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Effect of Spentwash Application on Potassium Dynamics in Soil

P. Kalaiselvi*

Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore 641003, Tamil Nadu, India.

* Corresponding author, E-mail: kalaiselvi.p@tnau.ac.in,

ABSTRACT

Distillery spentwash contains all nutrients and organic matter and is used in agriculture as a source of plant nutrients and irrigation water. Besides all the nutrients, spentwash contains high amount of potassium (K) also. The effect of different levels and methods of spentwash application on soil potassium dynamics was examined through a field experiment with groundnut (*Arachis hypogea* L.) as a test crop. At all stages of groundnut growth, the amounts of water soluble, exchangeable and non exchangeable potassium were greater in soil that received 120 m^3 of spentwash. Results shown that K added through the spentwash exceeded the crop removal (uptake); it initially increases solution K and subsequently increases the K concentration in the exchangeable and non-exchangeable forms through the shifting of equilibrium. The phenomenon of both the fixation of exchangeable K and release of non-exchangeable K play an important role in the dynamics of soil potassium.

Key Words: Nutrients; Mineralization; Groundnut; Exchangeable K; Non exchangeable K.

INTRODUCTION

In recent years, the demand for wastewater reuse has increased significantly worldwide. In particular, the arid and semiarid areas of the world can easily augment 15-20 % of their water supply through reuse of wastewater. The common and the most efficient form of wastewater reuse is in the area of agriculture. Such water reuse accomplishes several purposes such as minimizing the cost of wastewater treatment and disposal, providing essential plant nutrients and fertilizer to the soil when used for agriculture (Kannaiyan 2001). The spentwash, being originated from plant sources, contains almost all plant nutrients, besides high level of organic carbon and potassium and small amounts of micronutrients. The beneficial effect of spentwash on crop production was well documented (Rajukkannu and Manickam 1997, Thiyagarajan and Mahimairaja 2002). One time controlled application of diluted spentwash was found beneficial in improving the soil fertility and crop yields. Upon proper dilution (1:10 to 1:50) the primary treated spentwash could advantageously be used as a liquid fertilizer to crops, as it has reduced BOD and EC levels, they can be amenable for irrigation to crops (Zalawadia et al. 1997). In general, the spentwash contains more amount of K, mainly due to the reason that it was concentrated, evaporated and incinerated during processing that leads to accumulation of more K in comparison with other nutrients

Thus high concentration of nutrients, organic matter and salts present in spentwash may alter the chemistry of the soil. Such effect will have serious impact on various bio-chemical processes associated with soil and environmental quality. Information was scarce on nutrients and organic matter dynamics in soil under spentwash application and its environmental significance. Such details are needed for developing guidelines or strategies for effective utilization of distillery spentwash without any environmental hazards. The present study was, therefore, undertaken to study the nutrients and organic matter dynamics in soil under spentwash application and its impact on soil, crop and environmental quality.

MATERIALS AND METHODS

Characterization of Distillery Spentwash

The biomethanated distillery spentwash sample was collected from the Salem Co-operative Sugar Mills Ltd, Mohanur, Namakkal District. The sample was collected in a polycarboryl container, properly sealed and stored in a cool room at 4ºC until further analysis. This post biomethanated spentwash was subsequently used in the incubation and field experiments. The biomethanated distillery spentwash was characterized for its nutritive value and pollution load, by following standard methods (APHA 1989)

Field Experiment

A field experiment was conducted using groundnut (*Arachis hypogea* L.) as a test crop to examine the effect of spentwash on nutrient dynamics at Research and Development Cane Farm, The Salem Co-operative Sugar Mills Ltd., Mohanur, Namakkal, District in India. The experimental soil was sandy loam in texture; taxonomically the soil belongs to the family *Typic Rhodustalfs*. A representative soil sample, at 0-15 cm depth, was collected from the experimental plot to determine the initial properties of the soil. The experiment was laid out in a split plot design with two main plots and eight sub plot treatments with three replications consisting of different levels of spentwash with and without NP fertilizers were allotted to plots of 13.5 m^2 size (6 m x 2.25 m) leaving 1 m space between each replication for irrigation purpose following random principles. Treatment details of field experiment were:

Main plots: M_1 - One time application,
M_2 - Continuous split doses of application and Sub plots: T_1 - Control, T_2 - RD of NP, T_3 - Spentwash @ 40 m^3 ha^{-1}, T_4 - Spentwash @ 40 m^3 ha^{-1} + RD of NP, T_5 - Spentwash @ 80 m^3 ha^{-1}, T_6 - Spentwash @ 80 m^3 ha^{-1} + RD of NP, T_7 - Spentwash @ 120 m^3 ha^{-1}, T_8 - Spentwash @ 120 m^3 ha^{-1} + RD of NP (RD = Recommended Dose)

