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RESEARCH ARTICLE

Enhancement of production and quality of sugarcane using nitrogen and vinasses

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Abstract

The objective of this study was to evaluate the effect of N-fertilizer levels and vinasses on the yield and quality traits of two sugarcane varieties. Two field experiments were conducted at Shandaweel Agricultural Research Station in Sohag Governorate, Egypt in the 2020/2021 and 2021/2022 seasons to find out the appropriate level of nitrogen fertilizer (180, 210 and 240 kg N/fed.) and cane vinasses (0 and 50 l/fed.) to maximize yield and quality in sugarcane.

Experiments were conducted using RCBD in a split split-plot arrangement. The results showed that sugarcane varieties differed markedly in all studied traits.

The sugarcane variety G.T.54-9 recorded the highest values of yield and its component, while G.2003-47 was superior in juice quality traits in both seasons, as well as sugar yield/fed. in the 1st one.

Increasing N fertilizer level to 240 kg N/fed. resulted in a significant increase in yield and its component, in both seasons, while adding 210 kg N/fed led to a significant increase in juice quality traits, in both seasons, as well as sugar yield/fed in the 1st one. Results showed that the addition of 50 l/fed. of vinasses caused a significant increase in all the studied traits in both seasons. In the present study, it was found that growing sugarcane varieties studied and fertilizing them with 240 and/or 210 kg N/fed., combined with 50 l/fed of cane vinasses can be recommended to get the maximum cane and sugar yields/fed.

Keyword: Sugarcane varieties; Nitrogen; Vinasses; Cane yield; Juice quality

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Introduction

It is known that the sugarcane variety is the corner stone for maximizing the production of sugar to minimize the gap between the production and consumption of such a strategic commodity in Egypt. The commercial variety G.T.54-9 has been planted for so many years occupying almost 100% of the area planted with sugarcane in Egypt (Sugar Crops Council, annual report 2021). Nowadays, Sugar Crops Research Institute has developed a number of sugarcane varieties, of which G.2003-47 is considered a promising one.

The newly bred varieties showed variable responses to different agronomic practices. Makhlouf et al. (2016), Fahmy et al. (2017), El-Bakry (2018) Gadallah and Abd El-Aziz (2019), Gadallah et al. (2020), Gadallah and Mehareb (2020) and Ali et al. (2022) found that sugarcane variety G.T.54-9 showed the superiority in stalk height, stalk diameter, number of millable canes as well as cane and sugar yields/fed. while G.2003-47 was superior in juice quality characteristics.

The most significant ingredient for most farmed crops is nitrogen, which it is an essential and structural element for producing different organic compounds in plants such as proteins, nucleic acids, chlorophyll, protoplasm and vitamins, required for building up plant organs and enhancing its growth. Concerning effects of nitrogen fertilization levels on sugarcane traits, Osman et al. (2010) found that increasing N levels to 240 kg N/fed. recorded the highest values of stalk length, diameter, number of millable canes, cane and sugar yields/fed., while juice quality traits decreased significantly Bekheet and Abd El-Aziz . (2016) showed that raising N level to 220 kg N/fed resulted in increases in stalk height, diameter, number of millable canes/fed., cane and sugar yields/fed. Makhlouf et al. (2016) cleared that increasing N levels up to 240 kg N/fed led to significant increases in stalk length, diameter, number of millable canes/fed, cane and sugar yields/fed. Bekheet et al. (2018).

Showed that increasing nitrogen levels to 210 kg N/fed resulted in a significant increase in stalk length, diameter, number of millable canes, cane and sugar yields, as well as juice quality traits in both seasons. (Gadallah 2020) found that increasing N-levels to 240 kg N/fed resulted in a significant increase in stalk height, diameter, and number of millable canes/fed. as well as cane and sugar yields/fed., while the application of 210 kg N/fed. caused a significant increase in juice quality traits. Mineral fertilizers are used to improve soil fertility and plant nutrition, but crops benefit only with a portion of N added, while the rest is lost as nitrous oxide emissions, nitrate leaching, or in agricultural drainage, which lowers the efficiency of nitrogen used in agriculture Ngosong et al.(2019).

The sole use of chemical fertilizers degrades soil physicochemical and biological qualities, as well as being harmful to animals, plants, and human life Jjagwe et al. (2020). Alternative techniques of providing nutrients for plants had to be developed. Organic fertilizers are considered promising alternative approaches for sugarcane and other crop species production Gao et al. (2020). Therefore, it was necessary to use alternative organic nutrients that are safer than mineral nutrients, including vinasses. Cane vinasses is the final by-product of the cycle of distillation of alcoholic liquor, yeast and amino/organic acid fermentation of sugarcane molasses. Vinasses was documented as an agricultural fertilizer for recycling NPK and water in organic crop production since 1940 Fuess et al. (2017).

