Effect of value added product from sugar industry as a potassium source on growth and yield attributes of maize (*Zea mays* L.)

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ABSTRACT

India is the major producer and consumer of sugar in the world. Molasses based distillery along with their product (alcohol) generate wastewater called as spent wash. It is acidic nature characterized by high BOD, COD value. The Value Added Product from sugar industry is generated by incineration of spent wash results in ash powder which is found to be rich in potassium. Consequently, a study was conducted to compare the effect of applying Value Added Product (VAP) as a potassic source on maize hybrid COHM(8) with that grown on Muriate of Potash (MOP) as a fertilizer source using a Randomized Complete Block Design with three replications. The treatments include absolute control (T1), 50% STCR (Soil Test Based Crop recommendation) -K through VAP (T2), 75% STCR-K through VAP (T3), 100% STCR-K through VAP (T4), 125% STCR-K through VAP (T5), 50% STCR-K through VAP + 50% STCR-K through inorganic fertilizers (T6) (MOP) and 100% STCR-K through inorganic fertilizer (MOP) (T7). The results showed that, 125 % STCR-K as VAP produced better growth and yield characteristic, it was similar with 100 percent STCR-K as VAP and followed by 75 percent STCR-K as VAP when compared to control (T_1). It is concluded that application of VAP from distillery spent wash (DSW) can be used as a substitute for inorganic potash fertilizer in maize crop cultivation to get higher yield and sustain soil health.

Keywords: ***Value added product, Distillery spent wash and Molasses, Growth and yield attribute, Maize*.**

1. INTRODUCTION

Maize (Zea mays L.) is the world's third most widely grown crop. Consumed not just to meet energy and protein requirements, but also for industrial and bio fuel production (CruzCárdenas et al., 2019). It has higher productive potential compared to any other cereal crops hence; it is called as "king of cereals" (Adiveppa *et al*., 2014). It is being cultivated in all the seasons' *viz*., *kharif, rabi* and *summer* with a production and productivity of 27.71 MT, 3.07 t ha^{-1} (FAO STAT, 2019). Maize genotypes respond to potassium application contrarily due to modification in its uptake, translocation, accumulation, growth and utilization. Potassium (K) is a macro nutrient, known to play major role in cell expansion and maintaining turgidity (Bappa mandal *et al*., 2020). It helps in osmo- regulation of plant cell, assists in opening and closing of stomata and more than 60 enzymes (Mengel and Kirkby, 1996). Potassium protects the plant from both biotic and abiotic stress like diseases, pests, drought, salinity, water logging, frost etc, (Hasanuzzaman *et al.*, 2018). India is the major producer and consumer of sugar in the world. Molasses based distillery along with their product (alcohol) generate wastewater called spent wash (Susheel kumar sindhu *et al.*, 2007). The spent wash is acidic (pH 3.94 to 4.30) and loaded with organic and inorganic salts, resulting in high EC (30 - 45 dS/m). Being plant originated, the spent wash also contains considerable amounts of plant nutrients and organic matter (Susheel kumar sindhu *et al.*, 2007). Nitrogen (N) content in spent wash ranges from 1660 to 4200 mg/l, phosphorus (P) from 225 to 3038 mg/l and potassium (K) from 9600 to 17475 mg/l. Calcium (Ca), magnesium (Mg), sulphate (SO_4) and chloride (Cl) are also present in appreciable amounts. Thus, it can effectively be used as a source of plant nutrients and as soil amendment (Santiago mahimairaja *et al*., 2014). The potassium salts generated from distillery spent wash after incineration is found to contain on an average of about 37 per cent of potash as potassium oxide (Sarika Goel *et al.*, 2015). The value added product was produced from the distillery spent wash by bio-digestion, 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 (Saranya *et al.*, 2019). Holding this in mind, this study investigate the effect of applying VAP as a potassium source from distillery spent wash on various growth and yield parameters of maize (*Zea mays* L.) crop.

