Research Article

Distillery Spent Wash Enhances Sugarcane (*Saccharum officinarum* L.) Growth

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Abstract | The effective handling of waste is one of the paramount global environmental challenges. Various industries generate diverse wastewater pollutants, often presenting complex and expensive treatment challenges. The attributes of wastewater and concentrations of contaminants vary significantly from one industry to another. Recently, there has been a growing interest in utilizing industrial waste as a soil amendment. The distillery spent wash (DSW) released through the sugarcane processing, is abundant in organic materials and a variety of essential nutrients, including Nitrogen, Phosphorus, Potassium, Calcium, and Sulphur. Different concentrations of spent wash were applied to sugarcane crops to explore their effects on the development, production, and yield at the Sugar Crops Research Institute (SCRI) Mardan. Four different concentrations of distillery spent wash were applied (i.e. 30%-DSW, 40%-DSW, 50%-DSW, and 60%-DSW) to a sugarcane variety "Israr Shaheed SC (CP 80-1827)". Our results showed that the application of a 50%-DSW increased plant height, cane diameter, leaf count per plant, and tillers per plant, while 60%-DSW had a diminishing trend compared to the other concentrations.

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Introduction

Saccharum officinarum L. a member of the family Poaceae, is commonly referred to as a noble cane. Sugarcane is an important crop across the globe as China has preserved about 3300 germplasms of Saccharum and related species (Qi *et al.*, 2022). Pakistan is among the top 10 countries in sugarcane production and consumption (Hussain, 2023). Pakistan is an agricultural country, which contributes 19.2 % to the

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GDP and provides 38.5 % of employment directly or indirectly (finance.gov.pk). Sugarcane is regarded as a vital cash crop in Pakistan, which wields significant influence on the nation's economic landscape and serves as a substantial generator of employment opportunities. It holds a prominent position as the second most vital cash crop as well as the 2nd largest agro-industry sector after Textile in Pakistan, making a substantial and noteworthy contribution to the nation's agro-based sector and various related industries. It plays a vital role by supplying essential raw materials to sugar mills, chipboard manufacturers, and paper industries, thereby making a noteworthy contribution to the country's economic value. This agricultural commodity is responsible for augmenting the agricultural value added by 3.4 %, and it further contributes 0.7 % to Pakistan's Gross Domestic Product (Khan *et al*., 2023). A surge of 12 % has been reported in the cultivation of sugarcane during 2020-2021, where 1165 thousand hectares of land were utilized compared to that of 1040 thousand hectares during 2019-2020. This has resulted in a 22 % increase in the production of sugarcane from 81.009 million tonnes (2020-2021) to that of 66.380 million tonnes (2019-2020) (Pakistan Bureau of Statistics, 2022).

Sugarcane holds immense importance globally due to its diverse applications in both industrial and agricultural contexts, making it a highly valuable crop cultivated worldwide. Brazil stands as the world's leading sugarcane producer, yielding a staggering 677.9 million tons in the 2019/2020 crop season across an expansive 8.6 million hectares of cultivated land (Bohórquez-Sánchez *et al*., 2023). India holds the position of being the world's second-largest producer of sugarcane and a substantial consumer of sugar (Shinde *et al*., 2020).

Sucrose is the primary component derived from sugar cane in the industrial extraction process (Arain *et al*., 2017). Sugarcane is commercially cultivated by employing stalk cuttings or setts, which are 25-30 cm long pieces of stalk containing 2-3 buds each. However, this cultivation method is becoming increasingly unsustainable because the expense associated with acquiring seed cane for replanting constitutes more than 20 percent of the overall production costs (Galal, 2016). Introducing bud chips instead of setts for sugarcane cultivation has the potential to reduce approximately 80% of the stalk material by weight. Nevertheless, the widespread adoption of this technology in commercial settings has been hindered by the low survival rate of bud chips in field conditions (Jain *et al*., 2010).

Spent wash, also known as vinasse, is a dark brown colored byproduct generated from the distillation of alcohol, particularly in the production of ethanol and alcoholic beverages (Shinde *et al*., 2020). It is a liquid residue remaining after the fermentation and distillation processes, containing various organic and inorganic compounds, including water, unfermented sugars, alcohol, and other substances (Hassan *et al*., 2021). Spent wash is an important aspect of the distillery and ethanol production industry, and its management and disposal pose environmental challenges due to its high organic load and potential impact on ecosystems if not properly treated or utilized (Suganya and Rajannan, 2009). One of the foremost global environmental challenges is the effective handling of waste management. Various sectors generate a wide range of wastewater contaminants, posing significant challenges in terms of treatment due to the complexities and associated costs.