Different levels of spentwash was applied to the field uniformly by spraying manually to each plot 15 days before sowing for first main plot treatment (M_1). In the second main plot treatment (M_2), the spentwash was applied in three equal splits along with irrigation water. The first split dose of spentwash was applied 15 days after sowing. The crop was supplied with N and P fertilizers, as per the treatments at the recommended dose of 17 and 34 kg ha^{-1}, respectively. Only the N and P fertilizers were applied in the form of urea and single super phosphate. The K was entirely supplied through the spentwash. Sowing was done with groundnut seeds of TMV 7 by adopting a seed rate of 125 kg ha^{-1} and a spacing of 30 cm x 10 cm. All other routine cultural operations until the harvest of the crop, were followed as per the recommendations of crop production guide of Tamil Nadu Agricultural University.

Sampling and Analysis of Potassium (K) Fractions

The soil samples were collected from each experimental plot at 30, 60 and 90 DAS. The collected soil samples were air dried, powdered with a wooden mallet, sieved through 2 mm sieve and stored in polyethylene bags for various analysis.

Water soluble potassium

The water soluble potassium was determined by employing the method of Narayanan Nambiar (1972). A 10 g of soil sample was transferred to a centrifuge tube and 25 mL of distilled water was added. The tube was shaken for 10 min, centrifuged and the clear supernatant liquid was filtered and collected in a 100 mL volumetric flask. Three additional extractions were made similarly and the combined extract diluted to 100 mL with distilled water. The extract thus obtained was mixed well and K was determined using flame photometer.

Exchangeable potassium

The exchangeable potassium was determined by using the method of Pratt (1965). A 10 g of soil sample was transferred to a centrifuge tube and 25 mL of neutral normal ammonium acetate was added to the tube. The tube was shaken for 10 min, centrifuged and the clear supernatant liquid filtered and collected in a 100 mL volumetric flask. Three additional extractions were made in the same manner and the combined extract diluted to 100 mL with neutral normal ammonium acetate. The extract thus obtained was mixed well and K was determined using Flame photometer. The difference between water soluble and the ammonium acetate extractable K was computed as the exchangeable K.

Non exchangeable potassium

The normal nitric acid extractable potassium was determined by employing the method of Srinivasa Rao et al. (2000). A 2.5 g of finely ground soil sample was transferred to a 100 mL flask and 25 mL of normal nitric acid was added. The flask was then heated over a gas burner and the content was made boil gently for 10 min. The content was then cooled, diluted, filtered and the filtrate collected in a 100 mL volumetric flask. The soil residue was then washed four times with 15 mL portions of 0.1N HNO_3 and collected in the same volumetric flask, mixed thoroughly and K was determined using flame photometer. The difference between the nomal nitric acid extractable K and water soluble + exchangeable K were taken as the non - exchangeable K.

Statistical analysis

The data on various characters studied during the investigation were statistically analysed by the method given by Gomez and Gomez (1984). The critical difference was worked out at 5 percent (0.05) probability levels

RESULTS AND DISCUSSION

The chemical characteristics of the spentwash are presented in Table 1. During the field experiment, changes in the available K (NH_4OA_c-K) in soil as influenced by varied levels and methods of spentwash application are presented in Table 2. The NH_4OA_c-K ranged from 280 to 587 kg ha^{-1} initially before sowing under one time application and from 278 to 282 kg ha^{-1} under continuous application. The lowest concentration of K was in control, whereas, the highest was recorded in soil that received 120 m^3 of spentwash with N and P fertilizers. Irrespective of methods of application, the concentration was found increased significantly up to pod formation stage, but decreased at post harvest stage. Increase in the rate of spentwash application had significantly increased the NH_4OA_c-K in soil and such increase was pronounced due to N and P fertilizers application. The interaction effect of methods of application and different levels of spentwash was significant.

The available K (NH_4OAc – K) level in soil markedly increased by application of spent wash. Increase in the levels of spentwash had resulted significant increase in the availability of K in soil and the effect was more visible at higher levels of spentwash application, probably due to a high concentration (9097 mg L^{-1}) of K found in the biomethanated spentwash. When spentwash is applied, it increases the NH_4OAc – K content of soil. Irrespective of large addition of spentwash -K to the soil, a substantial decrease in the available K in soil was observed in soil amended with distillery spentwash by Valliappan (1998). This result also agreed with the findings of Murugara-gavan (2002).

