Research Article

Integrated use of distillery spent wash and NP fertilizers on FH-142 cotton-a low cost practice

Waqar Hussain Shah¹ and Mehrunisa Memon^{1*}

1. Department of Soil Science, Sindh Agriculture University, Tandojam-Pakistan

*Corresponding author's email: nisamemon@gmail.com

Citation

Waqar Hussain Shah and Mehrunisa Memon. Integrated use of distillery spent wash and NP fertilizers on FH-142 cotton-a low cost practice. Pure and Applied Biology. Vol. 10, Issue 2, pp430-437.

<http://dx.doi.org/10.19045/bspab.2021.100046>

Received: 06/07/2020

Revised: 26/09/2020

Accepted: 07/10/2020

Online First: 20/10/2020

Abstract

Distillery spentwash, a sugar-industry discharge of plant origin generated during ethanol production can be used to fertilize the plants, instead of polluting the environment. A field experiment arranged in a split plot design consisted five spentwash spray concentrations (0, 5, 10, 15 and 20 %) as main split and four N-P rates i.e. 0, 1/3rd, 2/3rd and full recommended (0-0, 46-23, 93-46 and 140-70 kg N-P₂O₅ ha⁻¹) as sub-split, replicated thrice. Increasing the concentration of spentwash or N-P fertilizer rates alone and their interaction significantly increased growth, yield and leaf tissue NPK concentration. Yet, increasing the rates of N-P alone from 1/3rd to full, did not increase the leaf tissue K concentration till foliar spray of spentwash. A full N-P fertilizer rate with 20% spentwash spray resulted in maximum plant height (130.77 cm), number of leaves (25.13), sympodia (20.12), squares (27.70), bolls (40.24) plant⁻¹, seed cotton yield (4025 kg ha⁻¹) and leaf tissue N (3.40%) and P (0.20%) without any adverse effects on soil or cotton plant. However, increasing the rate of N-P fertilizer from 2/3rd to full or spentwash concentration from 15% to 20% did not influence the cotton attributes and yield. A 2/3rd N-P rate with 20% spentwash spray increased seed cotton yield by 20%, even over full N-P, which saved 1/3rd cost of each N-P and complete K, the best way to economize the chemical fertilizer inputs.

Keywords: Chemical fertilizer; Foliar spray; Leaf tissue; NPK substitution; Seed cotton yield

Introduction

Cultivation of cotton (*Gossypium hirsutum* L.) in Pakistan is mainly associated with the fiber used in textile industry. It contributes 4.5% to agriculture as a value addition and 0.8% to gross domestic product (GDP) of the country [1]. About 11% of the cultivable agricultural land is under cotton. However, the area under cotton has decreased from 2961 thousand hectares in 2014-15 to 2373 thousand hectares in 2018-19 [1], corresponding to a 20% decrease in the area and 12% in cotton production. The average seed cotton yield of the country is very low (1990 kg ha⁻¹) [1] in comparison to the yield by Australia (5416 kg ha⁻¹), Turkey (5048 kg ha⁻¹), China (4748 kg ha⁻¹) and Mexico

(4675 kg ha⁻¹) [2]. The low yields of cotton may be related to many problems like high or low population of plants, narrow row spacing, shortage of irrigation water, seed rate, variety, weed infestation, pest (sucking or bollworms), disease and yet the fertilizer management issues [3, 4]

Adequate supply of major nutrients increases the seed cotton yield and lint percentage [5]. Nitrogen is necessary throughout the growing season, its deficiency can reduce the vegetative and reproductive processes that leads to potential yield loss [6]. Phosphorus is necessary in cell division and stimulates the number of flowering buds and bolls. It effectively improves the growth, uptake of

