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Effect of value added product from sugar and distillery industry on physico-chemical and biological properties of calcareous sodic soil

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Abstract
The distillery effluents are disposed indiscriminately cause severe problems to soil and water quality. Therefore, to convert this effluents into an economic source of soil amendment as value added product (VAP) by biodigestion, reverse osmosis and evaporation process. Being a plant origin it is a rich source of essential nutrients for plant growth particularly potassium. In view of utilizing the VAP from distillery effluent as a substitute of inorganic K, a field experiment was conducted with different levels of VAP as a source of potassium along with inorganic nitrogenous and phosphatic fertilizers using Rice (TRY 3) as a test crop to study the influence of this VAP on physico-chemical and biological properties of sodic soil. The result of the study showed that reduction in soil pH and EC due to application of VAP with inorganic fertilizers. The addition of 125% STCR-K through VAP significantly favoured the availability of nutrients and organic carbon in soil, which was on par with 100% STCR-K through VAP and 75% STCR-K through VAP. The VAP with inorganic fertilizers also have positive influence on soil microbial population dynamics and enzyme activity. It has substituted 100% requirement of inorganic K fertilizers. Thus, the application of VAP will be a valuable substitute for inorganic fertilizers as well as safe option for disposal of the distillery industry waste.

Keywords: Value added product, sodic soil, effluent, physico-chemical and biological properties

Introduction
Rice is one of the major leading food crops of the world and it is one of the most important cereal crop in India occupying an area of about 43.39 million hectare with an annual production of 104.32 million tonnes and average productivity of 2404 kg ha^{-1} (Hemavathi and Prabakaran, 2018) [6]. India is the second largest producer and consumer of rice and accounts for 22.3% global production. Rice contributes 40.8% of total food grain and remains the principal source of livelihood for more than 58% of the population. In Tamil Nadu, it occupies third position in productivity and ranks first in area and production among other cereal crops (Policy Note 2015-16, Govt of TN) [12].
Sugar mills are one of the most important agro-based industries and 600 of these are doing sugar production in India. The sugar industry is contributing significant role in the Indian economy not only to the domestic sugar demand, but also in earning valuable foreign exchange through export. The sugar production in India is about 15 million tonnes achieved by crushing 150 million tonnes of cane with a recovery of 10 percent (Dharmendra *et al*., 2018) [9]. The byproducts of sugar industry are pressmud, bagasse and molasses. Molasses are used for the production of alcohol, for each litre of alcohol production 12-15 litres of spentwash is generated. The value added product was produced from the distillery spentwash by biodigestion, reverse osmosis and evaporation process. It increases the availability of nutrients and the possibility of substituting the inorganic fertilizer for crop production has a great promise. The addition of organic matter through effluent is favourable for the microorganisms and enzyme activities in soil (Vadivel *et al*., 2017) [18].
Sodic soils are characterized by a relatively high concentration of sodium in the exchange complex causing adverse effects on physical, chemical, biological properties of soil and ultimately resulted in poor plant growth. In India nearly 6.73 million hectare area is salt affected and out of that 3.77 million hectare of land is affected by sodic soil. Tamil Nadu alone has 3.5 lakh hectare of sodic soil (CSSRI, Karnal, NRSA, NBSS&LUP, 2006)
Reclamation of sodic soils are normally achieved by supplementing readily available calcium (Ca^{2+}) sources to replace the excess sodium (Na^{+}) on the exchange complex and leaching the

displaced Na^+ from the root zone through excess irrigation water with better drainage facilities (Bharath Kumar *et al*., 2017) [3]. Amelioration of these soils has been predominantly achieved through the application of chemical amendments. However increasing cost and non availability of chemical amendments, recurrent sodicity issues necessitated the identification of alternative low cost approaches to sustain the productivity of these soils. Distillery spent wash contains good amount of soluble organic matter, Ca, Mg and other essential plant nutrients especially K gaining its importance in the reclamation of sodic soil and as K source that helps in sustainable farming and increased food production.

