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Research Note

Assessment of Distillery Spent Wash Water as a Potential Bionutrient Supplement for Spring-Planted Sugarcane (*Saccharum officinarum* L.)

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The study was conducted to evaluate the effect of the combined application of the sugar industry by-product spent wash water (SWW) and inorganic fertilizers on the growth, yield and quality of spring-planted sugarcane. The experiment was conducted for two consecutive years (2013 and 2014) in a randomized complete block design with three replications. The combined application of spent wash water (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}) markedly increased the leaf area index, crop growth rate, net assimilation rate and total dry matter of millable canes, cane length (cm), weight per stripped cane (kg), and yield of unstripped and stripped cane compared with the other treatments. Moreover, the reduction in spent wash water and NPK rate substantially decreased the quantitative attributes of the crop. Owing to the increase in growth and quantitative traits, the application of spent wash water and NPK considerably increased the quality parameters such as brix (%), sucrose content in cane juice (%), sugar recovery (%) and total sugar yield. Moreover, the maximum improvement for quality parameters was obtained in the spent wash (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}) treatment. Results of the study showed that application of spent wash (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}) can effectively improve the growth, yield and quality of spring-planted sugarcane.

Key Words: sugarcane, spent wash water, NPK

Abbreviations: LAI – leaf area index; NPK – nitrogen, phosphorus, and potassium; SWW – spent wash water

INTRODUCTION

Sugarcane is a major cash crop around the world and is mainly grown for the manufacture of sugar and sugar-related products. It provides raw material for the paper and chipboard industry among others. Imbalanced fertilizer application is the major cause of low yield in sugarcane (Malik and Gurmani 2005). A balanced fertilization not only guarantees optimal crop production but also gives higher benefits to the growers and is the best option to mitigate the hazardous effect of nutrient losses to the environment. Nutrient application varies with soil types, seasons and conditions (Schroeder et al. 1998; Ghaffar et al. 2011).

Spent wash water (SWW), the residual liquid waste from alcohol production, is usually discarded. The ever-escalating quantity of spent wash and its clearance have given rise to the need of developing new strategies to process this waste efficiently and cost-effectively (Sarayu et al. 2009).

Spent wash water is a good source of N, P and K (3.68%, 1.1%, and 1.1% respectively) and Ca, Mg and Cu (0.45%, 0.50% and 0.035%, respectively) (Pujar 1995). Bioactives substances such as hormones, humic acids and vitamins which have low molecular mass are also present in SWW (Sarwar et al. 2008). This industrial discharge is rich in organic and inorganic matter and serves as an excellent source of plant nutrients such as N, P, K, and S (Bharagava et al. 2008). The waste water can essentially act as a soil fertilizer and is utilized for crop irrigation. Several studies have suggested the use of adequate distillery effluents in enhancing the productivity and agronomic value of various crops such as *Casuarina equisetifolia* (Banerjee et al. 2004), mung bean (Kannan and

Upreti 2008), mustard (Bharagava et al. 2008), maize and rice (Pandey et al. 2008). The dilution of waste water (at 25–50%) showed positive effects on plant growth and production and was supposed to be beneficial for crops. However, the result available after seed bioassay test indicated that the use of pure distillery effluent without dilution may adversely affect plant productivity (Singh and Swami 2014).

Rath et al. (2013) reported that spent wash at 20% v/v serves as an important liquid fertilizer for germination and growth of rice. Kuntal et al. (2004) reported that use of spent wash water had no hazardous effect on germination; in fact it also improved the growth of maize. Growth parameters of sugarcane such as plant height, leaf length, breadth of the leaves, girth of the stem, leaf area index, number of leaves, and number of tillers per plant were enhanced with increase in the concentration of distillery spent wash up to 75% (Rath et al. 2010). SWW at 90–150 tons ha^{-1} significantly increased the cane girth and cane weight in addition to sugar yield (Viera 1996). Similarly, Chandraju et al. (2012) reported that diluted SWW improved the nutrient uptake, growth and yield of vegetables. Integrated use of SWW with inorganic fertilizers significantly increased all the growth attributes of the sugarcane plant (Diangan et al. 2008).