Table 1. Characteristics of biomethanated distillery spentwash

Characters	Value*
Colour	Dark brown
Odour	Unpleasant burnt sugar
pH	7.1
Electrical Conductivity (dS m^{-1})	38
Total dissolved solids	50000
Total suspended solids	3300
Total solids	53300
Biological oxygen demand	12800
Chemical oxygen demand	35000
Carbon (g L^{-1})	24
Total Nitrogen	420
Total Phosphorus	40
Total Potassium	9097
Total Sodium	357
Total Calcium	4600
Total Magnesium	1752
Chloride	13471
Bicarbonates	195
Sulphate	947
Oil and grease	19.6
Total sugars (%)	3.49
Reducing sugars (%)	1.77
Total phenols	84
Total Zinc	7.20
Total Iron	78
Total Manganese	5.3
Total Copper	5.5
Bacteria (x 10^6 CFU** mL^{-1})	12
Fungi (x 10^4 CFU mL^{-1})	19
Actinomycetes (x 10^3 CFU mL^{-1})	Nil

* Mean of triplicate samples; Values are in mg L^{-1} unless otherwise stated (CPCB 2001)

** CFU- Colony Forming Units

The application of spentwash had tremendous impact on soil K dynamics. Similar to N and P different methods and levels of spentwash application significantly influenced the available K (NH_4OAc-K) in soil. Increasing the rate of application remarkably increased the K content in soil and the application of 120 m^3 of

Table 2. Effect of different levels of spentwash application on NH_4OAc-K (kg ha^{-1}) content of soil

Treatments	Stage I			Stage II			Stage III		
	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean
T_1- Control	280	281	281	225	252	239	192	198	195
T_2 - NP alone	284	282	283	241	231	236	201	206	204
T_3 - Spentwash @ 40 m^3 ha^{-1}	325	278	302	269	286	278	218	231	225
T_4- Spentwash @ 40 m^3 ha^{-1}+ NP	346	278	312	294	315	305	225	287	256
T_5- Spentwash @ 80 m^3 ha^{-1}	415	279	347	356	383	370	293	311	302
T_6- Spentwash @ 80 m^3 ha^{-1}+ NP	442	280	361	382	412	397	315	355	335
T_7- Spentwash @ 120 m^3 ha^{-1}	574	282	428	453	467	460	366	382	374
T_8- Spentwash @ 120 m^3 ha^{-1}+ NP	587	281	434	476	481	479	387	397	392
Mean	407	280	343	337	353	345	275	296	285

	SEd	CD (0.05)	SEd	CD (0.05)	SEd	CD (0.05)
T	9.85	21.12	6.79	13.91	5.58	11.43
M	5.48	11.61	2.16	4.41	1.79	3.65
T x M	14.73	31.38	8.05	16.47	6.63	13.56
M x T	15.49	32.83	6.12	12.47	5.06	10.31

M_1 - One time application; M_2 - Continuous application
Stage I - Before sowing; Stage II - Pod formation; Stage III - Post harvest

spentwash per hectare recorded the highest concentration of available K. As the spentwash had a high concentration of K (9097 mg L^{-1}), its direct input resulted in an increase in the K content initially (before sowing). During the pod formation stage significant increase in NH_4OAc-K content was observed due to spentwash application. Darmalingaiah (2011) also observed that with an increase in the concentration of distillery spentwash, there was a significant increase in available k_2O. The highest available k_2O was recorded by 1.5 N through spentwash (574.13 kg ha^{-1}) in groundnut crop. Besides leaching and uptake of K by groundnut the increase was possibly due to the release of fixed K from exchange sites or consequential solubilization of K from K-bearing mineral. Similar results were reported by and Valliappan (1998).

A substantial decrease in NH_4OAc-K in all treatments at post harvest stages was attributed to the continuous removal of K by groundnut and also due to chemical fixation of K on clay complex (exchange sites). Bertranou et al. (1987) reported that the available K was increased by 4 to 5 times due to effluent irrigation which might be due to the fact that K is the element supplied in large quantities. Rehaman et al. (2007) reported that when one cm of post methanation effluent was applied on one ha of agricultural land annually, it supplies nearly 600 kg of potassium, 360 kg of calcium, 100 kg of sulphates, 28 kg of nitrogen and 2 kg of phosphates. Similar results were also reported by Baskar et al. (2001); Kayalvizhi et al. (2001) and Selvalakshmi et al. (2001).

As K is subject to leaching, significant amount might have also leached down in the soil profile. The sandy loam characteristics of soil and the large amount of rainfall and net cumulative drainage occurred during crop growth might have facilitated the K-leaching in soil. However, greater amount of NH_4OAc-K at pod formation and harvest stages was associated with continuous application of spentwash, probably due to reduction in the leaching loss of K from soil.

The relative distribution of different forms of K in post harvest soil without (control) and with the spentwash application of 120 m^3 ha^{-1} is shown in Figure 1. The H_2O-K constitutes only 1.5 % of the total K in soil without any spentwash application. It was estimated that at a rate of 120 m^3 of spentwash addition about 1679.4 mg of K per kg soil seems to be added. However, the relative proportion of H_2O-K was remained constant with the application of spentwash (120 m^3 ha^{-1}). However, the proportion of exchangeable K was increased from 7.4 % (in control) to 11 % only due to spentwash treatment. Correspondingly, the non exchangeable K was found decreased from 91 (in control) to 87 % (in spentwash treatment). The relative proportion of exchangeable and non-exchangeable K did not differ significantly between the methods of application.