In this concern, (Parnaudeau et al. 2006) indicated that vinasses is used in farming for cheap supplement sources. Reis and Hu (2017) and Bastos et al. (2021) mentioned that vinasses contains important macro minerals such as N, K, Ca sulfate and Mg. It contains vitamins and organic acids such as vitamin B complex and amino acids from yeast autolysis, which are required for crop production and soil organic matter content improvement. It also contains chelated organic material, which contains micronutrients such as Fe, Mn, Zn, and Cu. In addition, vinasses contains some organic acids such as acetic, lactic, nicotinic, malice, and citric acids, which can play an important role in reducing soil alkalinity. Some constrains due to its salinity, high density (1.3 g/cm3) and low P content (P2O5 0.12 g/kg) Murillo et al. (1993) and Martın-Olmedo et al. (1996). Some of these problems may be overcome by composting the vinasses with other solid agricultural wastes Diaz et al. (1996) and Madejon et al. (1996). Gomez and Rodriguez (2000) found that sugar and cane yields increased with the application of vinasses. Moreover, the foliar application of vinasses to sugar beet promotes root yield, Pol %, recoverable sugar %, quality index% and recoverable sugar yield. Meanwhile, Na%, K% and α-amino-N%, sugar loss% and sugar loss yield were reduced in response to vinasses foliar application Ahmed et al. (2023) a&b. Besides, compared to the control treatment, the foliar application of vinasses at the rate of 4% (v/v) enhanced quality index, recoverable sugar% and recoverable sugar yield and reduced Na%, K%, α-amino-N% sugar loss% and sugar loss yield Abofard et al. (2021).

Materials and methods

Two field experiments were conducted at Shandaweel Agricultural Research Station (latitude of 26.33° N, longitude of 31.41° E and altitude of 69 m), Sohag Governorate, Egypt in the 2020/2021 and 2021/2022 seasons to evaluate the impact of N-fertilizer levels (180, 210 and 240 kg N/fed) and two sugarcane vinasses rates (0 and 50 liter/fed.) on cane yield and quality of two sugarcane varieties G.2003-47 (Giza 3) and the commercial variety G.T.54-9 (C9).

The experiments included 12 treatments represented the combinations of two sugarcane varieties viz G.2003-47 named Giza-3 variety, compared to G.T.54-9 known commercially as C9 variety, three nitrogen fertilizers levels (180-210 and 240 kg N/fed.) and two cane vinasses rates (0 and 50 l/fed.). Sugarcane was planted in the first week of March and harvested after 12 months in both seasons.

Randomized complete block design in a split split-plot arrangement with three replications was used. Sugarcane varieties were distributed in the main plots, whereas the three N-fertilizers levels were applied in the sub-plots and vinasses rates were added to the sub sub-plots. Each sub-sub-plot area was 35 m^2 “1/120 feddan” including 5 rows of 7 m in length and 1.0 m apart. Nitrogen fertilizer was applied as urea (46% N), which was split into two equal doses; after the1st and 2^{nd} hoeing i.e., 60 and 90 days from planting. Sugarcane vinasses Table 2 liquid was added by a knapsack sprayer on the soil as a single dose after 60 days from planting in the early morning with the 1st dose from N-fertilization at a rate of 50 l/fed. then the field was immediately irrigated. Phosphorus fertilizer was added once during seed-bed preparation as calcium super phosphate (15% P_2O_5) at the rate 30 kg P_2O_5/fed.., Potassium fertilizer was added once as potassium sulfate (48% K_2O) at the rate of 48 kg K_2O/fed. with the 2nd dose of N fertilizer. The other agricultural practices were done as recommended by Sugar Crops Research Institute. The chemical analyses and types of the soil were taken from the experimental sites before planting Table 1 were performed, according to the protocols given by Piper (1950) and Jackson (1967).

Table 1. Chemical and physical properties of the upper 40-cm of the experimental soil

Season		1st season	2nd season
Mechanical analysis	Sand%	21.5	21.7
	Silt	29.3	28.8
	Clay	49.2	49.5
Soil texture		Clay loam	Clay loam
Available macronutrients	N (ppm)	94	110
	P (ppm)	18	19
	K (ppm)	917	950
Chemical analysis: $CaCO_3$%		1.20	1.47
Chemical analysis: Anion meq l^{-1}	CO_3^-	0	0
	HCO_3^-	0.69	0.73
	CL^-	0.52	0.89
	SO_4^{--}	1.57	1.18
Chemical analysis: Cation meq l^{-1}	Ca^{++}	0.55	0.56
	Mg^{++}	0.68	0.38
	Na^+	1.09	1.31
	K^+	0.47	0.55
Chemical analysis: EC ds/m (1:5)		0.278	0.281
Chemical analysis: pH (1: 2.5)		7.55	7.60

Table 2. Chemical composition of the applied raw cane vinasses

Chemical composition	1st season	2nd season
Total sugar% (mg)	6	6
Total soluble solids%(Brix)	31%	32%
Nitrogen% (mg)	0.75	0.73
Organic matter% (mg)	5.38	5.32
Phosphorus%(mg)	0.08	0.08
Potassium%(mg)	2.03	2.00
Calcium% (mg)	1.21	1.20
Magnesium% (mg)	0.53	0.54
Ash %(mg)	6.4	6.5
pH	4.5	4.5
Appearance	Dark brown liquid	

The following data were recorded at harvest

1. Stalk height (cm) was measured from land level to the point of visible dewlap.

2. Stalk diameter (cm) was measured at the middle part of cane stalk.

3. Number of millable canes was calculated on plot basis, then converted into 1000/fed. (4200 m2).

Juice quality and chemical constituents

At harvest, a sample of 20 millable canes from each treatment was collected at random, cleaned and crushed to extract the juice, which was analyzed to determine the following quality traits:

1-Brix% (total soluble solids, TSS%), was determined using " Hydrometer" according to the method described by "The Chemical Control Lab" of Sugar and Integrated Industries Company Anonymous (1981).