This study was conducted to evaluate the effect of spent wash water on the growth, yield and quality of spring-planted sugarcane, and to formulate appropriate doses of spent wash water in combination with NPK.

MATERIALS AND METHODS

The study was conducted for two consecutive years (2013 –14 and 2014–15) at the Research Farm, Shakarganj Sugar Research Institute, Shakarganj Mills Limited, Jhang, Pakistan. The climate of the region is semi-arid to subtropical. Normally, the temperature ranges from 2 to 3 °C in January and up to 48 °C in June with a mean annual rainfall of about 200–250 mm. The prevailing climatic conditions during both cane-growing years are presented in Fig. 1(a & b).

Seven treatments were laid out in randomized complete block design (RCBD) with three replications. The sugarcane variety S2003-US-114 (CPF 248) was planted on 22 February 2013 and on 26 February 2014. The net plot size was 4.8 m × 9 m and trenches were made 1.20 m apart with the help of a specially designed sugarcane ridger. Physico-chemical analysis of the experimental soil was conducted before sowing and after harvest of the crop during both years of the study. Collected samples were chemically analyzed by following the standard protocols of Homer and Pratt (1961). The soil

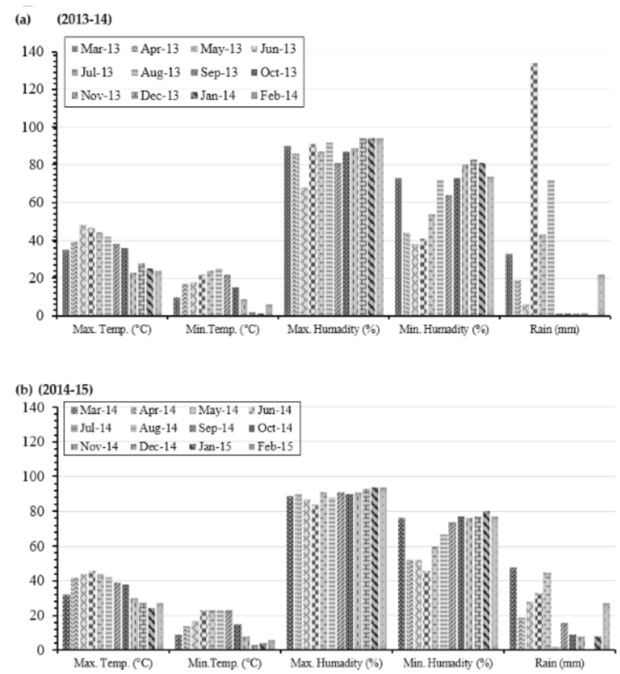

Fig. 1. Meteorological data of sugarcane growing season during (a) 2013–14 and (b) 2014–15.

analysis is shown in Table 1(a) and the composition of spent wash in Table 1(b). The experiment consisted of seven treatments: T_1 = Control (no spent wash + no NPK), T_2 = Spent wash (160 t ha^{-1}) alone, T_3 = NPK (168:112:112 kg ha^{-1}) alone, T_4 = Spent wash (120 t ha^{-1}) + NPK (42:28:28 kg ha-1), T_5 = Spent wash (80 t ha-1) + NPK (84:56:56 kg ha $^{-1}$), T_6 = Spent wash (40 t ha^{-1}) + NPK (126:84:84 kg ha^{-1}), and T_7 = Spent wash (160 t ha^{-1}) + NPK (42:28:28 kg ha^{-1}). The sources of N, P and K were urea (N 46%), diammonium phosphate (46% P and 18% N) and sulphate of potash (50% K), respectively.