2. MATERIALS AND METHODS

The maize hybrid COHM (8) having 95 days crop duration was used as a test crop. Maize COHM (8) seed was brought from Departments Of Millets in TNAU (Tamil Nadu Agricultural University), Coimbatore. The field experiment was conducted at (Agricultural College and Research Institute), Kudumiyanmalai, Pudukkottai, Tamil Nadu, India in *kharif* season (July to October), 2020. It was laid out in randomized block design with seven treatments and three replications. The crops were grown under irrigated condition and the seeds were planted by dibbling method at 60cm row spacing and 30cm spacing between plants. The treatments include absolute control (T1), 50% STCR (Soil Test Crop Response)-K through VAP (Value Added Product) (T2), 75% STCR-K through VAP (T3), 100% STCR-K through VAP (T4), 125% STCR-K through VAP (T5), 50% STCR-K through VAP + 50%

STCR-K through inorganic fertilizers (T6) and 100% STCR-K through inorganic fertilizer (MOP) (T7). The full dose of nitrogenous (urea @375 kg ha^{-1}) and phosphatic (SSP – single super phosphate@ 91 kg ha^{-1}) fertilizers were applied based on STCR through inorganic fertilizers to all the treatments except in control plot. An initial property of the experimental soil is presented in Table 1. The characteristics of VAP collected from the EID parry industry, Nellikuppam is presented in Table 2.
(STCR: Soil Test Based Crop recommendation)

Table 1: Physico-chemical properties of the experimental field

S.No.	Particulars	Values
Physical properties		
1	Bulk density (Mg m^{-3})	1.33
2	Particle density (Mg m^{-3})	2.25
3	Total porosity (%)	40
5	Soil texture	Sandy Loam
Chemical properties		
1	pH	7.81
2	EC (dS m^{-1})	0.30
3	Organic carbon (%)	0.51
4	Available Nitrogen (kg ha^{-1})	235 (low N according to fertility rating of soil)
5	Available phosphorus (kg ha^{-1})	16 (medium P according to fertility rating of soil)
6	Available potassium (kg ha^{-1})	153(low K according to fertility rating of soil)
7	Exchangeable Calcium (c mol (p^+) kg^{-1})	8.543
8	Exchangeable Magnesium (c mol (p^+) kg^{-1})	5.962
9	Exchangeable Sodium (c mol (p^+) kg^{-1})	3.921
10	Exchangeable Potassium (c mol (p^+) kg^{-1})	1.174

Table 2: Characterization of Value Added Product (VAP)

S.No.	Particulars	Values
Physical properties		
1	Bulk density (Mg m^{-3})	0.80
2	Particle density (Mg m^{-3})	1.05
3	Total porosity (%)	24
4	Moisture content (%)	9.85
Chemical properties		
1	pH	8.45
2	EC (dS m^{-1})	7.71
3	Organic carbon (%)	15.39
4	Total potassium (%)	11.32

Data collected

The growth parameters like plant height (cm) and Leaf Area Index (LAI) were recorded at different growth stages *viz*., 30 DAS, 60 DAS and 90 DAS (DAS- Days after sowing). The crop was harvested at 95 DAS. The yield and yield parameters were reported after the maize cobs in the net plots were threshed to separate the grains. Yield parameters like cob length, cob girth, cob weight, number of rows per cob, number of grains per row, number of seeds per cob, and test weight were recorded. Stover yield was recorded after sun drying the harvested plants.

Data analysis

Plant height

The plant height was measured from the base of plant to the tip of the top most opened leaf. The height of five plants was measured in centimetre and their average was taken as plant height.

Leaf area index (LAI)

From five randomly selected plants in each plot, maximum length and breadth of the fully opened third leaf from the top of the plant was measured. The total number of leaves in all the five plants was counted. The mean values were worked out for the maximum length, breadth and number of leaves $plant^{-1}$.

The leaf area index (LAI) was calculated by using the following formula as suggested by Mckee (1964)

$$LAI = \frac{L \times B \times K}{N}$$

L - Length of leaf (cm) N - Number of leaves B - Breadth of leaf (cm) K - 0.796

Yield and yield parameters

The cobs from five randomly selected plants in the net plot at the time of harvest were used and the following observations on yield parameters were recorded.

Number of grains per cob, Number of seeds per cob row & Number of rows per cob

The number of grains per cob was worked out on randomly selected cobs by counting the total number of seeds (grains) from all the observational cobs and dividing them by the number of cobs. Number of seeds per row of five randomly selected cobs was measured and the average was recorded as number of seeds per cob row. The number of rows per cob was counted and recorded for five randomly selected cobs. The average was taken as number of rows per cob**.**

Test weight

One hundred completely filled grains was collected from each treatment randomly and weighed to express in grams (g).