2-Sucrose% was determined using “Sacharemeter” according to A.O.A.C. (2005).

3-Sugar recovery% was calculated as shown by Yadav and Sharma (1980) as follows:

Sugar recovery % = [sucrose% - 0.4 (brix% - sucrose %) × 0.73].

4-Nitrogen % in leaves and stalks were determined using the method of micro-Kjeldahl, mentioned in A.O.A.C. (2005).

Yields

1-Canes yield/fed. (ton) was determined on plot basis (kg), then converted into ton/fed.

2-Sugar yield/fed. (ton) was estimated according to the following equation:

Sugar yield/fed. (ton) = cane yield (ton) x sugar reco0very/100

Statistical analysis

The collected data were statistically analyzed according to Gomez and Gomez (1984) using "MSTAT-c" statistical analysis package described by Freed et al. (1989). The least significant difference (LSD) at 0.05 level of probability was calculated to compare the differences among means of treatments according to Snede corand Cochran (1981).

Results and discussion

Stalk height

The results in Table 3 showed that the commercial variety G.T.54-9 had higher stalk preceding G.2003-47 variety and an increase in stalk height by 31.9 and 47.4 cm, in the 1st and 2nd seasons, respectively. e variance between the two cane varieties in this trait may be due to their gene makeup. Similar observations were reported by Makhlouf et al. (2016), Fahmy et al. (2017) Gadallah and Abd El-Aziz (2019), Gadallah et al. (2020), and Ali et al. (2022). Increasing N- level given to sugarcane to 210 and 240 kg N/fed. led to a significant increase in stalk height reached (8.5 and 17.4 cm) and (8.8 and 16.7 cm), compared to that provided with 180 kg N/fed., in the 1st and 2nd season, successively (Table 3). The increase in stalk height may be attributed to the role of nitrogen as an essential element in building-up plant organs and enhancing their growth. These results are similar to these obtained by Osman et al. (2010), Bekheet and El-Aziz (2016), Makhlouf et al. (2016), and Gadallah (2020).

The results cleared that using 50 l/fed. of cane vinasses at age of 60 days from planting significantly increased stalk height in both seasons compared to 0 (without vinasses). These results may be due to that, sugarcane vinasses contains important macro minerals such as N, K, Ca, S, P and Mg used as organic fertilizer for crop production as shown by Fuess et al. (2017), and Gloria (1985). Similar trends were reported by Gomez and Rodriguez (2000).

Table 3. Stalk height (cm) of sugarcane varieties as affected by nitrogen and vinasses fertilization and their interactions in the 2020/2021 and 2021/2022 seasons.

Sugarcane varieties (A)	N fertilizer level kg N/fed. (B)	Stalk height (cm) 2020/2021 Vinasses doses/l (C) 0	50	Mean	2021/2022 Vinasses doses/l (C) 0	50	Mean
G.T.54-9	180	308.8	309.4	309.1	324.0	325.4	324.7
	210	310.6	311.0	310.8	326.7	327.6	327.2
	240	312.0	317.2	314.6	327.9	329.7	328.8
Mean		310.5	312.5	311.5	326.2	327.6	326.9
G.2003-47	180	263.0	266.4	264.7	263.6	265.8	264.7
	210	277.2	282.8	280.0	273.4	286.4	279.9
	240	287.5	300.5	294.0	286.8	301.0	293.9
Mean		275.9	283.2	279.6	274.6	284.4	279.5
Average of N	180	285.9	287.9	286.9	293.8	295.6	294.7
	210	293.9	296.9	295.4	300.0	307.0	303.5
	240	299.8	308.8	304.3	307.4	315.4	311.4
Mean of vinasses doses		293.2	297.9	295.5	300.4	306.0	303.2
LSD at 0.05							
Cane varieties (A)			**			**	
N-level (B)			1.31			1.39	
Vinasses (C)			**			**	
A×B			1.82			1.97	
A×C			0.99			1.37	
B×C			1.22			1.68	
A×B ×C			NS			2.38	

NS: non-significant, **: significant

Stalk height was markedly influenced by the interactions among the studied factors except for that between the 2nd order interactions among the three factors, in the 1st season. Planting G.T.54-9 variety, fertilized with 240 kg N/fed. and 50 l/fed. of cane vinasses resulted in the longest stalks.

Stalk diameter

The tested sugarcane varieties varied significantly in stalk diameter in both seasons.

The promising G.2003-47 variety had the thickest stalks by 0.03 and 0.04 cm more than the variety G.T.54-9 in the 1st and 2nd seasons respectively (Table 4). The variance between cane varieties in these traits may be due to their gene structure. These findings coincide with those obtained El-Bakry (2018) and Gadallah and Abd-El-Aziz (2019).