The leaf area index was determined by using the standard method of Watson (1947), and the mean crop growth rate, total dry matter and net assimilation rate were determined by using the standard method of Hunt (1978). The quantitative parameters were recorded using the standard procedures. Number of millable canes in each plot was counted at harvest and then converted into number of millable canes per ha. At harvest, the length of 10 randomly selected canes from each treatment was measured and averaged. The 10 randomly selected stripped canes from each treatment were weighed together. Then weight per stripped cane (kg) was calculated. All unstripped canes (two trenches in each plot) were weighed (kg) before stripping and then converted to tons per hectare. All stripped canes from two trenches in each experimental unit were weighed and converted to tons per hectare. Total brix (%), commercial cane sugar (%), sucrose content in cane juice (%), sugar recovery (%) and total sugars (t ha^{-1}) were determined by

Table 1(a). Soil analysis.

Treatment	pH	EC (dS m^{-1})	OM (%)	N (%)	P (ppm)	K (ppm)
Analysis before sowing of crop (Each value is the average of 2 yr)						
Composite Sample	7.89	1.79	0.66	0.043	4.60	123
Analysis after harvest of crop (Each value is the average of 2 yr)						
T_1	7.88	1.81	0.60	0.038	4.41	120
T_2	7.82	1.68	0.72	0.042	4.53	134
T_3	7.86	1.73	0.64	0.041	4.49	127
T_4	7.85	1.69	0.63	0.040	4.51	125
T_5	7.85	1.70	0.73	0.044	4.59	131
T_6	7.87	1.71	0.70	0.039	4.51	126
T_7	7.83	1.70	0.72	0.043	4.51	135

T_1: Control (no compost + no fertilizer), T_2: Compost alone at 1124 kg ha^{-1}, T_3: fertilizer alone at 168:112:112 kg NPK ha^{-1}, T_4: Compost (843 kg ha^{-1}) + fertilizer(42:28:28 kg NPK ha^{-1}), T_5: Compost (562 kg ha^{-1}) + fertilizer (84:56:56 kg NPK ha^{-1}), T_6: Compost (281 kg ha^{-1}) + fertilizer(126:84:84 kg NPK ha^{-1}), T_7: Compost (1124 kg ha^{-1}) + fertilizer(42:28:28 kg NPK ha^{-1}).

Table 1(b). Chemical analysis of spent wash.

Parameter	Range Value*
pH	3.9 – 4.3
EC (d Sm^{-1})	30.5 – 45.2
Biological oxygen demand	46100 – 96000
Chemical oxygen demand	104000 – 134400
Total dissolved solids	79000 – 87990
Nitrogen	1660 – 4200
Phosphorus	225 – 3038
Potassium	9600 – 17475
Calcium	2050 – 7000
Magnesium	1715 – 2100
Sodium	492 – 670
Sulphate	3240 – 3425
Chloride	7238 – 42096
SAR	5.0 – 7.3
Zinc	3.5 – 10.4
Copper	0.4 – 2.1
Manganese	4.6 – 5.1
Gibberellic acid	3246 – 4943
Indole acetic acid	25 – 61

*All values are in mg L^{-1} unless otherwise stated.

the standard procedure of Spencer and Meade (1963). The crop was harvested manually at its full physiological maturity in the month of March during both years. All the crop husbandry practices were kept normal and uniform except the treatments under study. The recorded data was analyzed by using Tukey's HSD and treatment means were compared at 0.05 probability level. A specific computer software program (Statistics 8.1) was used for this purpose.

RESULTS

Application of spent wash water and NPK markedly affected the growth parameters of sugarcane during both years. The maximum improvement in leaf area index (LAI) was recorded from the treatment with the combined application of spent wash water (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}) during both years with minute difference (Fig. 2). However, minimum improvement for