Grain yield & Stover yield

At physiological maturity, plants from each net plot were harvested and cobs were separated, air dried, shelled, cleaned and weighed. Grain yield per hectare was worked out and expressed in q per ha. Stover yield was recorded after complete sun drying of the stalk from each net plot and expressed in tonne per ha.

Statistical analysis

The data obtained from the above experiments were subjected to statistical scrutiny (Snedecor and Cochran, 1967) and the analysis was carried out in Agres – Agdata statistical software. The critical difference was worked out at 5 per cent (0.05) probability levels.

3. Results and Discussion

3.1 Effect of VAP application on different growth parameters of maize crop

3.1.1 Plant height (cm)

The data pertaining to plant height as influenced by VAP from distillery industry are presented in Table 3. At 30th and 60th DAS, the maximum plant height was recorded in 125% STCR-K through VAP (134.0cm and 267.3cm) which was similar to with 100% STCR-K as VAP (123.7cm and 240.4cm) followed by 75% STCR-K through VAP (118.0cm and 231.2cm). The lowest plant height (86.9cm and 147.3) was observed in control. At harvest, the plant height ranged from 180.6 to 290.6 cm. Among the treatments, the application of 125% STCR-K through VAP produced the maximum plant height of 290.6cm while, the minimum plant height was recorded in the control treatment (180.6cm).

Table3. Plant height (cm) as influenced by graded levels of VAP at various stages of maize crop

Treatments	Plant height (cm)		
	30th DAS	60th DAS	90th DAS
T_1 - Absolute control	86.9	147.3	180.6
T_2 - 50% STCR-K through VAP	107.5	200.2	230.2

T_3 - 75% STCR-K through VAP	118.0	231.2	260.5
T_4 - 100% STCR-K through VAP	127.0	240.4	270.4
T_5 - 125% STCR-K through VAP	134.0	267.3	290.6
T_6 - 50% STCR-K through VAP + 50% STCR-K through MOPkl	113.0	217.4	244.1
T_7 - 100% STCR-K through MOP	117.7	215.6	245.6
SEd	6.30	13.26	8.48
CD(P=0.05)	13.74(S)	28.89(S)	18.49(S)

Mean of three replications

DAS- Days After Sowing VAP- Value Added Product MOP- Muriate Of Potash STCR – Soil Test Crop Response

3.1.2 Leaf Area Index

LAI was significantly affected by the VAP application at 30 DAS (Table 4). Significantly higher LAI was observed at 30 DAS in 125% STCR-K through VAP (1.906) which was not differed from the 100% STCR-K through VAP (1.795) followed by 75% STCR-K through VAP (1.732). The lowest LAI at 30 DAS (0.901) was observed in control (T_1). At 60 and 90 DAS higher LAI was observed in treatment receiving 125% STCR-K through VAP (T_5) (4.133 and 5.246, respectively) on par with application of 100% STCR-K through VAP (T_4) (3.902 and 5.112, respectively) and application of 75% STCR-K through VAP (T_3) (3.867 and 4.945, respectively). Lowest LAI at 60 and 90 DAS (2.693 and 3.692, respectively) were observed in control (T_1).

Table 4. Leaf area index (LAI) as influenced by graded levels of VAP at various stages of maize crop

Treatments	Leaf Area Index		
	30th DAS	60th DAS	90th DAS
T_1 - Absolute control	0.901	2.693	3.692
T_2 - 50% STCR-K through VAP	1.466	3.590	4.537
T_3 - 75% STCR-K through VAP	1.732	3.867	4.945
T_4 - 100% STCR-K through VAP	1.795	3.902	5.112
T_5 - 125% STCR-K through VAP	1.906	4.133	5.246
T_6 - 50% STCR-K through VAP + 50% STCR-K through MOP	1.627	3.553	4.626

T_7 - 100% STCR-K through MOP	1.573	3.573	4.518
SEd	0.06	0.12	0.20
CD(P=0.05)	0.14(S)	0.27(S)	0.43(S)

Mean of three replications

DAS- Days After Sowing VAP- Value Added Product MOP- Muriate Of Potash STCR – Soil Test Crop Response