Stalk diameter increased substantially and gradually when N-fertilizer level given to cane plants was raised from 180 up to 240 kg N/fed., in the 1st and 2nd seasons (Table 4).

These results may be attributed to the role of N element in building-up plant organs and enhancing plant growth. These results are in agreement with those reported by Osman et al. (2010), Bekheet and Abd-El-Aziz (2016), Makhlouf et al. (2016), and Gadallah (2020).

Data in the same Table revealed that supplying canes with 50 l of cane vinasses/fed. appreciably increased stalk diameter, in both seasons compared to that left without vinasses. Similar trends were reported by Gomez and Rodriguez (2000), Stalk diameter was insignificantly influenced by the interactions among the studied factors in both seasons, except that of (sugarcane varieties x N levels) and (N levels x vinasses) in the 1st season. The thickest stalks were produced when sugarcane variety G.2003-47 was fertilized with 240 kg N and 50 l of vinasses/fed. in both seasons.

Table 4. Stalk diameter (cm) of sugarcane varieties as affected by nitrogen and vinasses fertilization and their interactions in the 2020/2021 and 2021/2022 seasons.

Sugarcane varieties (A)	N fertilizer level kg N/fed. (B)	Stalk diameter (cm) 2020/2021 Vinasses doses/l (C) 0	50	Mean	2021/2022 Vinasses doses/l (C) 0	50	Mean
G.T.54/9	180	2.40	2.41	2.41	2.41	2.42	2.42
	210	2.45	2.46	2.46	2.42	2.45	2.44
	240	2.47	2.50	2.48	2.46	2.48	2.47
	Mean	2.44	2.46	2.45	2.43	2.45	2.44
G.2003/47	180	2.46	2.47	2.46	2.46	2.47	2.45
	210	2.48	2.49	2.48	2.48	2.48	2.48
	240	2.49	2.51	2.50	2.48	2.50	2.49
	Mean	2.48	2.49	2.48	2.47	2.48	2.48
Average of N	180	2.43	2.44	2.44	2.44	2.44	2.44
	210	2.47	2.48	2.47	2.45	2.47	2.46
	240	2.48	2.51	2.49	2.47	2.49	2.48
Mean of vinasses doses		2.46	2.47	2.47	2.45	2.47	2.46
LSD at 0.05							
Cane varieties (A)			**			**	
N-level (B)			0.01			0.01	
Vinasses (C)			**			**	
A×B			0.02			NS	
A×C			NS			NS	
B×C			0.01			NS	
A×B ×C			NS			NS	

NS: non-significant, **: significant

Number of millable cane

Data in Table 5 showed that the commercial variety G.T.54-9 had more millable cane preceding G.2003-47 variety in number of millable cane/fed. by 2.040 and 1.760 thousand/fed. in the 1st and 2nd seasons, respectively. The variance between the two cane varieties in this trait may be due to their gene make-up. Similar trends were reported by Makhlouf et al. (2016), Fahmy et al. (2017), Gadallah and Abd El-Aziz (2019), Gadallah and El-Mehareb (2020), and Ali et al. (2022). Results in Table 5, showed that increasing nitrogen fertilizer levels given to sugarcane plants from 210 to 240 increased substantially and gradually in number of millable cane/fed. amounted to (2.440 and 1.160 thousand/fed.) in the 1st season, corresponding to (2.210 and 1.330 thousand/fed.) in the 2nd one, respectively as compared with that recorded when fertilization was given at 180 kg N/fed. This result may be due to the role of N in promotes tillering and canopy development and stalk formation. these results are in a good line with that reported Osman et al. (2010), Bekheet and El-Aziz (2016), Makhlouf et al. (2016) and Gadallah (2020).

Data in the same Table revealed that supplying canes with 50 l of cane vinasses/fed. appreciably increased number of millable cane/fed. in both seasons compared to that left without vinasses. This result may be due to the vital role of vinasses due to the content of NPK elements (shown Table 2) and their role in promoting tillering. Those mentioned by Garcia (1994).

As for the interactions among the studied factors, all of them were not significant on the number of millable cane in both seasons, except for that of interaction between cane varieties x N-levels in the 2nd season, which was significant. The highest millable cane was produced when sugarcane variety G.T.54-9 was fertilized with 240 kg N/fed.

Table 5. Number of millable cane1000/fed. of sugarcane varieties as affected by nitrogen and vinasses fertilization and their interactions in the 2020/2021 and 2021/2022 seasons.

