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Characterization of Organic Manures and Incineration Ash for Physical and Chemical Properties to Evaluate their Efficacy on Growth and Yield of Maize (*Zea mays* L.)

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Abstract

A field experiment was conducted at Maddur taluk, Mandya to study the influence of different organic manures along with incineration ash as a source of potassium on growth and yield of maize. The characterization of manures indicated that the major, secondary and micronutrients were higher in the pressmud compost (PMC) compared to FYM. The incinerated ash (IA) was used as an alternative source of potassium fertilizer as it is having higher total K (12.34 %) content. The results revealed that application of PMC irrespective of the level of K applied through IA recorded greater influence on increasing the growth and yield of maize compared to FYM. Application of PMC + 100 per cent NP + 125 per cent K through IA recorded higher plant height (33.54, 205.1 and 222.7 cm) at 30, 60 days after sowing (DAS) and at harvest, respectively and higher number of leaves at 90 DAS in maize. However, at 90 DAS, higher plant height and higher number of leaves plant^{-1} (8.433, 15.10 and 14.49 at 30 DAS, 90 DAS and at harvest, respectively) was recorded with FYM + 100 per cent NPK (150:75:40). Significantly higher test weight (31.88 g) was recorded with the application of PMC + 100 per cent NP + 125 per cent K through IA. Similarly, significantly higher maize grain (8473, 8956 and 8715 kg ha^{-1} during 2019-20, 2020-21 and pooled mean, respectively) and stover yield (12125, 11974 and 12050 kg ha^{-1} during 2019-20, 2020-21 and pooled mean, respectively) were recorded in the treatment supplied with PMC + 100 per cent NP + 125 per cent K through IA. Therefore, application of 100 per cent NP and PMC along with 125 per cent K through IA could be a viable option in increasing maize yield in and around the areas of sugar industry.

Keywords : FYM, Pressmud compost, Incineration ash, Maize production

In India, many industries are consuming agricultural produce as raw material and generate various types of wastes in which, sugarcane industries are one of them, generating huge amount of by-products, such as bagasse, pressmud and distillery spent wash etc., which are creating the storage problem across the country. There is a growing concern among the scientific community, policy makers, industrialists and environmentalists for its safe disposal without compromising on the ecosystem. Among different by-products, distillery spent wash is one which is an unwanted residual liquid waste generated during alcohol production. The pollution caused by it is one of the most critical environmental issues where, untreated or partially treated effluent very often finds access to water courses which gives characteristic unpleasant odour posing a serious threat to the water quality. The ever-increasing generation of distillery spent wash on the one hand and stringent legislative regulations of its disposal on the other has stimulated the need for developing new technologies to process this effluent efficiently and economically.

A number of clean up technologies have been put into practice wherein, conventional method of treating this effluent is mixing with pressmud to produce biocompost or pressmud compost (PMC); by this the distillery can operate only for 270 days to meet the zero liquid discharge. Whereas, by adopting incineration technology the distillery can operate 365 days with zero liquid discharge, in addition creating waste to wealth in terms of potash rich fertilizer. Direct spent wash as well as bio-methanated effluent is concentrated in a multistage vacuum evaporator from 4 to 6 per cent to 40 to 60 per cent solids and this is dried in a rotary

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or spray dryer after mixing it with supporting fuels like rice husk or bagasse or coal to produce potash rich powder called incineration ash which may be used as a source of fertilizer (K) for crop growth (Goel). In India, potassium requirement is completely met through import from other countries due to less K bearing minerals. In addition, Indian soils are deficient in soil organic carbon content due to the low production and availability of organic manures which lead to lesser application to soil.

Intensive agriculture coupled with increasing food production caused second generation problems in respect of nutrient imbalance including greater mining of soil nutrients resulting in depletion of soil fertility. Though, chemical fertilizers are a major source of nutrients to crops, use of chemical fertilizers alone for a long period of time leaves unfavorable effects on soil physical, chemical and biological properties and environment. The better approach is to integrate chemical fertilizers and organic manures along with locally available nutrient sources to improve the soil fertility and to avoid the ill effects of wastes on soil and environment due to their improper disposal.