3.2 Effect of VAP application on different yield parameters and yield of maize crop

3.2.1 Cob length and Cob girth (cm)

The cob girth of maize ranged from 12.1 to 15.1 cm. However, the highest cob girth (15.1 cm) was recorded in the treatment received T_5 (125% STCR-K through VAP) which was smilar with T_4 (100% STCR-K through VAP) and T_3 (75% STCR-K through VAP) by recording the value of 14.8 and 14.5 cm respectively and lowest in Control (T_1) (12.1cm). The cob length was found to be influenced significantly by the application of graded levels of VAP. The cob length of maize ranged from 12.7 to 16.8 cm. The length of cob (16.8 cm) was found to be higher in the plots which received treatment T_5 (125% STCR-K as VAP) which was same as T_4 (100% STCR-K as VAP) and T_3 (75% STCR-K as VAP) by recording the cob length of 16.6 and 15.9 cm respectively. The minimum cob length (12.7 cm) was recorded in T_1 (control).

3.2.2 Number of grains per cob, No. of grain rows per cob and No. of grains per row

Number of grains per cob, number of grain rows per cob, and number of grains per rows showed significant difference among treatments. Number of grains per cob (467.2) was recorded in treatment received T_5 (125% STCR-K through VAP) and lowest number of grains per cob (278.2) was recorded in Control (T_1). In number of grain rows per cob, application of T_5 (125% STCR-K through VAP) recorded the highest number of grain rows per cob (15.1) and lowest number of grain rows per cob was recorded in Control (T_1) (11.9). The number of grains per row ranged from 23.2 to 30.9 and the highest number of grains per row (30.9) was recorded in treatment T_5 which received (125% STCR-K through VAP and the lowest number of grains per row (23.2) was recorded in Control (T_1).

3.2.3 Test weight and Cob weight

The weight of cob was significantly influenced by application of graded levels of VAP as well as different levels of inorganic nutrients. It was seen that the application of (125% STCR-K through VAP) exhibited higher cob weight (104.1 g) which was on par with and T_4 (100% STCR-K through VAP) and T_3 (75% STCR-K through VAP) with a value of 98.6 g and 95.8 g respectively and lower cob weight (58.3 g) recorded in Control (T_1). The data on test weight indicated that a significant difference was existed between the treatments. The treatment received (125% STCR-K through VAP) recorded the highest test weight of 26.5 g which was on par with T_4 (100% STCR-K through VAP) and T_3 (75% STCR-K through VAP) with a value of 26.1 g and 25.5 g respectively and the lowest test weight (19.5 g) in Control (T_1).

3.2.4 Grain yield and Stover yield of maize

The grain yield and stover yield of maize was found to be influenced significantly by the application of value added product (VAP) along with inorganic fertilizer (Fig.1). The maize grain yield ranged from 3011 to 6875 kg ha^{-1}. Application of (125% STCR-K through VAP) recorded the highest grain yield of 6875 kg ha^{-1} and the lowest grain yield (3011 kg ha^{-1}) in Control (T_1). The highest stover yield (8954 kg ha^{-1}) was recorded in treatment which received (125% STCR-K through VAP) (T_5) and lowest stover yield (5029 kg ha^{-1}) in Control (T_1) (Fig.1).