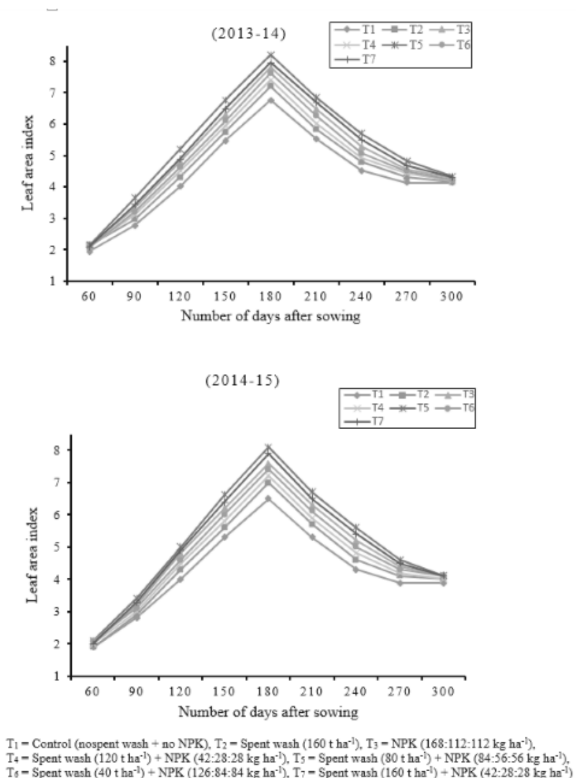

Fig. 2. Influence of spent wash water and NPK application on leaf area index of spring-planted sugarcane.

leaf area index was recorded from the plants with no spent wash water and no NPK application. Similarly, the crop had the maximum LAI (7.57) in 2013–14 compared with LAI of 7.34 during 2014–15 in crops applied with spent wash water (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}). The lowest crop growth rate was recorded in crops with no spent wash water and no NPK application (Fig. 3). Likewise, the highest total dry matter production was recorded in crops with the combined application of spent wash water (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}) while the minimum increase in total dry matter production was observed in the treatment with no spent wash water and NPK application (Fig. 4). Moreover, the combined application of spent wash water (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}) resulted in maximum net assimilation rate in spring-planted sugarcane during both years, followed by spent wash water (160 t ha^{-1}) + NPK (42:28:28 kg ha^{-1}) and NPK (168:112:112 kg ha^{-1}) alone, while the treatment with no spent wash water or no NPK gave poor response for net assimilation rate of sugarcane (Table 2).

The application of spent wash water and NPK markedly improved the quantitative traits of sugarcane crop during both cane-growing years (Tables 2 and 3). The maximum number of millable canes and maximum cane length were observed where the combined application of spent wash water (80 t ha^{-1}) + NPK (84:56:56

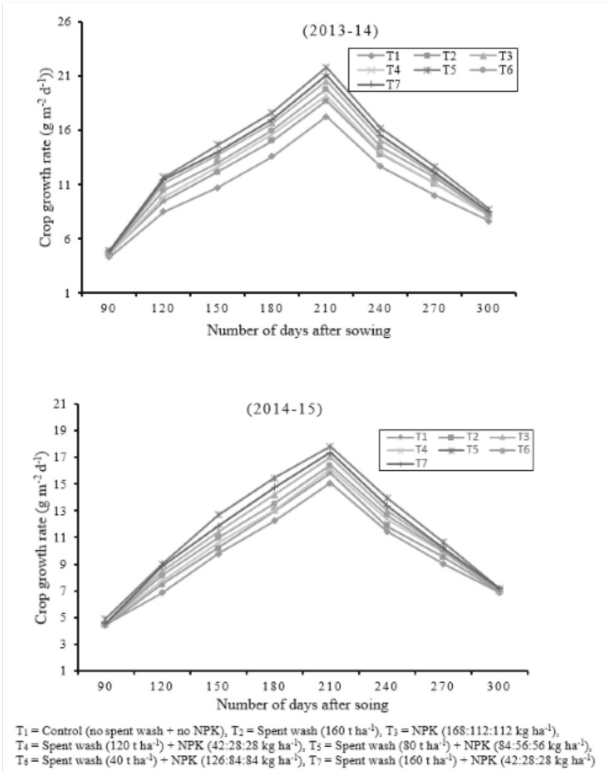

Fig. 3. Influence of spent wash water and NPK application on crop growth rate (g m^{-2} d^{-1}) of spring-planted sugarcane.