Therefore, an attempt was made to characterize the locally available resources in and around the sugar industry like incineration ash and pressmud compost for their nutrient composition and also to know their efficacy on growth and yield of maize (*Zea mays* L.).

Material and Methods

Characterization of PMC, FYM and IA

Incineration ash was collected from M/s. Bannari Amman Sugars Ltd., located at Alaganchi Village, Nanjangud Taluk, Mysore District. The pressmud compost (PMC) was collected from Shri Chamundeswari Sugars Ltd., Bharathi Nagar, Maddur taluk, Mandya District.

The bulk density and maximum water holding capacity of the samples were determined by Keen Raczkowski cup method (Piper, 1966). The samples were analyzed for pH, electrical conductivity and total organic carbon by following potentiometric method (Jackson, 1973), conductometric method (Jackson, 1973) and Walkley and Black titration method (Walkley and Black, 1934), respectively. The FYM, PMC and IA were subjected to digestion and analyzed for total major, secondary and micronutrients and also heavy metals. Total N concentration was determined using Kjeldahl digestion and distillation method (Piper, 1966) after digesting the samples with concentrated H_2SO_4 using digestion mixture. The samples were subjected to diacid digestion for estimation of nutrients except N. The total P (Colorimentry using vanadomolybdate reagent), K and Na (Flame Photometry method), Ca and Mg (Versenate titration method), S (Turbidometric method) were analyzed using standard procedure as given by Piper (1966). Micronutrients and heavy metals were determined using Atomic Absorption Spectrophotometry (Lindsay and Norvell, 1978) and B by Colorimetry using Azomethane-H reagent as given by Page *et al.* (1982).

Field Experiment

The field experiment was conducted at Shri Chamundeswari Sugars Ltd. in *kharif* season during 2019 and 2020 with ten treatments in randomized complete block design replicated thrice. The incineration ash, pressmud compost and FYM were applied fifteen days before sowing of maize as per the treatments. The recommended dose of fertilizers (150:75:40 N, P_2O_5, K_2O kg ha^{-1})) was applied at the time of sowing. The sowing of maize seeds was done by dibbling method with a spacing of 60 cm between the rows and 30 cm between the plants. The growth parameters like plant height (cm) and number of leaves were recorded at 30, 60, 90 days after sowing (DAS) and at harvest. The yield and yield parameters were recorded after harvest of the crop. Both grain and straw yield was recorded when the moisture content reached below 14 per cent. The harvest index was calculated by using the formula as given by Donald (1962).

$$\text{Harvest Index} = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Total biological yield (kg ha}^{-1})}$$

Treatment details

T_1 : Absolute control

T_2 : FYM + 100% NPK (POP)

T_3 : FYM + 100% NP + 50% K through inorganic + 50% K through IA

T_4 : FYM + 100% NP + 25% K through inorganic + 75% K through IA

T_5 : FYM + 100% NP + 100% K through IA

T_6 : FYM + 100% NP + 125% K through IA

T_7 : PMC + 100% NP + 50% K through inorganic + 50% K through IA

T_8 : PMC + 100% NP + 25% K through inorganic + 75% K through IA

T_9 : PMC + 100% NP + 100% K through IA

T_{10} : PMC + 100% NP + 125% K through IA

Note : FYM: Farmyard Manure; PMC : Pressmud compost; IA: Incineration ash

Results and Discussion

Characterization of Organic Manures and Incineration Ash

The physical and chemical properties of FYM, pressmud compost (PMC) and IA used in the field experiment are presented in Table 1.