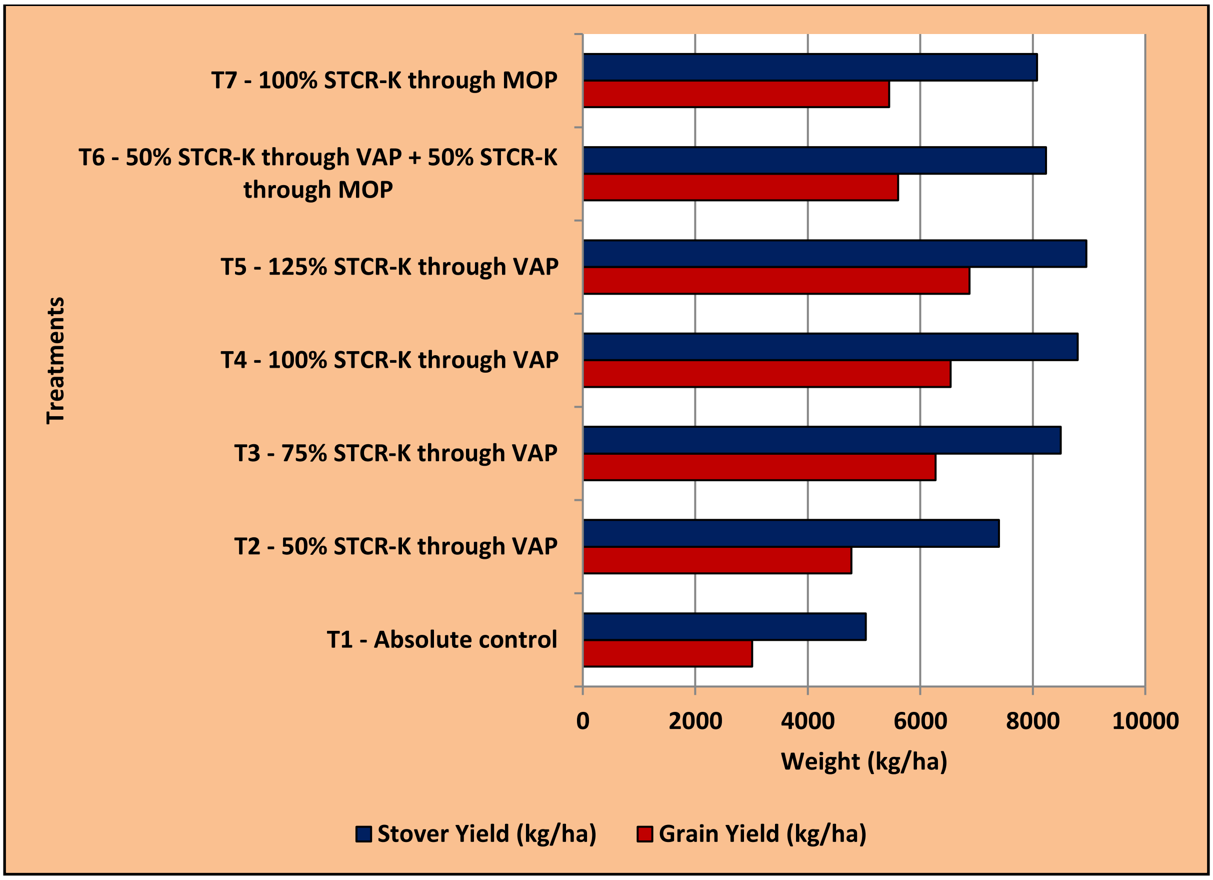

Fig 1. Grain yield and Stover yield of maize as influenced by graded levels of VAP

Table5: Influenced by graded levels of VAP on yield attributes and yield of maize crop

Treatments	Cob length (cm)	Cob girth (cm)	No. of grain rows per cob	No. of grains per row	No. of grains per cob	Test weight (g)	Cob weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1 - Absolute control	12.7	12.1	11.9	23.2	278.4	19.5	58.3	3011	5029
T_2 - 50% STCR-K through VAP	14.0	13.5	12.9	28.6	370.7	23.1	79.3	4777	7400
T_3 - 75% STCR-K through VAP	15.9	14.5	14.7	29.9	441.3	25.5	95.8	6272	8300
T_4 - 100% STCR-K through VAP	16.6	14.8	14.8	30.3	449.7	26.1	98.6	6537	8800
T_5 - 125% STCR-K through VAP	16.8	15.1	15.1	30.9	467.2	26.5	104.1	6875	8954
T_6 - 50% STCR-K through VAP + 50% STCR-K through MOP	15.6	13.9	13.9	29.7	415.2	24.3	89.1	5607	8233
T_7 - 100% STCR-K through MOP	15.3	13.8	13.8	29.3	405.6	24.1	88.6	5448	8077
SEd	0.51	0.50	0.51	1.55	13.73	1.05	3.81	194.6	273
CD (p = 0.05)	1.11(S)	1.09(S)	1.13(S)	3.37(S)	29.92(S)	2.30(S)	8.31(S)	423(S)	596(S)

Mean of three replications

DAS- Days After Sowing VAP- Value Added Product MOP- Muriate Of Potash STCR – Soil Test Crop Response