Sugarcane varieties (A)	N fertilizer level kg N/fed. (B)	Number of millable cane (1000/fed.) 2020/2021 Vinasses doses/l (C) 0	50	Mean	2021/2022 Vinasses doses/l (C) 0	50	Mean
G.T.54/9	180	42.150	43.060	42.605	42.250	43.040	42.645
	210	43.063	44.080	43.572	43.663	44.167	43.915
	240	44.080	46.483	45.282	44.200	44.947	44.573
Mean		43.098	44.541	43.819	43.371	44.051	43.711
G.2003/47	180	43.098	44.541	40.600	40.140	41.017	40.578
	210	43.098	44.541	41.932	41.687	42.267	41.977
	240	43.098	44.541	42.795	43.000	43.583	43.292
Mean		41.491	42.060	41.776	41.609	42.289	41.949
Average of N	180	41.112	42.093	41.603	41.195	42.028	41.612
	210	42.428	43.075	42.752	42.675	43.217	42.946
	240	43.343	44.733	44.038	43.600	44.265	43.933
Mean of vinasses doses		42.294	43.304	42.799	42.490	43.170	42.830
LSD at 0.05							
Cane varieties (A)			**			**	
N-level (B)			0.626			0.171	
Vinasses (C)			**			**	
A×B			NS			0.242	
A×C			NS			NS	
B×C			NS			NS	
A×B ×C			NS			NS	

NS: non-significant, **: significant

Brix%

Data in Table 6 showed that the promising variety G.2003-47 had the highest brix% compared to that of G.T.54-9 in both seasons. The variance between cane varieties in this trait may be due to their gene structure. Such varietal differences between cane verities were reported by Fahmy et al. (2017), El-Bakry (2018), Gadallah and El-Mehareb (2020) and Ali et al. (2022).Data in the same Table, cleared that increasing N fertilizer-levels given to sugarcane plants from 180 up to 210 kg N/fed. substantially and gradually improved in brix%, thereafter, it decreased with raising nitrogen fertilization level to 240 kg N/fed., in both seasons. These results may indicate that 210 kg N/fed. was the best dose recording the highest total soluble solids in cane juice, while the highest N-level may direct cane plants for more vegetative growth rather than dry matter accumulation.

These results are in line with those mentioned by Bekheet et al. (2018) and Gadallah (2020). The results showed that using 50 l/fed. of cane vinasses at the age of 60 days from planting significantly increased brix%, in the 1st season only compared to 0 treatment (without vinasses), while had insignificant in the 2nd season. Vinasses is a good source of organic matter, NPK and other important nutrients according to Copersugar (1986) (as shown in Table 2), this will be reflected on the juice quality characters. As for the interactions among the studied factors, all of them were not significant on brix% in both seasons, except for the interaction between cane varieties x N-levels in both seasons, which was significant. Planting G.2003-47 variety and fertilized with 210 kg N/fed. resulted in the highest brix%.

Table 6. Brix % of sugarcane varieties as affected by nitrogen and vinasses fertilization and their interactions in the 2020/2021 and 2021/2022 seasons.

Sugarcane Varieties (A)	N fertilizer level kg N/fed. (B)	Brix (%) 2020/2021 Vinasses doses/l(C) 0	50	Mean	2021/2022 Vinasses doses/l (C) 0	50	Mean
G.T.54/9	180	21.53	21.84	21.69	21.78	21.83	21.81
	210	21.87	22.02	21.95	21.88	22.03	21.96
	240	20.83	20.97	20.90	21.29	21.50	21.40
Mean		21.41	21.61	21.51	21.65	21.79	21.72
G.2003/47	180	23.20	23.22	23.21	23.19	23.21	23.20
	210	23.66	23.84	23.75	23.25	23.37	23.31
	240	22.98	23.06	23.02	23.02	23.09	23.06
Mean		23.28	23.37	23.33	23.15	23.22	23.19
Average of N	180	22.37	22.53	22.45	22.49	22.52	22.51
	210	22.76	22.93	22.85	22.56	22.70	22.63
	240	21.91	22.01	21.96	22.16	22.30	22.23
Mean of vinasses doses		22.35	22.49	22.42	22.40	22.51	22.45
LSD at 0.05							
Cane varieties (A)			**			**	
N-level (B)			0.11			0.03	
Vinasses (C)			**			NS	
A×B			0.16			0.04	
A×C			NS			NS	
B×C			NS			NS	
A×B ×C			NS			NS	

NS: non-significant, **: significant

Sucrose%

Data in Table 7 showed that the promising variety G.2003-47 had the highest sucrose% preceding G.2003-47 compared to G.T.54-9 in the 1st and 2nd season. Such varietal differences among cane varieties in sucrose% were reported by Fahmy et al. (2017), El-Bakry (2018), Gadallah and El-Mehareb (2020) and Ali et al. (2022).

Sucrose% increased substantially and gradually when N-fertilizer level given to cane plants was raised from 180 up to 210 kg N/fed. in the 1st and 2nd seasons (Table 7), thereafter, it decreased with raising nitrogen fertilization level to 240 kg N/fed., in both seasons.

These results may indicate that 210 kg N/fed. was the best dose recording the highest sucrose in cane juice, while the highest N-level may direct cane plants for more vegetative growth rather than dry matter accumulation. These results are in line with those mentioned by Bekheet et al. (2018) and Gadallah (2020).

Data in same Table, cleared that supplying canes with 50 l of cane vinasses/fed. appreciably increased sucrose%, in both seasons compared to that left without vinasses. Vinasses is a good source of organic matter, NPK and other important nutrients (as shown in Table 2), this will be reflected on the juice quality characters

As for the interactions among the studied factors, all of them were not significant on sucrose% in both seasons, except for the interaction between varieties x N-levels in the 1st and 2nd seasons. Planting G.2003-47 variety and fertilized with 210 kg N/fed. resulted in the highest sucrose%

Table 7. Sucrose% of sugarcane varieties as affected by nitrogen and vinasses fertilization and their interactions in the 2020/2021 and 2021/2022 seasons.