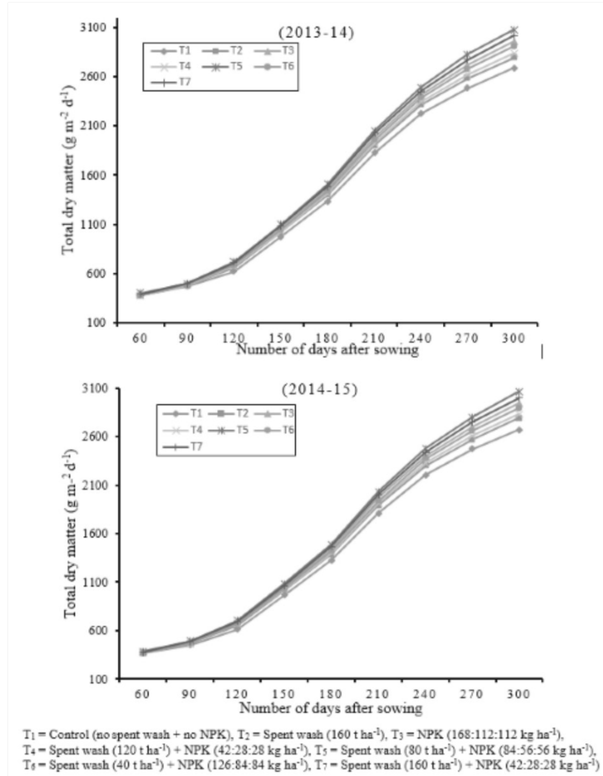

Fig. 4. Influence of spent wash water and NPK application on total dry matter (g m^{-2} d^{-1}) of spring-planted sugarcane.

Table 2. Influence of spent wash water and NPK application on quantitative parameters of spring-planted sugarcane.

Treatment	Net Assimilation Rate (g m^{-1} d^{-1})		No. of Millable Canes		Cane Length (cm)	
	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15
T_1	2.25 d	2.17 c	6.19 c	5.33 c	135.26 c	119.67 d
T_2	2.29 c	2.28 b	9.38 b	8.67 b	207.03 b	186.00 c
T_3	2.34 ab	2.32 ab	11.40 ab	10.67 ab	221.19 abc	216.00 abc
T_4	2.30 c	2.29 b	10.15 b	9.00 b	209.59 c	191.00 c
T_5	2.37 a	2.36 a	13.58 a	13.33 a	259.23 a	255.00 a
T_6	2.31 bc	2.30 b	10.63 b	9.67 b	211.67 bc	198.33 bc
T_7	2.35 a	2.32 ab	13.32 a	13.00 a	249.01 ab	246.00 ab
HSD at P ≤ 0.05	**0.031**	**0.053**	**2.197**	**2.998**	**38.973**	**49.388**

T_1 = Control (no spent wash + no NPK), T_2 = Spent wash (160 t ha^{-1}), T_3 = NPK (168:112:112 kg ha^{-1}), T_4 = Spent wash (120 t ha^{-1}) + NPK (42:28:28 kg ha^{-1}), T_5 = Spent wash (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}), T_6 = Spent wash (40 t ha^{-1}) + NPK (126:84:84 kg ha^{-1}), T_7 = Spent wash (160 t ha^{-1}) + NPK (42:28:28 kg ha^{-1})

Table 3. Influence of spent wash water and NPK application on quantitative parameters of spring-planted sugarcane.

Treatment	Weight per Stripped Cane (kg)		Unstripped Cane Yield (t ha^{-1})		Stripped Cane Yield (t ha^{-1})	
	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15
T_1	0.56 d	0.48 d	40.79 d	31.33 d	31.93 d	23.20 d
T_2	0.75 c	0.71 c	85.29 c	69.18 c	69.00 c	55.15 c
T_3	0.87 a	0.83 a	117.75 ab	106.14 ab	96.43 ab	87.62 ab
T_4	0.77 bc	0.73 bc	92.80 c	79.84 bc	74.94 c	65.05 bc
T_5	0.90 a	0.87 a	141.25 a	137.78 a	117.60 a	113.62 a
T_6	0.80 b	0.76 b	104.97 bc	87.55 bc	83.95 bc	71.72 bc
T_7	0.88 a	0.85 a	138.76 a	131.85 a	113.30 a	107.98 a
HSD at P ≤ 0.05	**0.031**	**0.043**	**23.561**	**31.650**	**21.203**	**25.112**