Materials and methods

The experiment was conducted in Anbil Dharmalingam Agricultural College and Research Institute farm, Tiruchirapalli, Tamil Nadu, India. Geographically, the experimental region was located in Cauvery delta zone of Tamil Nadu at $10^0$45’ N Latitude and 78^0 36’ E Longitude at an altitude of 85 m above MSL. The experimental field was laid out in randomized block design with three replications. The rice variety TRY 3 having sodicity tolerance was used for the study. The treatments includes absolute control (T_1), 50% STCR-K through VAP (T_2), 75% STCR-K through VAP (T_3), 100% STCR-K through VAP (T_4), 125% STCR-K through VAP (T_5), 50% STCR-K through VAP + 50% STCR-K through inorganic fertilizers (T_6) and 100% STCR-K through inorganic fertilizer (T_7). The full dose of nitrogenous and phosphatic fertilizers were applied based on STCR through inorganic fertilizers as urea and SSP respectively to all the treatments except in control plot. The soil of the experimental field was sandy clay loam in texture with pH of 8.50, EC of 0.35 dS m^{-1}, CEC of 17.30 c mol (p^+) kg^{-1} and organic carbon 0.65%. It is low in available nitrogen (208 kg ha^{-1}), medium in available phosphorus (21.5 kg ha^{-1}) and potassium (215 kg ha^{-1}). The considerable population of micro-organisms (bacteria, fungi and actinomycetes) and enzyme activities (dehydrogenase and urease) were also assayed. The characteristics of VAP collected from the EID parry industry, Nellikuppam was alkaline in nature with pH of 9.49, salt content of 7.71 dS m^{-1} and organic carbon of 15.39%. It also contains total nitrogen content of 0.13%, total phosphorus of 0.09% and highest value of total potassium 11.32%.

The soil samples were collected at different stages of crop growth. The collected samples were air dried, processed and used for the chemical analysis like pH, EC, available NPK and organic carbon. The freshly collected soil from post harvest stage is used for the microbial population and enzyme analysis.

Result and discussion

Effect on soil pH

The application of VAP had numerical influence in the reduction of soil pH at different stages of crop growth (Table 1). The maximum reduction was observed in 125% STCR-K through VAP (T_5) followed by 100% STCR-K through VAP (T_4) and 75% STCR-K through VAP (T_3). This might be due to the release of organic acids during decomposition of organic matter in the effluent solubilize the native lime which released free Ca^{2+} ions into soil. The Ca ions replaces Na ions and forms soluble salts which gets leached out during leaching (Bharath Kumar *et al*., 2017) [3]. Similar results were reported by Selvamurugan *et al*. (2013) [16] where they observed reduction in soil pH due to dissolution of Ca, Al and Fe by the root exudation which in turn produces organic acids in the rhizosphere.

Table 1: Effect of VAP on soil pH at different stages of rice

Treatments	Active tillering	Panicle emergence	Post Harvest
T_1 - Absolute control	8.48	8.45	8.40
T_2 - 50% STCR-K through VAP	8.46	8.40	8.32
T_3 - 75% STCR-K through VAP	8.40	8.33	8.24
T_4 - 100% STCR-K through VAP	8.39	8.30	8.20
T_5 - 125% STCR-K through VAP	8.37	8.28	8.18
T_6 - 50% STCR-K through VAP + 50% STCR-K through inorganic fertilizers	8.42	8.36	8.27
T_7 - 100% STCR-K through inorganic fertilizers	8.45	8.38	8.29
SEd	0.13	0.18	0.14
CD (0.05)	NS	NS	NS

Effect on soil EC

The result of the present investigation (Table 2) indicated that numerical increase in soil EC at active tillering stage in all the treatments but decreased trend was observed in the progressive growth stages. This findings is in accordance with Selvamurugan *et al*. (2013) [16] who suggested that increase in soil EC at initial stages of crop growth but it is in the safer limit of 1.0 dS m^{-1} but at later stages the salt concentration was progressively decreased due to crop removal or leaching of salts from surface to subsurface layer by continuous stagnation of water for crop growth.

Table 2: Effect of VAP on soil EC (dS m^{-1}) at different stages of rice

Treatments	Active tillering	Panicle emergence	Post harvest
T_1 - Absolute control	0.36	0.35	0.34
T_2 - 50% STCR-K through VAP	0.37	0.36	0.35
T_3 - 75% STCR-K through VAP	0.37	0.36	0.35
T_4 - 100% STCR-K through VAP	0.38	0.37	0.36
T_5 - 125% STCR-K through VAP	0.38	0.37	0.36
T_6 - 50% STCR-K through VAP + 50% STCR-K through inorganic fertilizers	0.38	0.37	0.36
T_7 - 100% STCR-K through inorganic fertilizers	0.37	0.36	0.35
SEd	0.01	0.01	0.01
CD (0.05)	NS	NS	NS