DSW, a byproduct generated in substantial quantities, presents a significant organic load, rendering it a promising candidate as an agricultural input (Rath *et al*., 2011). Notably, DSW, derived from plant sources, lacks any toxic metals. Furthermore, it offers noteworthy levels of macronutrients (such as Nitrogen, Potassium, Sulphur, and Phosphorus) and micronutrients (including iron, copper, and zinc). It also contains minimal amounts of heavy metals originating from the sugar production process (Hassan *et al*., 2021). The recent focus on using industrial waste as a soil enhancer has sparked considerable attention (Jain and Srivastava, 2012). This surplus wastewater has the potential to fulfill the water requirements of cultivated crops on an ongoing basis (Rath *et al*., 2011). The present investigation aims to study how different concentrations of distillery spent wash (DSW) influence growth indicators of sugarcane. Therefore, we have selected different concentrations of DSW for commercial application on an approved variety Israr Shaheed SC (CP 80-1827) at the Sugar Crops Research Institute (SCRI) Mardan.

Materials and Methods

The research aimed to assess how different concentrations of spent wash impact the development, production, and yield of sugarcane. The variety tested was Israr Shaheed SC (CP 80-1827). The chip-bud or axillary buds ranging from 0.5-2 cm in size of fleshy stalks used were as starting material. The buds were cut off with the help of a bud chipper machine. The plants were classified into five groups (Control, T1, T2, T3, T4). In each group, 16 plants were planted in a wooden tub, followed by a Complete Randomized Design (CRD). Before plantation, the tubs were ploughed, labelled, and divided into ridges and furrows with uniform distances (25 cm). The sugarcane seeds were kindly provided by the SCRI for planting.

After plantation with regular watering once a week, the plants were allowed to grow for three months. After three months different growth parameters were recorded and tubs were treated with various concentrations of Distillery Spent Wash (DSW) 30 %, 40 %, 50 %, and 60 %. Out of the five groups of tubs of the glasshouse, one was kept without any treatment and labelled as the Control group.

Distillery spent wash (DSW)

Spent wash contains water, unfermented sugars, organic compounds, and byproducts from the fermentation and distillation of raw materials. The distillery spent wash was kindly provided by Premier Sugar Mills (PSM) Mardan. The Distillery Spent Wash (DSW) chemical analysis was performed at the Department of Soil and Environmental Sciences, University of Agriculture, Peshawar (Tables 1 and 2).

Table 1: *Chemical composition of liquid distillery spent wash.*

Chemical parameters	Units	Amount
pH	-	8.24
EC	ds m^{-1}	42.3
Dry Matter	gL^{-1}	74.2
$CaCO_3$	gL^{-1}	43.4
OM	gL^{-1}	11
P	gL^{-1}	32.6
K	gL^{-1}	22100
Ca+ Mg	meq L^{-1}	100
K	meq L^{-1}	566

pH = Power of Hydrogen; EC= Electrical Conductivity; OM= Organic Matter; P= Phosphorus; calcium =(Ca) and magnesium = (Mg), K = Potassium), dsm = decisiemens per meter, gL = gram per Liter, meq L^{-1} = milliequivalents per Liter).

Table 2: *Chemical composition of dry Distillery Spent Wash (7.48 g solid substances were present in 100 ml spent wash).*

Substances	Units	Amount
N	%	1.75
P	%	0.13
K	%	40
SOM	%	7.28
Lime	%	59.5
N	g 1000 L^{-1}	1298
P	g 1000 L^{-1}	93.6
K	g 1000 L^{-1}	30051

N = Nitrogen; P = Phosphorus; K = Potassium; SOM= Soil Organic Matter.

Data analysis

All the parameters were statistically analysed and the data relating to agronomic parameters was analysed by one-way ANOVA (Analysis of Variance). Results of different conditions were computed over control and their difference among treatments was tested through least significant difference (LSD).