NPK, chlorophyll and dry matter content in cotton [7]. While K mainly improves fiber quality and is involved in different biochemical and physiological processes i.e. photosynthetic apparatus and root stimulus [8, 9]. After the appearance of deficiency symptoms of K on cotton leaves, it is very difficult to achieve optimum cotton yield [10]. The cotton growers are generally applying ample quantities of N, with some P and with no or very little K. Therefore, application of major nutrients is not carried out as per crop requirement. According to [11], 150 kg of K in a hectare can give a cotton lint yield of 2500 kg ha⁻¹. This quantity of K fertilizer is almost equal to N. The timely availability and cost related issues of chemical fertilizers with special reference to K are the most common limitations for a cotton grower, hindering its application and ultimately the yield targets. Under present scenario, nutrient management of cotton, at low-cost practice is of primary importance and can have a huge impact on the growth and yield targets [8]. Therefore the alternate nutrient sources of plant origin must be included in the fertilizer management program.

In this connection, huge quantities of sugar-industry based distillery spentwash are generated locally after the production of ethanol. This liquid, a rich source of K (5000-7500 mg L⁻¹) some N (477-581 mg L⁻¹), P (55-210 mg L⁻¹) and other nutrients is disposed off in the vicinity of sugar mills and polluting the environment. The utilization of this liquid on agricultural crops can instead benefit the cotton grower by substituting part of the chemical fertilizer [12]. Application of spentwash in soil with or without dilution can increase the salt content of soil and may be harmful for the agricultural lands in the long run [13]. On the other side, foliar spray of spentwash after proper dilution with or without chemical fertilizers has been reported to be beneficial in vegetables i.e. tomato [14], legumes i.e. soybean [15] and fodder crops i.e. sorghum [16] as it is directly applied on the plant. The studies

integrating chemical fertilizer with spentwash spray are scarce [14-16]. Yet, there are no studies on the use of local spentwash in the form of foliar spray either on cotton or other crops.

Keeping the farmers perspective of low-cost nutrient necessity in achieving sustainable yield targets, this study evaluated the effect of various concentrations of spentwash spray in conjunction with chemical fertilizer (N-P) rates in cotton.

Materials and methods

Cotton experiment

The field experiment conducted (2018) at farmer's field, district Matiari, Sindh, Pakistan was a split plot design, with 20 treatments replicated thrice. The sub-plot size was 6 m x 2.25 m. The treatments consisted of five spentwash concentrations (0, 5, 10, 15 and 20 %) as main splits and four chemical (N-P) fertilizer rates i.e. 0-0 (0), 46-23 (1/3rd), 93-46 (2/3rd) and 140-70 kg N-P₂O₅ ha⁻¹ (full recommended) as sub-splits, applied in the form of urea and diammonium phosphate (DAP). All the DAP and 1/4th of the urea were applied at sowing time, and leftover urea in three splits during the crop growth. To ensure better crop growth, spentwash spray was carried out after 25 days of germination and continued at 15 days interval till maturity. Plastic sheet partitions were used to separate out the spray of different concentrations. All the agronomic practices, insect pest and disease control measures were taken as and when required. The crop was harvested at maturity. Plant height, number of leaves, sympodial branches, squares, bolls and seed cotton yield were recorded.

Sampling and processing

One liter polycarbonyl containers were sterilized prior to collection of spentwash from Matol Distillery Unit at Matiari Sugar Mills, district Matiari, Sindh-Pakistan. The samples were stored in ice boxes right away, transported to Soil Fertility Research Laboratory, Department of Soil Science, Sindh Agriculture University, Tandojam

and refrigerated at 4°C [17]. Before its application, necessary dilutions (0, 5, 10, 15, and 20 %) were prepared and analyzed for some spentwash characteristics. Prior to sowing of cotton, five soil samples were randomly collected at 0-15 and 15-30 cm from the experimental field and composited depth-wise. After the removal of unwanted material, the samples were kept under shade for drying, brought to 2 mm particle size and preserved for the analysis of some soil properties. Composite main branch leaves (3rd leaf from top) were collected, packed in paper envelopes and brought to laboratory. The leaves were rinsed with tap water, followed by distilled water and dried first in shade, later in hot oven at 68°C. The leaves were ground to fine powder and preserved for N, P and K analyses.