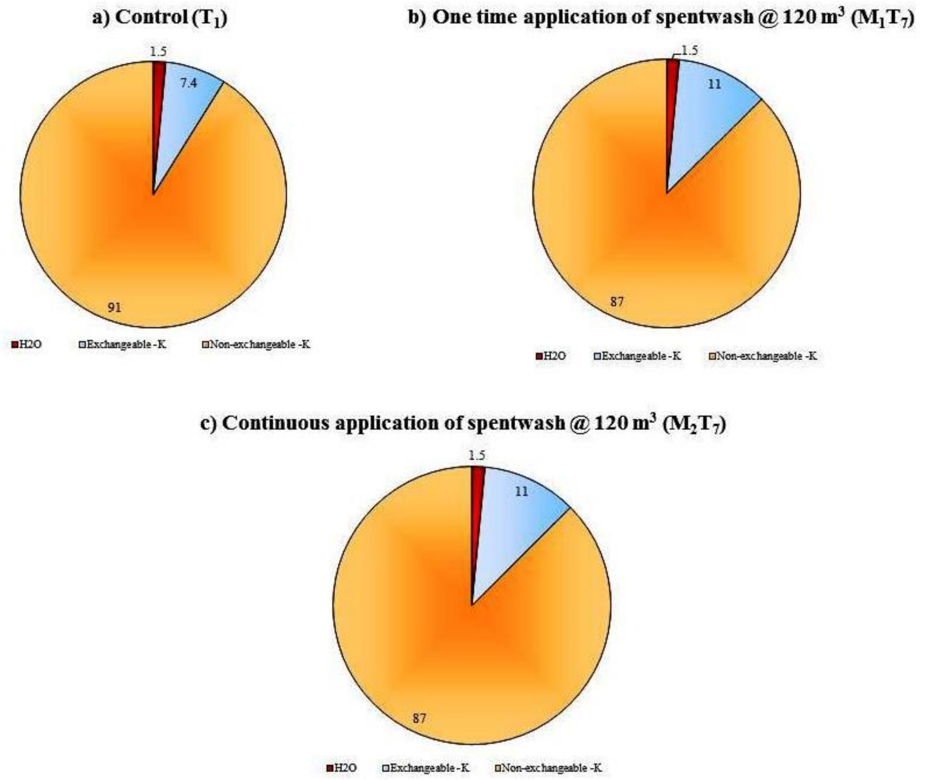

Figure 1. Forms of soil K in post harvest soil without and with application of spentwash

The K occurs in soil solution as cations, held in minerals in exchangeable or non-exchangeable forms and also as a part of mineral lattice (mineral-K). Plants absorb K ion from solution which temporarily distributes the equilibrium between solution and exchangeable forms and some of the exchangeable K moves to solution form to maintain the equilibrium. Similarly, leaching and fixation of K on minerals also affect the K equilibrium temporarily. The K in the exchangeable and solution forms constitutes the fraction readily available to plant for absorption at a given time. The exchangeable K tends to attain equilibrium with solution K rapidly, but, only slowly with non exchangeable K. The solution concentration largely controls the K movement (diffusion) towards the plant roots and thereby the K uptake by crop. As and when the exchangeable form is depleted substantially or removed (by plant uptake, leaching and fixation) the non-exchangeable form of K replenishes the exchangeable form and the supply of K to crop is maintained. It is likely that when K added through the spentwash exceeded the crop removal (uptake); it initially increases solution K and subsequently increases the K concentration in the exchangeable and non-exchangeable forms through the shifting of equilibrium. The phenomenon of both the fixation of exchangeable K and release of non-exchangeable K play an important role in the dynamics of soil potassium (Dhillon and Dhillon 1992). A previous study demonstrated the application of spent wash as calcium containing chemical amendment helped to reclaim the sodic and calcareous sodic soils, the distillery spent wash samples had acidic pH (4.11), it has high content of potassium, calcium and magnesium this cations had influenced the physical conditions of the soils and sodium buildup (Bhagya Lakshimi et al. 2019).

The results from the field experiments have clearly demonstrated that the dynamics of potassium and thus their availability in soil are markedly effected with the application of spentwash. These soil processes will have a serious impact not only on crop growth and yield, but also on environmental quality.

SUMMARY AND CONCLUSION

The application of 120 m^3 of spentwash recorded the highest concentration of NH_4OAc-K in soil. The results from the field experiments indicate that besides the direct input from the spentwash application, the large amount of K pool in soil was also due to release of fixed

K from exchange sites and/or consequential solubilization of K from K bearing minerals.

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