Effects on available nutrients

Available nitrogen

Nitrogen is the foremost element required for plant growth. Sufficient nitrogen results in higher biomass yields. The application of distillery effluent significantly increased the available nitrogen status in soil. The highest available nitrogen was recorded in 125% STCR-K through VAP (T_5) in all stages of rice which was on par with 100% STCR-K through VAP (T_4) and (T_3) 75% STCR-K through VAP (Table 3). Though the distillery effluent had small quantity of nitrogen, its application to soil increased the available nitrogen status and it might be due to its direct contribution to N supply as well as the increased microbial activity due to added organic matter which in turn increased the release of native N source reported by Bose *et al*. (2002) [4]. The increased mineralization of nitrogen by effluent application also reflected in the increased available nitrogen status of the soil (Anandakrishnan *et al*., 2008) [1]. A marked decline in available N in the soil was observed with the advancement of crop growth which might be due to the progressive removal of nitrogen by the crop, losses due to volatilization and leaching which is in accordance with the findings of Selvamurugan *et al*. (2013) [16] and Selvakumar *et al*. (2006) [14].

Table 3: Effect of VAP on available N status (kg ha^{-1}) of soil at different stages of rice

Treatments	Active tillering	Panicle emergence	Post harvest
T_1 - Absolute control	210	201	195
T_2 - 50% STCR-K through VAP	234	220	209
T_3 - 75% STCR-K through VAP	264	254	240
T_4 - 100% STCR-K through VAP	268	259	245
T_5 - 125% STCR-K through VAP	273	265	250
T_6 - 50% STCR-K through VAP + 50% STCR-K through inorganic fertilizers	255	235	227
T_7 - 100% STCR-K through inorganic fertilizers	245	226	214
SEd	4.80	6.26	5.52
CD (0.05)	10.47	13.64	12.03

Available phosphorus

Phosphorus is an essential nutrient for all living organisms and vital component of the substances that are building blocks of genes and chromosomes. The application of VAP increased the available P status in soil (Table 4). The maximum availability was recorded in 125% STCR-K through VAP (T_5) which was on par with 100% STCR-K through VAP (T_4) and 75% STCR-K through VAP (T_3) in all stages of crop growth. The decomposition of organic matter in the effluent produce organic acids which helps to solubilize the native source of P in soil (Baskar *et al*., 2005) [2]. A steady supply of phosphorus in soil might be due to the presence of easily degradable organics in the effluent reduced the binding energy and P sorption capacity of the soil, favouring higher P availability in the soil (Sivaloganathan *et al*., 2013) [17]. A decline in the available P status was noticed with the progressive growth stages of the crop. Similar findings were reported by Selvamurugan *et al*. (2013) [16] who stated that immobilization of phosphorus into insoluble forms and microbial immobilization responsible for the decline in P status with progressive growth stages of the crop.

Table 4: Effect of VAP on available P status (kg ha^{-1}) of soil at different stages of rice

Treatments	Active tillering	Panicle emergence	Post harvest
T_1 - Absolute control	23.1	22.7	22.4
T_2 - 50% STCR-K through VAP	25.2	24.8	24.5
T_3 - 75% STCR-K through VAP	27.0	26.5	26.1
T_4 - 100% STCR-K through VAP	27.4	26.8	26.4
T_5 - 125% STCR-K through VAP	28.3	27.1	26.7
T_6 - 50% STCR-K through VAP + 50% STCR-K through inorganic fertilizers	26.2	25.8	25.2
T_7 - 100% STCR-K through inorganic fertilizers	25.6	25.1	24.9
SEd	0.64	0.43	0.30
CD (0.05)	1.40	0.93	0.66

Available potassium

Potassium has long been referred to as the ‘quality nutrient’. It plays a regulatory role in plant metabolism and development and also regulated the opening and closing of stomata. In this experiment, soil available K was increased with the increased level of VAP application but there was a decreased trend was occurred between the stages of the crop growth (Table 5). The highest available K was noted in 125% STCR-K through VAP (T_5) which was on par with 100% STCR-K through VAP (T_4) and 75% STCR-K through VAP (T_3) and the lowest value was recorded in control (T_1). The available K in soil got increased due to the effluent application which might be the fact that K was one of the components supplied in larger quantities (Sivaloganathan *et al*., 2013) [17]. The improvement in K status may be ascribed to the reduction in K fixation and release of K due to the interaction of organic matter from the effluent was reported by Raju *et al*. (2017) [10].