Analytical methods

The spentwash samples were analyzed for EC, pH, organic matter, N, P and K concentration as outlined by [17]. The soil samples were analyzed for soil particle-distribution (texture) by Bouyoucos hydrometer method [18], EC and pH in 1:2 (soil:water) extracts by EC and pH meter, organic matter by Walkley-Black method [19], total N by Kjeldahl's method [20] and P and K by ammonium bicarbonate diethylene triamine penta-acetic acid (AB-DTPA) extractable method [21]. Nitrogen in leaf tissue was determined by same method as in case of soil [20]. For P and K, the samples were acid digested in 1:5 HClO₄:HNO₃. Phosphorus in the digests was quantified by yellow colour (vanado-molybdo-phosphoric acid) method [22] by using absorption spectrophotometry, while K was directly determined by emission spectroscopy [23].

Statistical analysis of the data

The data of growth parameters, yield and yield contributing parameters and N, P and K concentrations in cotton leaf tissue at maturity were subjected to analyses of variance using split plot design (major split - spentwash and sub-split as N-P rates). Data were statistically analyzed through Statistix 8.1 [24]. The means were

compared using the Honest Significant Difference (HSD) only if the general treatment F test was significant at probability of ≤ 0.05 [25].

Results

Spentwash characteristics

The analytical data of spentwash samples indicated that 20% spentwash had a highest EC of 9.75 dS m⁻¹, followed by 15% spentwash (8.85 dS m⁻¹), 10% (7.25 dS m⁻¹) and 5% which had a lowest EC of 4.15 dS m⁻¹ (Table 1). As for pH the values decreased with the increase in spentwash concentration (i.e. from 5% to 20%). The respective pH values for 5, 10, 15 and 20% spentwash concentration were: 8.20, 8.12, 7.91 and 7.85. The organic matter content was also higher in samples having higher spentwash concentration i.e. 5% (0.25%), 10% (0.71%), 15% (1.15%) and 20% (1.30%). The total N of 176, 389, 725 and 889 mg L⁻¹, total P of 24.0, 52.2, 58.7 and 66.5 mg L⁻¹ and total K of 900, 2132, 3686 and 4345 mg L⁻¹ was observed in 5, 10, 15 and 20 % spentwash. The data showed that N, P, and K concentrations increased with increasing the spentwash concentration.

Soil properties

The soil of experimental site was silty clay loam in texture, consisting 20% of sand, 42.5% of silt and 37.5% of clay at surface and 18% sand, 43% silt and 39% clay at sub-surface with EC value of 0.7 dS m⁻¹ and pH of 7.15 and 7.51 at respective soil depths (i.e. 0-15 and 15-30 cm). The organic matter content of the soil was 0.81% and 0.65%, Kjeldahl's N of 0.045% and 0.032%, AB-DTPA extractable P of 1.25 and 1.0 mg kg⁻¹ and K concentration of 80 and 70 mg kg⁻¹ correspondingly at surface and subsurface (Table 2).

Effect of spentwash and chemical fertilizer (N-P) on growth, yield and leaf tissue N, P and K

The data (Table 3) showed that the foliar application of spentwash concentrations (0, 5, 10, 15 and 20 %), N-P rates (0, 1/3rd, 2/3rd and full) and the interaction of both chemical fertilizer and spentwash significantly ($p < 0.01$) influenced the

growth parameters (i.e. plant height, number of leaves and sympodial branches plant⁻¹, yield and yield contributing parameters (i.e. number of squares and bolls plant⁻¹ and seed cotton yield ha⁻¹) and leaf tissue nutrients (N, P and K) concentration in cotton. All the growth parameters, yield and yield contributing parameters and nutrient concentration increased with increasing the spentwash concentration from 0% to 20% or the N-P rates from 0 to full, except in case of K, where the increase in N-P rates did not have a significant effect.

