57	15.30	2.22	2.28	3.92	3.40	0.59	13.48
		Vinasse	26.79	16.77	2.05	1.53	3.49	3.38	0.55	15.12
		Yeast	27.70	16.65	2.33	1.75	3.85	4.19	0.65	14.72
		Vinasses + Yeast	28.45	16.18	1.43	1.92	3.97	4.41	0.69	14.64
		$LSD_{0.05}$	**NS**	**0.35**	**0.24**	**0.42**	**0.49**	**0.83**	**0.07**	**0.45**

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