T_1 = Control (no spent wash + no NPK), T_2 = Spent wash (160 t ha^{-1}), T_3 = NPK (168:112:112 kg ha^{-1}), T_4 = Spent wash (120 t ha^{-1}) + NPK (42:28:28 kg ha^{-1}), T_5 = Spent wash (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}), T_6 = Spent wash (40 t ha^{-1}) + NPK (126:84:84 kg ha^{-1}), T_7 = Spent wash (160 t ha^{-1}) + NPK (42:28:28 kg ha^{-1})

kg ha^{-1}) was used. On the other hand, the treatment with no spent wash water and NPK application caused a marked reduction in number of millable canes and cane length during both years of study.

Application of NPK and spent wash water significantly affected the weight per stripped cane (Table 3). The maximum value of weight per stripped cane was recorded in the application of combined spent wash water (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}) during both years. The results indicated that application of no spent wash water and NPK application resulted in a substantial reduction in stripped cane weight. The crop yielded 5.33% more weight per stripped cane in 2013–14 compared with 2014–15 (Table 3). The influence of spent wash water and NPK application on stripped and unstripped cane yield was found significant during both cane-growing years (Table 3). Maximum yield of unstripped cane and stripped cane during both years was recorded in the treatment that used combined application of spent wash water (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}), followed by T_7 (Spent wash (160 t ha^{-1}) + NPK (42:28:28 kg ha^{-1}) and T_3 (NPK (168:112:112 kg ha^{-1}) alone, while the treatment with no spent wash water or no NPK resulted in poor response.

Although results varied among different treatments, application of spent wash water and NPK markedly improved the qualitative traits compared with the control (Table 4). A linear increase in brix (%), sucrose content, sugar recovery and total sugar yields was observed with increase in the spent wash water and NPK rate. Maximum improvement in brix (%), sucrose content, sugar recovery and total sugar yields was recorded in plots where spent wash water (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}) was applied. On the other hand, minimum improvement in qualitative parameters was recorded in the treatment with no spent wash water or no NPK application (Table 4).

DISCUSSION

The maximum leaf area index, crop growth rate (g m^{-2} d^{-1}), total dry matter (t ha^{-1}) and net assimilation rate (g m^{-2} d^{-1}) was observed in plots applied with spent wash water (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}) compared with those of other combinations and those of the sole application of spent wash water and NPK. Application of spent wash water (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}) increased the number of millable canes per m^2, cane length (cm), weight per stripped cane (kg), unstripped cane yield (t ha^{-1}) and stripped cane yield (t ha^{-1}) compared with other treatments. The increase in growth and yield might be due to integrated use of inorganic fertilizers along with organic fertilizers. Growth and yield attributes of cane proved that the supplementation of spent wash water in reduced fertilizer environment critically supported the plants for gathering better biomass and lush growth than those grown only or simply on fertilizers or by individual application of spent wash water.

Similar results had been reported by different researchers. It is well established that growth of maize plant for leaf area index, crop growth rate, plant height, net assimilation rate and total dry matter significantly differed when exposed to different fertilizer levels. The maximum leaf area index, crop growth, and net assimilation rate was recorded in the treatment combination that used 75% NPK and 25% spent wash + crop residues (Ashok et al. 2005). Similarly, Chand et al. (2006) reported that combined application of organic source nutrients and synthetic fertilizers markedly improved the crop growth and yield compared with their sole application. Spent wash water is useful in improving growth and yield of several crops as it judiciously alters soil characteristics such as pH, electrical conductivity (EC) and available nutrient form for better crop level utilization (Suganya and Rajannan 2009) as shown in their field experiment with different levels of distillery spent wash water on the sugarcane crop. Growth parameters such as cane height, leaf length, leaf breadth, stem girth,

Table 4. Influence of spent wash water and NPK application on qualitative parameters of spring-planted sugarcane.