Growth parameters

The interaction of 20% spentwash spray and full N-P rate gave tallest plants (130.77 cm), maximum number of leaves (25.13) and sympodia (20.12) plant⁻¹. While, shortest plants (103.20 cm), minimum number of leaves (16.24) and sympodia (11.31) plant⁻¹ were observed under control (0 spentwash and 0 N-P). This resulted in 26.71% increase in plant height, 54.74% in number of leaves and 77.89% in sympodia over control. Increasing the spentwash concentration correspondingly from 15% to 20% integrated with 2/3rd or full N-P rate did not have any significant effect on plant height (130.17, 130.37, 130.53 and 130.77 cm), number of leaves (25.05, 25.08, 25.11 and 25.13) plant⁻¹ and sympodia (20.07, 20.09, 20.11 and 20.12) plant⁻¹ as given under (Fig. 1).

Yield and yield contributing parameters

The highest number of squares (27.70), bolls (40.24) plant⁻¹ and seed cotton yield (4025 kg) ha⁻¹ were observed at 20% spentwash spray integrated with full N-P rate. The lowest number of squares (18.60) and bolls (20.66) plant⁻¹ and seed cotton yield (2067 kg) ha⁻¹ was recorded under

control. Resultantly, there was 48.92% increase in number of squares, 94.77% in number of bolls and 94.73% in seed cotton yield at 20% spentwash and full N-P fertilizer over no spentwash and no N-P. The data in (Fig 2) depicted statistically similar number of squares (27.55) plant⁻¹, bolls (40.18) plant⁻¹ and seed cotton yield (4018 kg) ha⁻¹ when N-P rate was reduced from full to 2/3rd at 20% spentwash concentration. Likewise, number of squares (27.48 and 27.35) plant⁻¹, bolls (40.23 and 40.15) plant⁻¹ and seed cotton yield (4023 and 4016 kg) ha⁻¹ recorded, correspondingly at 15% spentwash integrated with full and 2/3rd N-P were also at par with 20% spentwash at full and 2/3rd N-P rates (Fig. 2).

Leaf tissue nutrients (N, P and K)

Maximum N (3.40%) and P (0.2%) concentration in leaf tissue (Fig. 3) was observed at full N-P rate integrated with 20% spentwash and minimum N (2.19%) and P (0.09%) at control, which led to 55.25% increase in N and 122% in P over control. The treatments receiving 20% or 15% spentwash and full or 2/3rd N-P had correspondingly similar leaf tissue N (3.40%, 3.38%, 3.37% and 3.35%) and P concentration (0.2%, 0.19%, 0.19% and 0.19%) as in case of growth and yield parameters. In case of K in leaf tissue, the maximum value (2.83%) was observed at 20% spentwash spray with 2/3rd N-P and minimum (1.47%) under control, headed to 92.5% increase in K concentration against control. The interaction data further showed that the spray of 20% spentwash alone (2.79%), or integrated with each of three N-P rates i.e. 1/3rd (2.81%), 2/3rd (2.83%) and full (2.81%) did not significantly increase K concentration.

Table 1. Characteristics of spentwash concentrations used for foliar spray on cotton

Parameters	Spentwash concentrations (%)			
	5	10	15	20
EC (dS m ⁻¹)	4.15	7.25	8.85	9.75
pH	8.20	8.12	7.91	7.85
Organic matter (%)	0.25	0.71	1.15	1.30
Total N (mg L ⁻¹)	176	389	725	889
Total P (mg L ⁻¹)	24.0	52.2	58.7	66.5
Total K (mg L ⁻¹)	900	2132	3686	4345