Table 1
Physical and chemical properties of FYM, PMC and incineration ash

Particulars	FYM	PMC	IA
BD (Mg m^{-3})	1.19	1.06	0.79
MWHC (%)	42.86	64.42	86.76
pH (1:10)	8.26	8.52	11.00
EC (dS m^{-1}) (1:10)	0.66	1.36	27.29
Organic carbon (%)	6.83	11.33	0.98
Total N (%)	0.98	1.54	0.79
Total P (%)	0.41	1.71	0.34
Total K (%)	0.94	1.07	12.34
Total Na (%)	0.28	0.22	1.86
Total Ca (%)	0.71	2.84	2.36
Total Mg (%)	0.22	1.56	3.24
Total S (%)	0.38	1.93	3.24
Total Fe (%)	0.40	0.42	0.63
Total Mn (mg kg^{-1})	179.6	467.3	178.3
Total Cu (mg kg^{-1})	61.68	105.4	58.81
Total Zn (mg kg^{-1})	151.7	137.0	59.82
Total B (mg kg^{-1})	49.92	81.12	296.4
Total Ni (mg kg^{-1})	181.4	334.2	189.7
Total Cr (mg kg^{-1})	233.4	281.8	140.7
Total Pb (mg kg^{-1})	35.20	46.00	70.20
Total Cd (mg kg^{-1})	ND	ND	ND
Texture	-	-	Silt Loam
CO3 (meq L^{-1})	-	-	670.0
HCO3 (meq L^{-1})	-	-	701.5

Note : FYM-Farmyard manure; PMC-Pressmud compost; IA-Incineration ash; ND- Not detected

Physical Parameters

The organic manures used in the field experiment like FYM, PMC and IA were subjected to analysis of physical parameters like bulk density (BD) and maximum water holding capacity (MWHC).

Bulk Density (BD)

Among PMC, FYM and incineration ash, the bulk density was lower in incineration ash (0.79 Mg m^{-3}) compared to PMC (1.06 Mg m^{-3}) and FYM (1.19 Mg m^{-3}). The finer particles of incineration ash resulted in higher volume coupled with lower mass which showed lower bulk density compared to other manures. Organic manures like FYM and PMC contained a very small portion of the solids; thereby their BD is lower than soil. The lower values of BD can be attributed to porous nature (higher number of micropores) of manure, higher organic matter content, smaller particle size due to well decomposition together with higher surface area in PMC and IA compared to FYM.

Maximum Water Holding Capacity (MWHC)

The maximum water holding capacity was higher in IA (86.76%) followed by PMC(64.42%) due to more of fine particles like silt and clay-sized particles, as they have a larger surface area and lesser free space between the particles that allows the soil to hold

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a larger quantity of water. In addition due to its lower mass together constitutes higher MWHC compared to organic manures.

However, among the organic manures, PMC (64.42%) recorded higher MWHC compared to FYM (42.86%) because of the smaller particle size together with higher surface area due to higher organic carbon content and greater number of micropores which could retain more water. It could be observed that the bulk density of compost decreases with increasing the total organic matter content.

Physico-Chemical Parameters

pH

The pH of the FYM and PMC was slightly alkaline with pH of 8.26 and 8.52, respectively. The addition of spentwash to pressmud during composting process caused the increase in basic cations in it thereby the pH was comparatively higher for PMC over FYM. The alkaline pH of PMC was also reported by Kumar and Chopra (2016). The IA recorded very high pH to an extent of 11.00. The IA contains carbonates (670.0 meq L^{-1}) and bicarbonates (701.5 meq L^{-1}) with basic cations like Na (1.86%), Ca (2.36%), Mg (3.24%) and K (12.34%), which upon hydrolysis release s hydroxyl ion which caused the higher pH.

Electrical Conductivity

The electrical conductivity (EC) of the PMC (1.36 dS m^{-1}) was higher than FYM (0.66 dS m^{-1}). The higher EC is associated with the higher quantities of basic cations in PMC compared to FYM. The higher electrical conductivity of IA (27.29 dS m^{-1} with 1:100 IA:water ratio) was associated with the presence of sulphate salts of Ca, Mg, K and Na, as the ash was high in sodium (1.86%) and sulphur (3.24%) content. Chidankumar *et al.* (2010) characterized the primary treated spentwash collected from the sugar factory which has the EC of 28.8 dS m^{-1}, as the IA was produced from the combustion of spentwash, in a similar way which also recorded the higher EC. Similar results were also reported by Thangavel *et al.* (2013) and Latha *et al.* (2012).