Treatment	Brix (%)		Sucrose Content (%)		Sugar Recovery (%)		Total Sugars (t ha^{-1})	
	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15	2013–14	2014–15
T_1	17.95 c	18.06 c	15.02 c	14.56 d	10.38 b	9.76 b	3.53 d	2.51 d
T_2	18.58 bc	18.38 bc	16.05 bc	15.63 cd	11.32 ab	10.89 ab	8.28 c	7.67 bc
T_3	20.64 a	20.20 a	18.30 a	17.65 a	13.09 a	12.55 a	13.30 ab	11.84 ab
T_4	19.05 bc	18.95 abc	16.54 abc	16.02 bcd	11.72 ab	11.16 ab	9.35 c	6.70 cd
T_5	20.74 a	20.30 a	18.36 a	18.03 a	13.10 a	12.94 a	16.42 a	15.70 a
T_6	20.03 ab	19.92 ab	17.69 ab	17.10 abc	12.65 a	11.98 a	11.28 bc	9.28 bc
T_7	20.53 a	20.11 ab	18.13 a	17.51 ab	12.95 a	12.38 a	15.76 a	14.58 a
HSD at $P \leq 0.05$	**1.463**	**1.827**	**2.036**	**1.549**	**2.064**	**2.177**	**3.161**	**4.434**

T_1 = Control (no spent wash + no NPK), T_2 = Spent wash (160 t ha^{-1}), T_3 = NPK (168:112:112 kg ha^{-1}), T_4 = Spent wash (120 t ha^{-1}) + NPK (42:28:28 kg ha^{-1}), T_5 = Spent wash (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}), T_6 = Spent wash (40 t ha^{-1}) + NPK (126:84:84 kg ha^{-1}), T_7 = Spent wash (160 t ha^{-1}) + NPK (42:28:28 kg ha^{-1})

leaf area index, leaves per plant, and tillers per plant were enhanced with increased concentration of distillery spent wash up to 75% with NPK (Rath et al. 2010). Fertilizer application at NPK (170:85:85 kg ha^{-1}) + biocane (2.5 ha^{-1}) proved to be sufficient for getting higher cane growth, yield and sucrose content (Shahid et al. 2011). Supplementation of spent wash water with inorganic fertilizers increased the growth traits (leaf area index, total dry matter, crop growth rate, and net assimilation rate) of sugarcane and other crops such as wheat, maize, cotton and sunflower (Chandraju et al. 2011; Rath et al. 2013). Application of treated sugarcane distillery effluent supplemented with inorganic fertilizers to rice improved growth and productivity on a sustainable basis (Balasubramaniam et al. 2013). The highest cane yield, sugar yield and nutrient uptake were recorded at 25% NPK fertilizer + 75% effluent application (Sharma 2014). Integrated use of organic crop residues with fertilizers for the sugarcane crop was extremely important for growth parameters, cane yield and nutrient uptake where nutrients were supplied from 50% crop residues and 50% through inorganic fertilizers (Darandale 2015).

The maximum improvement in brix (%), sucrose content, sugar recovery and total sugar yield were recorded from plots where spent wash water (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}) was applied. Our study results revealed that cumulative use of spent wash water and mineral fertilizers increased the quality parameters of sugarcane. Our results are correlated with those of Kalaiselvi and Mahimairaja (2009) who observed that brix and polarity percentages of sugarcane juice increased with the combined application of spent wash water and inorganic fertilizers against sole use of fertilizers. Similarly, Singh et al. (2005) also recorded a considerable increase in quality parameters with the integrated use of nutrient management. Integration of spent wash water with inorganic fertilizers increased the commercial cane sugar (CCS) (16.04%), brix (22.68%), polarity percent (19.46) and purity (84.14) of sugarcane (Singandhupe et al. 2009). Spent wash water is a more effective fertilizer for improving cane juice quality of sugarcane crop than solid fertilizers (Rath et al. 2011).

CONCLUSION

Different doses of spent wash water and NPK had a significant effect on the growth, yield and quality of spring-planted sugarcane. Moreover, the maximum improvement in growth, yield and quality was recorded in the treatment that used combined application of spent wash (80 t ha^{-1}) + NPK (84:56:56 kg ha^{-1}).

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