Sugarcane varieties (A)	N fertilizer level kg N/fed. (B)	Sucrose (%) 2020/2021 Vinasses doses/l (C) 0	50	Mean	2021/2022 Vinasses doses/l (C) 0	50	Mean
G.T.54/9	180	19.62	19.93	19.78	19.85	20.00	19.93
	210	20.08	20.28	20.18	20.05	20.26	20.16
	240	18.95	19.17	19.06	19.4	19.68	19.54
Mean		19.55	19.79	19.67	19.77	19.98	19.87
G.2003/47	180	21.69	21.76	21.73	21.71	21.79	21.75
	210	22.29	22.45	22.37	21.69	21.92	21.81
	240	21.39	21.50	21.45	21.34	21.43	21.39
Mean		21.79	21.90	21.85	21.58	21.71	21.65
Average of N	180	20.66	20.84	20.75	20.78	20.89	20.84
	210	21.19	21.36	21.28	20.87	21.09	20.98
	240	20.17	20.34	20.26	20.37	20.56	20.47
Mean of vinasses doses		20.67	20.85	20.76	20.67	20.85	20.76
LSD at 0.05							
Cane varieties(A)			**			**	
N-level (B)			0.07			0.04	
Vinasses (C)			**			**	
A×B			0.09			0.05	
A×C			NS			NS	
B×C			NS			NS	
A×B ×C			NS			NS	

NS: non-significant, **: significant

Sugar recovery%

Data in Table 8 showed that sugar recovery% was markedly differed by the two tested sugarcane varieties, the new promising variety G.2003-47 had the highest sugar recovery% compared to G.T.54-9 in both seasons. Such varietal differences can be referred to the same trend of both brix% and sucrose% (Tables 6 and 7) recorded by the previously mentioned varieties. Similar results were reported by Fahmy et al. (2017), El-Bakry (2018), Gadallah and El-Mehareb (2020) and Ali et al. (2022).

Sugar recovery% increased substantially and gradually when N-level given to cane plants was raised from 180 up to 210 kg N/fed. in both seasons (Table 8), thereafter, it decreased with raising N fertilization level to 240 kg N/fed., in both seasons. This result is similar to that of brix and sucrose% (Tables 6 and 7) where it is known that sugar recovery% depends mainly on sucrose content. Similar results were given by Bekheet et al. (2018) and Gadallah (2020).

Data in the same Table resulted that supplying canes with 50 liters of cane vinasses/fed. appreciably increased sugar recovery%, in both seasons compared to that left without vinasses. This increase results due to an increase in the brix% and sucrose% (as shown in Tables 6 and 7).

As for the interactions among studied factors, all of them were not significant on sugar recovery% in both seasons, except for the interaction between varieties x N-levels and varieties x vinasses in the 1st season only, which was significant.

Planting G.2003-47 variety, fertilized with 210 kg N/fed. and 50 l/fed. of cane vinasses resulted in the highest sucrose%.

Table 8. Sugar recovery % of sugarcane varieties as affected by nitrogen and vinasses fertilization and their interactions in the 2020/2021 and 2021/2022 seasons.

Sugarcane varieties (A)	N fertilizer level kg N/fed. (B)	Sugar recovery (%) 2020/2021 Vinasses doses/l (C) 0	50	Mean	2021/2022 Vinasses doses/l (C) 0	50	Mean
G.T.54/9	180	12.17	12.36	12.27	13.12	13.26	13.19
	210	12.53	12.67	12.60	13.29	13.40	13.35
	240	11.81	12.00	11.91	12.89	13.09	12.99
	Mean	53.63	12.17	12.34	12.26	13.10	13.25
G.2003/47	180	13.64	13.70	13.67	14.3	14.35	14.33
	210	14.06	14.12	14.09	14.26	14.42	14.34
	240	13.41	13.49	13.45	14.03	14.09	14.06
	Mean	51.66	13.70	13.77	13.74	14.20	14.29
Average of N	180	12.90	13.03	12.97	13.71	13.81	13.76
	210	13.30	13.40	13.35	13.78	13.91	13.85
	240	12.61	12.75	12.68	13.46	13.59	13.53
Mean of vinasses doses		52.65	12.94	13.06	13.00	13.65	13.77
LSD at 0.05							
Cane varieties (A)			**			**	
N-level (B)			0.04			0.07	
Vinasses (C)			**			**	
A×B			0.06			NS	
A×C			0.05			NS	
B×C			NS			NS	
A×B ×C			NS			NS	

NS: non-significant, **: significant

Cane yield

Data in Table 9, exhibited a significant variance between the tested two varieties with respect to cane yield/fed. The commercial G.T.54-9 variety exhibited superiority in cane yield by 2.07 and 2.23 tons/fed. over those gained from other tested variety G. 2003-47, in the 1st and 2nd seasons respectively. Similar findings were reviewed by Fahmy et al. (2017), Gadallah and El-Mehareb (2020) and Ali et al. (2022).