Table 2. Properties of experimental soil

Soil Property	Soil depth (cm)	
	0-15	15-30
Particle distribution (%)		
Sand	20	18
Silt	42.5	43
Clay	37.5	39
Textural class	silty clay loam	silty clay loam
EC in 1:2 soil-water extract (dS m ⁻¹)	0.7	0.7
pH in 1:2 soil-water extract	7.15	7.51
Organic matter (%)	0.91	0.65
Kjeldahl's N (%)	0.045	0.032
AB-DTPA P (mg kg ⁻¹ soil)	1.25	1.0
AB-DTPA K (mg kg ⁻¹ soil)	80	70

Table 3. F values and significance from analysis of variance for various growth parameters, yield and yield contributing parameters and leaf tissue N, P and K as affected by different spentwash concentrations and N-P fertilizer rates

Parameters	Spentwash concentrations (SW)	N-P rates	SW x N-P
Plant height (cm)	9299**	20061**	216**
Number of leaves plant ⁻¹	3066**	12777**	182**
Number of sympodial branches plant ⁻¹	20730**	21514**	294**
Number of squares plant ⁻¹	664**	562**	17.4**
Number of bolls plant ⁻¹	22116**	33846**	393**
Seed cotton yield (kg) ha ⁻¹	21920**	36154**	419**
N (%)	1388**	1978**	54.4**
P (%)	951**	1872**	176**
K (%)	1112**	422**	38.8**

NS - non significant; * and ** - significant at 0.05 and 0.01 probability level according to Honest Significant Difference (HSD) test

Figure 1. Effect of spentwash concentrations, N-P rates and their interaction on growth parameters. a Plant height. b Number of leaves plant⁻¹. c Number of sympodia plant⁻¹

Figure 2. Effect of spentwash concentrations, N-P rates and their interaction on yield and yield contributing parameters. a Squares plant⁻¹. b Bolls plant⁻¹. c Seed cotton yield ha⁻¹

Figure 3. Effect of spentwash concentrations, N-P fertilizer rates and their interaction on N, P and K concentration in cotton leaf tissue. a Leaf tissue nitrogen. b Leaf tissue phosphorus. c Leaf tissue potassium

Discussion

One of the major problems faced by farmer community is the unaffordable prices of chemical fertilizers, which has resulted in low fertilizer inputs, not fulfilling the nutrient requirements as per crop recommendations [14]. Under this setup, expected yield targets are not

achieved, unless a low-cost environment friendly nutrient addition, complimenting chemical fertilizers is available. In this study, we used sugar-industry based nutrient rich waste “spentwash” as a foliar spray in conjunction with chemical fertilizers. Past studies of soil-

application spentwash have already highlighted its drawback of increasing the salt content [13]. The results of this study demonstrated a positive outcome in growth and yield of cotton by foliar spray of spentwash with N-P fertilizers. All the growth (plant height, number of leaves and sympodia), yield contributing parameters (squares and bolls), seed cotton yield and nutrient concentration (N, P and K) in leaf tissue increased with the increase in spentwash (0, 5, 10, 15, 20 %), chemical fertilizer rates (0, 1/3rd, 2/3rd and full) and the combination of the two (20% spentwash and full N-P). [14] also reported significant increase in growth and yield of tomato at recommended rate of fertilizer and 20% spentwash spray. Our results also indicated 20% spentwash concentration as a cutoff point for cotton crop. As the concentration of spentwash increases, the colour intensity and the nutrient contents of this liquid also increase, which decrease the chlorophyll content, and slowing down the process of photosynthesis [26]. Analysis of the fertilizer treatments alone showed that varying the rate of N-P from 1/3rd to full did not influence the K contents. Cotton being highly sensitive to K has responded well to K additions through chemical fertilizers [10, 27]. Here, this is obvious, as no K was applied in the form of chemical fertilizer. The K increase was only prominent when spentwash was applied alone and is in line with the results given by [28].