Table 5: Effect of VAP on available K status (kg ha^{-1}) of soil at different stages of rice

Treatments	Active tillering	Panicle emergence	Post harvest
T_1 - Absolute control	217	210	201
T_2 - 50% STCR-K through VAP	280	273	261
T_3 - 75% STCR-K through VAP	309	300	293
T_4 - 100% STCR-K through VAP	315	307	297
T_5 - 125% STCR-K through VAP	320	312	302
T_6 - 50% STCR-K through VAP + 50% STCR-K through inorganic fertilizers	293	286	280
T_7 - 100% STCR-K through inorganic fertilizers	287	280	270
SEd	5.52	5.72	5.63
CD (0.05)	12.02	12.47	12.26

Soil organic carbon

Soil organic carbon is considered as the index of soil fertility and sustainability of any agricultural system. It improves the physical and biological properties of the soil. In the present investigation, highest organic carbon percentage was registered in 125% STCR-K through VAP (T_5) which was on par with 100% STCR-K through VAP (T_4) and (T_3) 75% STCR-K through VAP (Table 6). The increase in soil organic carbon might be due to the decomposition and humification of organic matter supplied through distillery effluent (Naorem *et al*., 2017) [11]. The addition of organic matter through effluent resulted in better crop growth with concomitant increase in the root biomass could be the probable reasons for the increase in soil organic carbon. Similar result was reported by Kuligod *et al*. (2014) [8] and Anandakrishnan *et al*. (2008) [1]. A decreasing trend was observed in organic carbon status of the soil irrespective of the levels of effluent application from initial to post harvest stage. It could be due to the organic matter decomposition and carbon loss mainly as CO_2 from soil (Selvamurugan *et al*., 2013) [16].

Table 6: Effect of VAP on soil organic carbon (%) at different stages of rice

Treatments	Active tillering	Panicle emergence	Post harvest
T_1 - Absolute control	0.66	0.63	0.60
T_2 - 50% STCR-K through VAP	0.72	0.69	0.67
T_3 - 75% STCR-K through VAP	0.86	0.82	0.81
T_4 - 100% STCR-K through VAP	0.88	0.84	0.82
T_5 - 125% STCR-K through VAP	0.89	0.86	0.84
T_6 - 50% STCR-K through VAP + 50% STCR-K through inorganic fertilizers	0.74	0.71	0.69
T_7 - 100% STCR-K through inorganic fertilizers	0.70	0.67	0.62
SEd	0.02	0.02	0.02
CD (0.05)	0.04	0.04	0.04

Effects on soil biological properties

Microbial population

Microbial activity had a direct impact on the plant nutrient availability as well as other properties related to soil productivity. The population of bacteria, fungi and actinomycetes were significantly increased due to application of VAP (Fig 1). The maximum microbial population of bacteria (103.1 × 10^6 CFU g^{-1} of soil), fungi (29.8 × 10^4 CFU g^{-1} of soil) and actinomycetes (150.6 ×10^2 CFU g^{-1} of soil) was recorded in 125% STCR-K through VAP (T_5) and the lowest counts of bacteria (72.9 × 10^6 CFU g^{-1} of soil), fungi (20.0 × 10^4 CFU g^{-1} of soil) and actinomycetes (132.0 × 10^2 CFU g^{-1} of soil) were observed in absolute control (T_1). Being rich in nutrients and organic material, particularly easily oxidizable and soluble organic carbon, the effluent might have favoured the proliferation of microbial population in soil throughout the crop growth by steady supply of nutrients and buildup of organic matter. This was in line with the findings of Kalaiselvi and Mahimairaja (2011)[7].