The results in the same Table showed that cane yield was increased significantly and gradually by increasing N-levels given to cane plants from 210 to 240 kg N/fed., which were 2.36 and 3.85 ton/fed. in the 1st season, corresponding to 2.44 and 4.26 ton/fed. in the 2nd season, successively as compared with that recorded when N-fertilizer was given at 180 kg N/fed. (as shown in Table 3). These results fairly proved that the supplying sugarcanes with 240 and 210 kg N/fed. nutrients was physiologically needed for better growth and efficient performance of plants to attain their highest potential, compared to those given 180 kg N/fed. nutrients at the lowest rate, it resulted in an increase in cane height, diameter and number of millable canes/fed. (Tables, 3, 4 and 5, respectively), which was reflected on the cane yield. These results are in agreement with those reported by Osman et al. (2010), Bekheet and El-Aziz (2016), Makhlouf et al. (2016) and Gadallah (2020).

Table 9. Cane yield (ton /fed.) of sugarcane varieties as affected by nitrogen and vinasses fertilization and their interactions in the 2020/2021 and 2021/2022 seasons.

Sugarcane varieties (A)	N fertilizer level kg N/fed. (B)	Cane yield (ton /fed.) 2020/2021 Vinasses doses/l (C) 0	50	Mean	2021/2022 Vinasses doses/l (C) 0	50	Mean
G.T.54/9	180	51.573	53.213	52.393	51.590	53.093	52.342
	210	53.843	55.613	54.728	53.710	55.010	54.360
	240	55.483	57.153	56.318	56.043	56.687	56.365
Mean		53.633	55.327	54.480	53.781	54.930	54.356
G.2003/47	180	49.473	51.250	50.362	48.767	50.590	49.678
	210	51.953	53.523	52.738	51.960	53.107	52.533
	240	53.570	54.710	54.140	53.607	54.713	54.160
Mean		51.666	53.161	52.413	51.444	52.803	52.124
Average of N	180	50.523	52.232	51.377	50.178	51.842	51.010
	210	52.898	54.568	53.733	52.835	54.056	53.447
	240	54.530	55.930	55.229	54.825	55.700	55.263
Mean of vinasses doses		52.649	54.244	53.446	52.613	53.867	53.240
LSD at 0.05							
Cane arieties(A)			**			**	
N-level (B)			0.250			0.295	
Vinasses (C)			**			**	
A×B			NS			NS	
A×C			NS			NS	
B×C			NS			NS	
A×B ×C			NS			NS	

NS: non-significant, **: significant

Data in the same Table revealed that supplying canes with 50 litter of cane vinasses/fed. at age of 60 days from planting appreciably increased cane yield by 1.59 and 1.25 tons/fed. in the 1st and 2nd seasons, respectively, compared to that left without vinasses. These results are probably due to the increase in all of cane height, diameter and number of millable canes/fed. (Tables 3, 4, and 5, respectively). These results show that the use of vinasses could be effectively used to increase the sugarcane yield. These results are in line with those reported by Rossetto (1977) and Orlando (1984). As for the interactions among factors, all of them were not significant on cane yield in both seasons.

Sugar yield/fed

Data in Table 10 manifested that sugar yield (ton/fed.) was markedly differed by the tow tested sugarcane varieties in the 1st season only. Sugarcane variety G.2003-47 occupied the 1st order in sugar production over the other variety, G.T.54-9 in both seasons, without significant difference between the two varieties in the 2nd one. These results were actually due to the same trend of the tested varieties with respect to their sugar recovery%, where it is well known that sugar yield is principally dependent on both cane yield and sugar recovery% percentage.

Such varietal differences were reported by Makhlouf et al. (2016), Fahmy et al. (2017), El-Bakry (2018), Gadallah and Abd El-Aziz (2019), Gadallah and El-Mehareb (2020) and Ali et al. (2022). The results in the same Table, showed that sugar yield/fed. was increased significantly and gradually by increasing N-levels given to cane plants from 210 to 240 kg N/fed., which were (0.511 and 0.283 tons/fed.) in the 1st season, corresponding to (0.383 and 0.459 tons/fed.) in the 2nd season, respectively as compared to that supplied with 180 kg N/fed. This resulted in an increase in sucrose and sugar recovery content as well as cane yield/fed. (Tables 7,8 and 9 respectively), which was reflected on the sugar yield. These results are in line with those reported by Osman et al. (2010), Bekheet and El-Aziz (2016), Makhlouf et al. (2016), Bekheet et al. (2018) and Gadallah (2020). Data in the same Table, showed that supplying canes with 50 litter of cane vinasses/fed. at age of 60 days from planting appreciably increased sugar yield by 0.271 and 0.235 tons/fed.) in the 1st and 2nd seasons, successively, compared to that left without vinasses. These results are probably due to the increase in all sucrose and sugar recovery percentages as well as cane yield/fed. (Tables 7, 8 and 9 respectively).