Results and Discussion

Distillery spent wash is the byproduct liquid that arises as an unwanted residue during the alcohol production process. The study revealed that all agronomic factors of sugarcane exhibited an upward trend in various treatment conditions when compared to the control group. The average height of the sugarcane plant after 150 days showed an increase of 16.5 % in the 50 %-DSW treated tub over the control (Figure 1). However, the growth showed a negative trend in the 60%-DSW in all the parameters analyzed. The average sugarcane diameter of the test crop after 150 days of plantation showed an increase of 18.9 % in 50 %-DSW treated plants over control and a negative trend in 60 %-DSW (Figure 2). The average number of leaves per plant of the sugarcane after 150 days of plantation showed an increase of 34.7 % in the 50 %-DSW treated plants over control and a negative trend in 60 %-DSW (Figure 3). Likewise, the average number of tillers per plant after 150 days of plantation showed an increase of 55.54 % in 50 %-DSW treated plants over control and a negative trend in 60 %-DSW (Figure 4). The analysis of variance (ANOVA) indicated a significant distinction across all stages of the plant's growth (Tables 3, 4, 5 and 6).

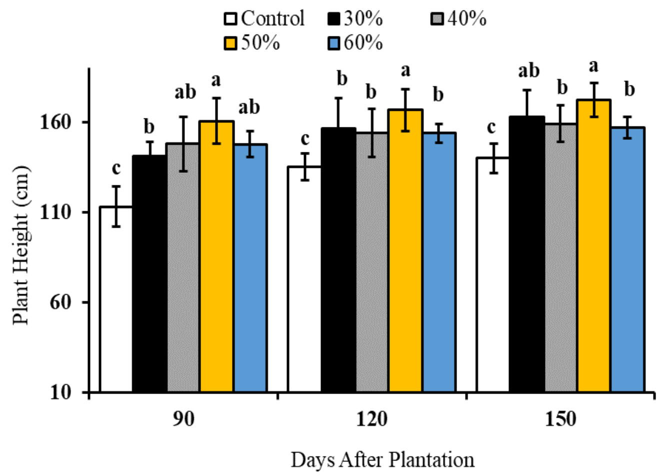

Figure 1: *Graphical presentation of plant growth/height of the sugarcane treated with different concentrations of spent washes. The Y-axis shows plant height in centimeter (cm) and the X-axis days after plantation (DAP).*

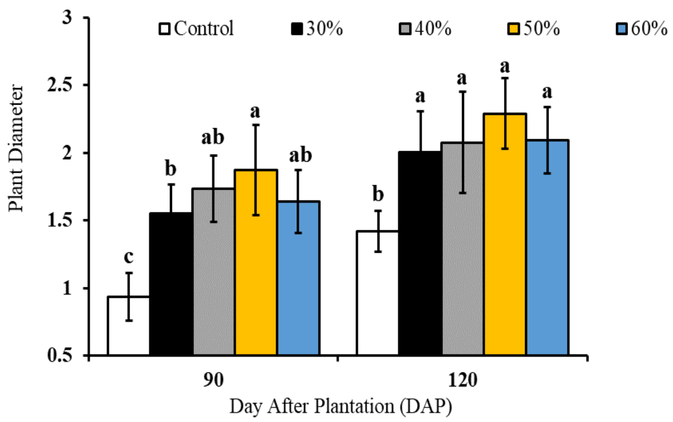

Figure 2: *Diameter of sugarcane plant at different growth periods with four treatments (30, 40, 50, and 60 %).*

Table 3: *Statistical analysis of the height of the sugarcane plant at different days of growth and different treatments.*

Days after plantation	F value for different treatments	Significance level (P-value)	LSD
90	17.6	0.05	12.26
120	5.98	0.05	13.56
150	8.50	0.05	11.77

Table 4: *Statistical analysis of the cane diameter of the sugarcane plant at different days of growth and different treatments.*

Days after plantation	F-value for different treatments	Significance level (P-Value)	LSD
90	13.1	0.05	0.2923
120	8.53	0.05	0.3295

Table 5: *Statistical analysis of the number of leaves per sugarcane plant at different days of growth and different treatments.*

Days after plantation	F value for different treatments	Significance level (P value)	LSD
90	9.59	0.05	1.3418
120	16.1	0.05	1.2471
150	8.38	0.05	1.5595

Table 6: *Statistical analysis of the number of tillers per sugarcane plant at different days of growth and different treatments.*