Total Organic Carbon

The total organic carbon content of FYM and PMC was 6.83 and 11.33 per cent, respectively. The higher total organic carbon content of the PMC might be due to the well decomposition of pressmud due to the addition of spentwash during composting process. The organic carbon content of IA was 0.98 per cent which might be due to the combustion of spentwash at higher temperature resulted in conversion of organic forms of carbon into gaseous constituents (CO_2) and presence of some amount of carbon as inorganic forms in the form of carbonates and bicarbonates.

Chemical Properties

The total nitrogen, phosphorus and potassium contents in FYM and PMC were 0.98 and 1.54, 0.41 and 1.71 and 0.94 and 1.07 per cent, respectively. They also contained sodium (0.28 and 0.22, respectively), calcium (0.71 and 2.84, respectively), magnesium (0.22 and 1.56, respectively) and sulphur (0.38 and 1.93, respectively) in FYM and PMC, respectively. The micronutrient contents *viz.,* iron, manganese, copper, zinc and boron were 0.40 and 0.42 per cent, 179.6 and 467.3 mg kg^{-1}, 61.68 and 105.4 mg kg^{-1}, 151.7 and 137.0 mg kg^{-1} and 49.92 and 81.12 mg kg^{-1}, respectively in FYM and PMC.

The PMC showed comparatively higher major, secondary and micronutrients compared to IA ad FYM due to the well decomposition of pressmud due to the addition of spentwash during composting process which hasten the decomposition process.

The total nitrogen, phosphorus and potassium contents in IA were 0.79, 0.34 and 12.34 per cent, respectively. The lower nitrogen content in the incineration ash was due to the conversion of organic forms of nitrogen into gaseous constituents (NO_x). The lower phosphorus content in the spentwash might cause the lesser total phosphorus (0.34%) concentration in IA. The total potassium content of IA was 12.34 per cent indicating that IA

is rich source of potassium and can be used as an alternate source of potassic fertilizer. Spentwash analyzed by Wagh and Nemade (2015) recorded the potassium to an extent of 14300 ppm ~ 14.3 per cent, which may be due to higher total potassium content in IA. The IA also contained appreciable quantities of secondary nutrients like total calcium (2.36%), magnesium (3.24%) and sulphur (3.24 %) and micronutrients like iron (0.63%), manganese (178.3 mg kg^{-1}), copper (58.81 mg kg^{-1}), zinc (59.82 mg kg^{-1}) and boron (296.4 mg kg^{-1}). The crude spentwash analyzed by Jain and Srivastava (2012) observed higher concentration of iron (Fe) compared to other micronutrients which might cause the higher levels of Fe in IA.

Heavy Metals

Total nickel (Ni), chromium (Cr) and lead (Pb) contents in FYM were in the order of Cr (233.4 mg kg^{-1}) > Ni (181.4 mg kg^{-1}) > Pb (35.20 mg kg^{-1}). In comparison with FYM, PMC recorded higher heavy metal concentration to an extent of 334.2, 281.8 and 46.00 mg kg^{-1}, Ni, Cr and Pb, respectively. The higher OC content of sugarcane pressmud supports higher contents of heavy metals as stated by Kumar and Chopra (2016). The IA recorded heavy metals like nickel (Ni), chromium (Cr) and lead (Pb) in the order of Ni (189.7 mg kg^{-1}) > Cr (140.7 mg kg^{-1}) > Pb (70.20 mg kg^{-1}). The cadmium (Cd) was not detected in the IA which might be due to the very low concentration of Cd in the spentwash as characterized by Chidankumar *et al.* (2010); Wagh and Nemade (2015).