These results are in line with those reported by Copersugar (1980) and Gloria (1985). As for the interactions among factors, all of them were not significant on sugar yield in both seasons, except for the interaction between varieties x N-levels in the 1st season only, which was significant. Planting G.2003-47 variety and fertilized with 210 kg N/fed. resulted in the highest sugar yield (ton/fed.).

Table 10. Sugar yield (ton/fed.) of sugarcane varieties as affected by nitrogen and vinasses fertilization and their interactions in the 2020/2021 and 2021/2022 seasons.

Sugarcane varieties (A)	N fertilizer level kg N/fed. (B)	Sugar yield (ton/fed.) 2020/2021 Vinasses doses/l (C) 0	50	Mean	2021/2022 Vinasses doses/l (C) 0	50	Mean
G.T.54/9	180	6.277	6.575	6.426	6.772	7.034	6.903
	210	6.749	7.047	6.898	7.137	7.372	7.255
	240	6.554	6.858	6.706	7.224	7.422	7.323
Mean		6.527	6.827	6.677	7.044	7.276	7.160
G.2003/47	180	6.745	7.018	6.882	6.976	7.261	7.119
	210	7.305	7.560	7.433	7.410	7.655	7.533
	240	7.180	7.380	7.280	7.524	7.711	7.618
Mean		7.077	7.319	7.198	7.303	7.542	7.423
Average of N	180	6.511	6.797	6.654	6.874	7.148	7.011
	210	7.027	7.303	7.165	7.273	7.513	7.393
	240	6.867	7.119	6.993	7.374	7.566	7.470
Mean of vinasses doses		6.802	7.073	6.937	7.174	7.409	7.291
LSD at 0.05							
Cane varieties(A)			**			NS	
N-level (B)			0.038			0.058	
Vinasses (C)			**			**	
A×B			0.055			NS	
A×C			NS			NS	
B×C			NS			NS	
A×B ×C			NS			NS	

NS: non-significant, **: significant

Nitrogen% in leaves and stalks

Data in Table 11 pointed to a significant variation between the tested two varieties of sugarcane in content N% in leaves and stalks in the 1st and 2nd seasons. The results showed that leaves and stalks of sugarcane for G. 2003-47 variety contained the highest N% compared with the other variety G.T. 54-9. The difference between the evaluated varieties of sugarcane in N% in leaves may be due to their gene makeup. The results in Table 11, revealed that increasing N fertilizer- level from 180 up to 240 kg N/fed. was accompanied by a gradual and significant increase in N% in leaves and stalks at harvest, in both seasons.

This result can be attributed to the increase in nitrogen that the plant absorbs from the soil as a result of the increased N fertilizer levels added to the soil, perhaps the increase in length and diameter of the stalk, number of millable canes and cane yield (ton/fed.) was associated with the increase in N% in both leaves and stalks (as shown in Tables 3, 4, 5 and 9 respectively).

The decrease in quality of cane juice (brix, sucrose and sugar recovery percentages) may have been associated with an increase in N-fertilizer in both leaves and stalks above a rate of 210 up to 240 kg N/fed., which may lead to an increase in impurities in juice and a decrease in its quality, compared to fertilization at 210 and/or 180 kg N/fed. (as shown in Tables 6, 7 and 8 respectively). Data in the same Table, showed that supplying canes with 50 litter of cane vinasses/fed. at age of 60 days from planting appreciably increased N% in leaves and stalks in both seasons.

Concerning the effect of the interaction, inducted that the interaction between varieties x N-levels in the 1st one, and three interactions between varieties x N-levels x vinasses in both seasons on N% in leaves and stalk was substantial.

Table 11. Nitrogen% leaves and stalks of sugarcane varieties as affected by nitrogen and vinasses fertilization and their interactions in the 2020/2021 and 2021/2022 seasons.

Sugarcane varieties (A)	N fertilizer level kg N/fed. (B)	Nitrogen% leaves and stalk 2020/2021 Vinasses doses/l (C) 0	50	Mean	2021/2022 Vinasses doses/l (C) 0	50	Mean
G.T.54/9	180	2.197	2.337	2.267	2.277	2.387	2.332
	210	2.447	2.497	2.472	2.44	2.467	2.454
	240	2.663	3.123	2.893	2.507	2.687	2.597
	Mean	2.436	2.652	2.544	2.408	2.514	2.461
G.2003/47	180	2.437	2.553	2.495	2.43	2.54	2.485
	210	2.767	2.867	2.817	2.803	2.92	2.862
	240	3.027	3.253	3.140	2.997	3.287	3.142
	Mean	2.744	2.891	2.817	2.743	2.916	2.830
Average of N	180	2.317	2.445	2.381	2.353	2.463	2.408
	210	2.607	2.682	2.645	2.622	2.693	2.658
	240	2.845	3.188	3.017	2.752	2.987	2.870
Mean of vinasses doses		2.590	2.772	2.681	2.576	2.714	2.645
LSD at 0.05							
Cane varieties(A)			**			**	
N-level (B)			0.084			0.029	
Vinasses (C)			**			**	
A×B			NS			0.042	
A×C			NS			NS	
B×C			0.123			0.050	
A×B ×C			NS			NS	

NS: non-significant, **: significant

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