The nutrient application practices and its quantities from chemical fertilizers vary among cotton growers, however, majority of the growers apply 2/3rd (93-46 kg N-P₂O₅ ha⁻¹) of the recommended N-P (or little more N) with no K due to its cost-related issues. A comparison of seed cotton yield under similar (farmer's practice) rate of N-P fertilizer (2/3rd) with spentwash spray of 20% exhibited even more yield (20%) than that achieved at full N-P. Increasing the N-P rate from 2/3rd to full and spentwash concentration from 15% to 20% did not have any benefit in terms of growth and yield of cotton and would not be fruitful. This may be that 2/3rd rate of N-P with 20% spentwash has already fulfilled the nutrient requirement of cotton and the results of this study are proof of this. Under same setup, plant height (5.5%), number of leaves (16.1%), sympodia (20%), number of squares (9%), and bolls (20%) increased to relevant percentages to head the yield target. In case of leaf tissue nutrients, the interaction of 20% spentwash with 2/3rd N-P

increased N by 21%, P by 58% and K by 59% over full N-P alone. Our results are in line with the work of [14] and further supported by [16].

Conclusion

Spray of 20% spentwash on cotton leaves, either alone or with full N-P soil application increased the growth, yield parameters, seed cotton yield and N, P and K concentration in leaf tissue, leading to increased seed cotton yield. A 2/3rd N-P rate with 20% spentwash also gave similar outcome as that obtained at full N-P and substituted 33% of each N and P and 100% of K, saving N, P and K fertilizer cost of (Rs. 18750 ha⁻¹) and 20% increase in seed cotton yield ha⁻¹ over full N-P fertilizer alone.

Authors' contributions

Conceived and designed the experiments: M Memon, Performed the experiments: WH Shah, Analyzed the data: WH Shah & M Memon, Contributed materials/ analysis/ tools: M Memon, Wrote the paper: M Memon & WH Shah.

References

1. Pakistan Bureau of Statistics (2018-19). Pakistan Economic Survey, Economic Advisor Wing, Finance Division, Govt. Pakistan, Islamabad.
2. FAOSTAT (2016-17). Statistical Database. Food and Agricultural Organization (FAO). Available online, www.fao.org.
3. Ahmed AUH, Ali R, Zamir SI & Mahmood N (2009). Growth, yield and quality performance of cotton cultivar BH-160 (*Gossypium hirsutum* L.) as influenced by different plant spacing. *J Anim Plant Sci* 19: 189-192.
4. Munir MK, Tahir M, Saleem MF & Yaseen M (2015). Growth, yield and earliness response of cotton to row spacing and nitrogen management. *J Anim Plant Sci* 25(3): 729-738.
5. Sampathkumar T, Krishnasamy S, Ramesh S, Prabukumar G & Gobi R (2006). Growth, nutrient uptake and seed cotton yield of summer cotton as influenced by drip, surface irrigation methods and mulching practices. *Res J Agri Biol Sci* 2(6): 420-422.
6. Saleem MF, Bilal MF, Awais M, Shahid MQ & Anjum SA (2010). Effect of nitrogen on seed cotton yield and fiber qualities of cotton (*Gossypium hirsutum* L.) cultivars. *J Anim Plant Sci* 20(1): 23-27.