Days after plantation	F value for different treatments	Significance level (P-value)	LSD
90	2.73	0.05	0.9611
120	4.30	0.05	0.9853
150	4.39	0.05	0.9463

Plant height

The effect of different treatments on plant height at various growth periods is summarized in Figure 1. Out of four different treatments, the 50 %-DSW showed a maximum growth compared to that of 30 %, 40 %, and 60 % (Figure 1). A maximum plant height was observed in a 50 %-DSW treated was 170 cm after 90 days of plantation (DAP), while the same treatment showed the maximum plant height after 120 DAP i.e., 178 cm (Figure 2). The minimum height was recorded in the untreated control i.e. 101 cm in a 90 DAP. The 50 % DSW-treated plants exhibited an average height increase of 16.5 % compared to the control group after 150 days. In a 60 %-DSW treatment, a decline was observed in the plant height (Figure 1, Table 3).

Cane diameter

A comparison of different treatments indicated that the maximum diameter was recorded by treating sugarcane with a 50%-DSW. The Cane diameter was recorded to be 2.48 cm and 2.74 cm after 90 and 120 DAP, respectively, while the average value of both growth periods was 2.08 (Figure 2). A minimum diameter was recorded in the untreated (control), i.e. 0.82 cm and 1.17 cm after 90 and 120 DAP respectively, with an average of 1.18 (Figure 2; Table 4). This comparison indicates that the 50%-DSW showed the best result and recording was highest in all the growth periods. The mean cane diameter of the experimental crop, 150 DAP, exhibited a notable surge of 18.9 % in the group subjected to 50%-DSW treatment compared to the control group, while conversely, a diminishing trend was evident in the 60%-DSW treated plants (Figure 2; Table 4).

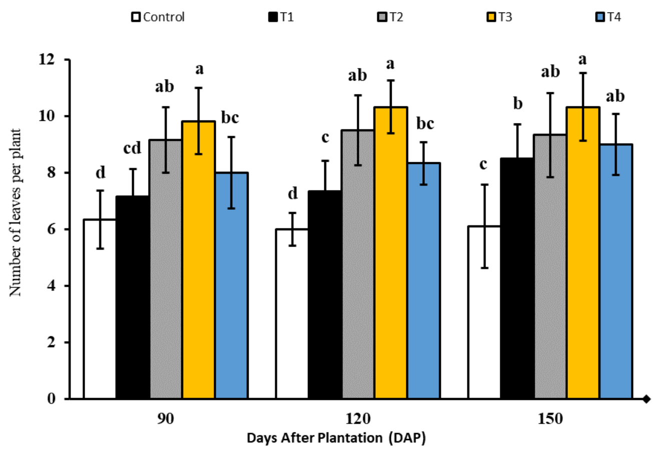

Figure 3: *Number of leaves per sugarcane plant at different growth periods with different treatments.*

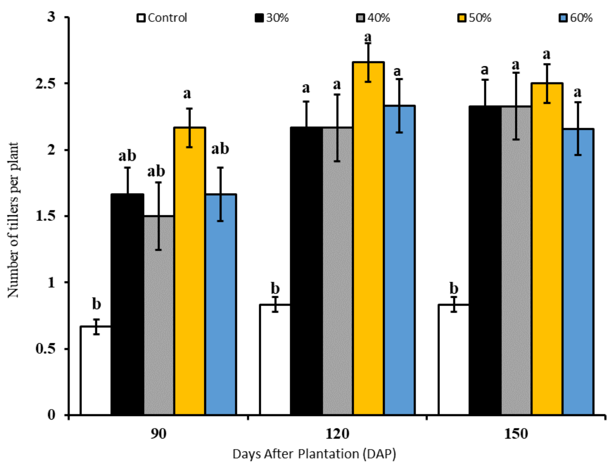

Figure 4: *Numbers of tillers per sugarcane plant at different growth periods with different treatments.*

Number of leaves

The effect of distillery spent wash on the number of leaves per plant was significant, while our results showed that the maximum number of leaves were produced during the treatment of a 50%-DSW in all three growth periods (Figure 3; Table 5). In the first growth period, the number of leaves per plant was 10, and in the second growth period, its production was 12. The leaves number per plant shows the highest trend across all treatments except control shows a negative trend (Figure 3).