4. Discussion

4.1 Effect of VAP application on different growth parameters of maize crop

The results revealed that all the growth parameters considered were affected by the application of 125% STCR-K as VAP which was same as with 100% STCR-K as VAP followed by 75% STCR-K as VAP. The increase in plant height might be attributed to the fact that higher potassium doses promoted plant growth increased the number and length of the internodes due to more cell division and cell elongation. The improvement in vegetative growth might be due to enhanced cell division, cell wall expansion, meristematic activity, photosynthetic efficiency and regulation of water intake into cells (Raju *et al.*, 2017). Swetha (2017) and Gnanasundari (2018), who suggested that improvement in growth parameters with potassium application, might be due to delayed leaf senescence, sustained leaf photosynthesis and better vegetative growth. Kumar (2014), who suggested that potassium from spent wash play a significant role in nutrient and sugar translocation in plants and maintains turgor pressure in plant cells. Doddamani *et al*. (2014) reported that, long-term spent wash application, improved the available status of N, P, K and micronutrients as evident by soil analysis. This facilitated better growth, dry matter accumulation and chlorophyll content of maize plants under spent wash compared to fertilizer alone applied plots. These results agree with the findings of Suganya and Rajannan (2009), who also reported that the growth attributes of maize like plant height, leaf length, leaf breadth, number of leaves per plant and leaf area index were higher in distillery spent washt irrigated treatments compared to control.

4.2 Effect of VAP application on different yield parameters and yield of maize crop

Being a plant origin, the value added product is rich in OC, and contains considerable levels of N, P and rich in K which were made available to the plants by mineralization thus, resulting in better growth, development and yield of the crop. This was possible due to the sustained supply of nutrients throughout the crop growth period by mineralization as indicated by higher microbial population and enzymatic activities in VAP applied plots than the plots received only Recommended Dose of Fertilizers. The application of spent wash significantly increased cob diameter, number of rows per cob, number of seeds per cob and grain yield of maize (Doddamani *et al.*, 2011). Aslam *et al. (*2004) found that potassium increased the activity of enzymes involved in carbohydrate translocation and deposition from source to sink, resulting in heavier grains. Srinivasa (2013), who suggested that continuous filling of grains with sufficient photosynthates lead to increased size of cob and also resulted in increased cob girth. Higher cob girth was also attributed to the supply of sufficient NPK nutrients essential for constituents of plant tissues involved in cell division and cell elongation (Gul *et al*., 2015). More nutrient availability resulting in higher leaf area index resulted in higher availability of assimilates thereby resulting in improved number of rows per cob (Gul et al., 2015). Mallika, 2001 reported that, the cob length, single cob weight, 100 grain weight and grain yield increased in maize due to the application of spent wash at 150 kL ha-1. Similarly, Sridharan (2007) concluded that one time land application of post methanated distillery spent wash at 60 m^3 ha^{-1} increased the yield of rainfed maize. Nandakumar (2009) reported that, basal application of PMDSW @ 80 KL ac -1 in maize registered higher cob, grain and stover yield of 6898, 5739 and 12983 kg ha-1, respectively over control.

Adiveppa *et al*. (2014) reported that application of distillery spent wash resulted in higher grain yield and stover yield. Due to its nutritional effects, improvement in physical and chemical properties of the soil leads to higher grain. Higher stover yield was due to higher soil available nitrogen. The results indicated that treatment receiving 150% N through distillery spent wash recorded significantly higher grain and stover yield than the plots receiving recommended dose of fertilizers only.

5. Conclusion

The combined management of soil, crop, climate and use of resources was necessary to provide the favorable environment for crop growth which directly influenced the growth and yield attributes of the crop. The application of 125 percent STCR-K through VAP had a significant impact on the crop's growth and yield attributes, it was comparable to 100 percent STCR-K through VAP followed by 75 percent STCR-K through VAP. Now a day's nutrients are supplied only through inorganic fertilizers in imbalanced proportion. Continuous application of inorganic fertilizers leads to pollution problems, salinity of soil and water. So, it is concluded that application or utilization of VAP from distillery spent wash in crop production serves as a nutrient source to crop throughout its growth period, and also improves fertility status of the soil due to addition of organic matter and improve the biological properties of soil. 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.

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