Effect of different Sources of Manures and Levels of Potassium through Incineration Ash on Growth and Yield of Maize

The growth and yield of crop mainly depends upon the synthesis and accumulation of photosynthates and their distribution to different parts of the plant. The extent of translocation of photosynthates into sink (grain) and also on plant growth and development takes place during early stage of crop growth. The production and translocation of synthesized photosynthates depends on mineral nutrition supplied by soil. Most of photosynthetic pathways are dependent on activity of enzymes and coenzymes which are synthesized from mineral elements such as major, secondary and micronutrients.

Growth Parameters

The data pertaining to plant height of maize as influenced by different sources of manures and levels of potassium through Incineration Ash at different growth stages are presented in Table 2.

Plant Height (cm)

Among the different treatments applied with different levels of potassium through Incineration Ash, the pooled data of two years (2019-20 & 2020-21) indicated that irrespective of levels of K applied, statistically no significant difference was observed in maize plant height at 30 DAS except control which recorded lower plant height of 23.89 cm. However, numerically higher plant height of 33.54 cm was recorded in the treatment received PMC + 100 per cent NP + 125 per cent K through IA. At 60 DAS in both the season plant height was found to be non significant including control. But the pooled data at 60 DAS indicated that the control treatment recorded statistically lower plant height of 175.5 cm.

At 90 DAS, significantly higher plant height (236.8 cm) was recorded in the treatment applied with FYM along with 100 per cent NPK (POP). In the first season (2019-20), the same treatment was found on par with all other treatments except control (198.0 cm) and the treatment which received FYM + 100 per cent NP + 50 per cent K through inorganic + 50 per cent K through IA (213.5 cm). But in the second season (2020-21) it was on par with treatments T_{10} (234.4 cm), T_9 (232.8 cm) and T_8 (229.2 cm) which received PMC + 100 per cent NP + 125 per cent K through IA, PMC + 100 per cent NP + 100 per cent K through IA and PMC + 100 per cent NP + 25 per cent K through inorganic + 75 per cent K through IA, respectively.

During the time of harvest, in the first season (2019-20), significantly higher plant height (222.4 cm) was recorded in treatment applied with

TABLE 2

Effect of different sources of manures and levels of potassium through incineration ash on plant height of maize crop at different intervals

Treatments	Plant height (cm)											
	At 30 DAS			At 60 DAS			At 90 DAS			At harvest		
	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean
T_1	21.30	26.47	23.89	171.3	179.7	175.5	198.0	196.2	197.1	193.7	191.6	192.7
T_2	27.44	36.47	31.96	197.7	207.8	202.7	235.5	238.1	236.8	222.4	222.3	222.4
T_3	26.77	31.23	29.00	189.9	204.3	197.1	213.5	216.2	214.9	206.1	211.8	209.0
T_4	26.53	29.47	28.00	190.1	199.1	194.6	217.8	224.2	221.0	215.3	217.2	216.3
T_5	26.33	34.07	30.20	192.7	198.5	195.6	219.1	220.9	220.0	217.3	218.8	218.1
T_6	25.99	35.31	30.65	198.2	202.1	200.1	217.3	225.4	221.4	207.0	219.1	213.0
T_7	26.11	28.13	27.12	193.0	194.5	193.7	216.4	221.6	219.0	212.3	215.9	214.1
T_8	23.81	30.60	27.21	195.1	195.7	195.4	218.0	229.2	223.6	213.3	219.9	216.6
T_9	26.65	35.41	31.03	196.0	198.7	197.4	216.5	232.8	224.7	213.7	225.4	219.6
T_{10}	28.70	38.38	33.54	202.5	207.7	205.1	225.9	234.4	230.2	219.2	226.1	222.7
SEm±	2.458	3.683	2.308	7.068	13.76	6.759	7.198	3.527	3.491	5.713	4.856	3.821
CD @ 5%	7.304	10.94	6.859	NS	NS	20.08	21.39	10.48	10.37	16.98	14.43	11.35

Treatments Details

T_1 - Absolute control

T_2 - FYM + 100% NPK (POP)