7. Sawan ZM, Mahmoud MH & El-Guibali AH (2008). Influence of potassium fertilization and foliar application of zinc and P on growth, yield and fiber properties of Egyptian cotton (*Gossypium barbadense* L.). *J Plant Ecol* 1: 259-270.
8. Zhao D, Oosterhuis DM & Bednarz CW (2001). Influence of potassium deficiency on photosynthesis, chlorophyll content, and chloroplast ultrastructure of cotton plants. *Photosynthetica* 39(1): 103-109.
9. Wang L & Chen F (2012). Genotypic variation of potassium uptake and use efficiency in cotton (*Gossypium hirsutum* L.). *J Plant Nutr Soil Sci* 175(2): 303-308.
10. Rosolem CA & Mikkelsen DS (1991). Potassium absorption and partitioning in cotton as affected by periods of potassium deficiency. *J Plant Nutr* 14(9): 1001-1016.
11. Silvertooth JC (2007). Cotton (*Gossypium* spp.). In: World Fertilizer Use Manual. International Fertilizer Industry Association (IFA). <http://www.fertilizer.org/ifa/publicat/html/pubman/cotton.htm>.
12. Kumar V & Chopra AK (2011). Impact on physico-chemical characteristics of soil after irrigation with distillery effluent. *Arch Appl Sci Res* 3(4): 63-77.
13. Kaloi GM, Memon M, Memon KS, Ahmad S, Sheikh SA & Jamro GM (2017). Effect of sugar industry spentwash (diluted) on the characteristics of soil and sugarcane (*Saccharum officinarum* L.) growth in the subtropical environment of Sindh, Pakistan. *Environ Monit Assess* 189: 127.
14. Savitha HR (2015). Studies on fortification of distillery spentwash for foliar application and its effect on soil properties, growth and yield of tomato. PhD thesis. Deptt. Of Soil Sci. & Agri Chem, Univ of Agri Sci, Bengaluru.
15. Ramana S, Biswas AK, Kundu S, Saha JK & Yadava RBR (2000). Physiological response of soybean (*Glycine max* L.) to foliar application of distillery effluent. *Ann Plant Soil Res* 2: 1-6.
16. Babu RS, Saralabai VC, Muralidharan KS & Vivekanandan M (1996). Foliar application of distillery spentwash as a liquid fertilizer for betterment of growth of *Sorghum vulgare* and *Cajanus cajan*. *Appl Biochem Biotech* 59: 87-91.
17. APHA, AWWA & WEF (1998). Standard methods for examination of water and wastewater. 20th Ed. DC: American Public Health Association; Washington.
18. Bouyoucos GH (1962). Hydrometer method improved for making particle-size analysis of soils. *Agron J* 54: 464-465.
19. Walkley A & Black IA (1934). An examination of the method for determining soils organic matter and a proposed modification of the chromic acid titration method. *Soil Sci* 37: 29-38.
20. Jackson ML (1958). Soil chemical analysis. Prentice-Hall, Inc., Englewood Cliffs; New Jersey, pp. 87-110.
21. Soltanpour PN & Workman S (1979). Modification of the NH_4HCO_3 -DTPA soil test to omit carbon black. *Commun Soil Sci Plant Anal* 10: 1411-1420.
22. Cottenie A (1980). Soil and plant testing as a basis of fertilizer recommendations. FAO Soils Bulletin, 38/2, FAO; Rome.
23. Knudsen D, Peterson GA & Pratt PF (1982). Lithium, sodium and potassium. In: AL Page (Ed.). Methods of Soil Analysis, Part 2: Chemical and microbiological properties. American Society of Agronomy; Madison, WI (USA), pp. 225-245.
24. Analytical Software (2005). Statistix 8.1 User's manual. Tallahassee, (FL): Analytical Software.
25. Gomez KA & Gomez AA (1984). Statistical procedures for Agricultural Research, 2nd Ed. John Wiley & Sons; New York.
26. Rath P, Pradhan G & Misra MK (2011). Effect of distillery spentwash (DSW) and fertilizer on growth and chlorophyll content of sugarcane (*Saccharum officinarum* L.) plant. *Rec Res Sci Tech* 3(4): 169-176.
27. Zia-ul-hassan, Kubar KA, Rajpar I, Shah AN, Tunio SD, Shah JA & Mailto AA (2014). Evaluating potassium-use-efficiency of five cotton genotypes of Pakistan. *Pak J Bot* 46(4): 1237-1242.
28. Krishnamurthy D (2010). Effect of fertigation with distillery spentwash on soil fertility, growth, yield and quality of banana (*Musa paradisiaca* L.). PhD thesis. Deptt of Agron, Univ of Agri Sci, Bengaluru.