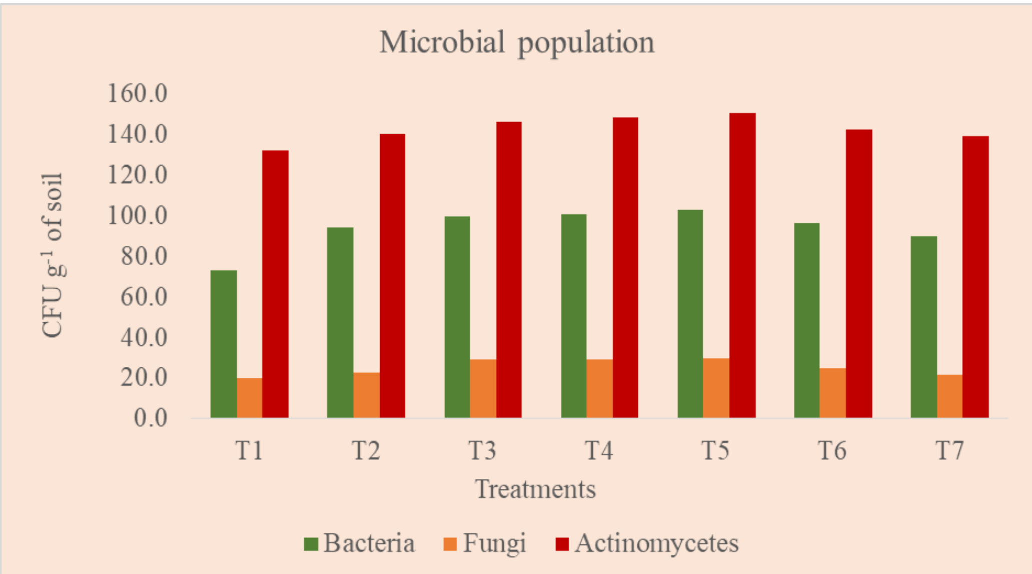

Fig 1: Effect of VAP on microbial population of post harvest soil

Soil enzyme activity

Enzyme activity in soil is an indirect indication of the microbial activity, which is directly correlated with soil microbial population (Fig 2). Dehydrogenase is considered to play an essential role in initial stages of the oxidation of soil organic matter by transferring hydrogen and electrons from substrates to acceptors (Selvamurugan *et al*., 2011) [15]. Remarkable increase in the dehydrogenase enzyme activity was observed due to the application VAP. The minimum activities of dehydrogenase was observed in control (1.19 µg TPF g^{-1} of soil hr^{-1}) and maximum with the application of 125% STCR- K through VAP (1.50 µg TPF g^{-1} of soil hr^{-1}) which was on par with 100% STCR-K through VAP (1.47 µg TPF g^{-1} of soil hr^{-1}) and 75% STCR-K through VAP (1.45 µg TPF g^{-1} of soil hr^{-1}). Ramana *et al*. (2002) [13] also reported that increase in enzyme activity due to the effluent application.

The enzyme urease was associated with N mineralization. The treatments which received 125% STCR-K through VAP (T_5) recorded highest urease activity (1.94 µg NH_4-N g^{-1} of soil hr^{-1}) which was on par with (T_4) 100% STCR-K through VAP (1.92 µg NH_4-N g^{-1} of soil hr^{-1}) and (T_3) 75% STCR-K through VAP (1.90 µg NH_4-N of soil g^{-1} hr^{-1}). These enzymes play a significant role in the bio-chemical transformation of nutrients in soil and thus influence the nutrient availability in soil and uptake by crops (Dinesh *et al*., 2000) [5].

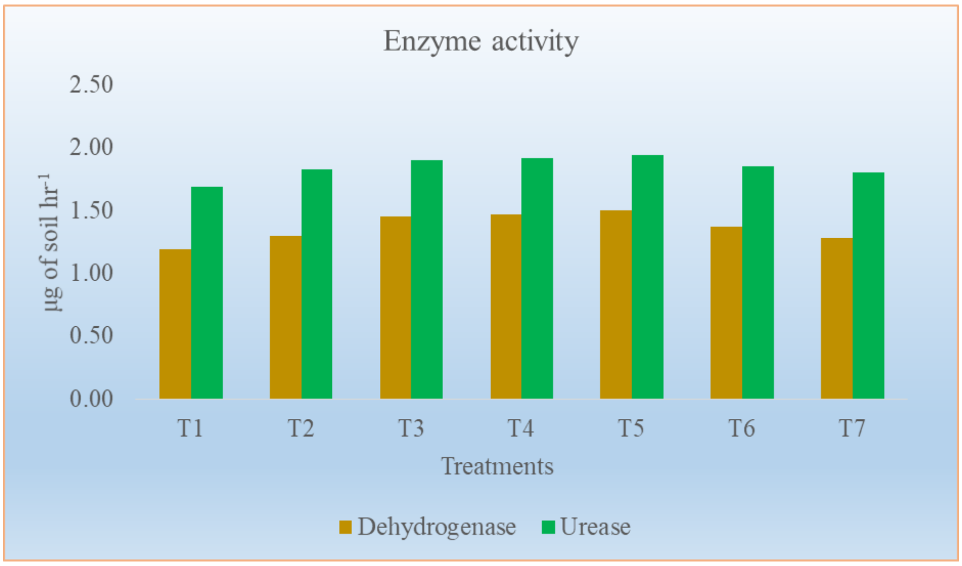

Fig 2: Effect of VAP on enzyme activities of post harvest soil

Conclusion

Based on the above results, it is concluded that application of value added product not only increased the soil available nutrients but also had positive influence on soil microbial population dynamics and enzyme activity. The application of VAP will be a valuable substitute for inorganic potash fertilizers as well as safe option for disposal of the distillery industry waste.

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