Number of tillers

By treating the sugarcane with a 50 % distillery spent wash, the number of tillers was more responsive in the first 120 days compared to that of 150 days after plantation (DAP) (Figure 4). The maximum number of tillers produced in the 50%-DSW treated sugarcane was 3 per plant, while the control with the minimum number of tillers (0 Tillers per plant) after 120 DAP. Even though the number of tillers per plant was 0 in the control at 150 DAP and 2.5 in the 50%-DSW treated plants. The mean count of tillers per plant observed at the end of 120 DAP, demonstrated a remarkable uptick of 59 % in the 50%-DSW treated plants compared to the control group. Furthermore, at the end of 150 DAP, the average number of tillers per plant exhibited a substantial increase of 55.54% in the 50%-DSW treated plants in contrast to the control group (Figure 4 and Table 6).

The results of the study offer insightful findings. It is observed that various agronomic factors of sugarcane, such as plant height, cane diameter, number of leaves per plant, and number of tillers per plant, exhibited an upward trend when treated with a 50%-DSW compared to the control group. These findings are per the research conducted by Rath *et al.* (2010), who also observed significant improvements in these growth parameters when DSW concentration increased. However, the results indicate a negative trend in growth when a 60%-DSW is used (Rath *et al.*, 2011).

Jayashree *et al.* (2021) examined that a notable rise in the application rate of distillery spent wash has led to a significant increase in the concentration of exchangeable Ca, Mg, Na, and K in the soil. The soil that received 40 Kilolitres of distillery spent wash with 1 ton of bio compost exhibited comparatively higher values. This heightened availability of nutrients in the soil is attributed to the mineralization of organic matter and the nutrients contained in the effluent.

Zalawadia *et al.* (1997) found that the application of distillery spent wash at any concentration resulted in a significant increase in sugarcane yield and nutrient uptake compared to the absence of spent wash (S0). Notably, a less diluted spent wash has led to a higher biomass yield compared to concentrated variants. While there was a slight tendency for increased soil salinity due to the use of spent wash, it was countered by a considerable improvement in the availability of essential nutrients such as phosphorus (P), potassium (K), and sulfur (S). Moreover, there were indications of enhancements in certain physical soil conditions.

Numerous studies have reported that the utilization of DSW applications has resulted in an elevation of organic matter contents and enhancements in the physio-chemical characteristics of the soil. Patil *et al*. (1987) reported that DSW is a rich source of organic matter, and the same results were reported by Sanjeevi (2002), Kumar *et al*. (2003), Rauf *et al*. (2023), Kalaiselvi and Mahimairaj (2010), Rath *et al*. (2010), Zalawadia *et al*. (1997), Murugaragavan (2002). Saliha *et al*. (2005) observed that DSW is effective organic liquid manure and Rajannan *et al*., (1998) reported that DSW has a comparatively higher manure potential. This product boasts exceptional nutritional value and serves as a highly effective organic fertilizer for sugarcane. Yang-Rulli *et al*., (2007) reported that the excessive concentrations of different cations and anions in the DSW can be mitigated to favorable levels through dilution, making it a viable alternative to chemical fertilizers.

Conclusions and Recommendations

From the current study, it is concluded that applying distillery spent wash at concentrations up to 50% is suitable for sugarcane cultivation. Based on the experimental findings, it can be inferred that a 50% v/v concentration of distillery spent wash can serve as an excellent liquid fertilizer for sugarcane crops, outperforming the fertilizers typically used by local farmers, while the same can be tested in other crops.

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Novelty Statement

The results showed that 50%-DSW application increased plant height, cane diameter, leaf count per plant, and tillers per plant, while a 60%-DSW had a negative effect.

Author's Contribution

The authors are grateful to the following for their contributions to this BS (Hons) research project: Dr. Abdur Rauf and Dr. Tanweer Kumar (research design); Mr. Ameer Sultan (execution); Dr. Ikramullah Khan, Dr. Farooq Jan, Dr. Muhammad Qayash and Dr. Muhammad Yaseen (manuscript proofreading), Dr. Wajid Khan, Mr. Muhammad Arif, Mr. Farhan Khan, Mr. S.S. Hussain, Miss Kashmala Jabbar and Mr. Wisal Khan (data analysis).

Conflict of interest

The authors have declared no conflict of interest.

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