T_3 - FYM + 100% NP + 50% K through inorganic + 50% K through IA

T_4 - FYM + 100% NP + 25% K through inorganic + 75% K through IA

T_5 - FYM + 100% NP + 100% K through IA

T_6 - FYM + 100% NP + 125% K through IA

T_7 - PMC + 100% NP + 50% K through inorganic + 50% K through IA

T_8 - PMC + 100% NP + 25% K through inorganic + 75% K through IA

T_9 - PMC + 100% NP + 100% K through IA

T_{10} - PMC + 100% NP + 125% K through IA

Note: FYM: Farmyard Manure (10 t ha^{-1}) PMC: Pressmud Compost (2.5 t ha^{-1}) IA: Incineration Ash

FYM along with 100 per cent NPK (POP) which was on par with all other treatments except control which recorded significantly lower plant height of 193.7 cm. In the second season (2020-21) significantly higher plant height of 226.1 cm was recorded in the treatment receiving PMC + 100 per cent NP + 125 per cent K through IA which is statistically on par with all other treatments except control (191.6 cm). The pooled data at harvest recorded significantly higher plant height of 222.7 cm in PMC + 100 per cent NP + 125 per cent K through IA treatments which is on par with all other treatments except control (192.7 cm) and the treatment applied with FYM + 100 per cent NP + 50 per cent K through inorganic + 50 per cent K through IA (209.0 cm).

Number of Leaves Per Plant

Data pertaining to influence of different sources of manures and levels of potassium on number of leaves in maize is presented in Table 3. Different sources and levels of potassium application through Incineration Ash on number of leaves at 30 DAS found to be non significant ($P<0.05$). However, pooled data represents that numerically higher value (8.433) with the application of FYM + 100 per cent NPK (POP) and lower value (7.733) was noticed in control treatment.

Significantly higher number of leaves (13.16) during 2019-20 and 2020-21were recorded in the treatment applied with PMC + 100 per cent NP + 125 per cent K through IA and it was on par with all other treatments except control, T3 (FYM + 100% NP + 50% K through inorganic + 50% K through IA) and T5 (FYM + 100% NP + 100% K through IA). But, during 2020-21 treatment effect was found to be non significant with respect to number of leaves in all the treatments except control (11.03), whereas numerically higher number of leaves were recorded with the application of PMC + 100 per cent NP + 125 per cent K through IA (13.33). Significantly higher number of leaves (14.87 &15.10 during 2019-20 and pooled mean, respectively) were recorded with the application of FYM + 100 per cent NPK (POP) at 90 DAS.

However, in the second season (2020-21) the treatment effect for the number of leaves was found to be non significant except control which recorded significantly lower value of 13.60. In a similar way at harvest significantly higher number of leaves with a value of 14.49 (pooled mean) was recorded in the treatment applied with FYM + 100 per cent NPK (POP) and was on par with all the other treatments except control (13.00) and the treatment with FYM + 100 per cent NP + 50 per cent K through inorganic + 50 per cent K through IA (13.53).

Increase in growth parameters with increased level of K applied through IA might be due to increased physiological processes by better utilization of applied NPK fertilizers by maize leading to higher plant growth (Arun Kumar *et al*., 2007).

Effect of different Sources of Manures and Levels of Potassium through Incineration Ash on Yield Parameters and Yield of Maize

Test Weight : Irrespective of different sources of manures and levels of K applied, significant difference in test weight was recorded (Table 4). Significantly higher test weight of 31.85 and 31.91 g was recorded with PMC + 100 per cent NP + 125 per cent K through IA (T_{10}) and was on par with the treatments T_9 (29.77 & 29.95 g), T_8 (29.31 & 29.34 g), T_2 (28.19 & 29.46 g) and T_7 (28.12 & 28.79 g) which received PMC + 100 per cent NP + 100 per cent K through IA, PMC + 100 per cent NP + 25 per cent K through inorganic + 75 per cent K through IA, FYM + 100 per cent NPK (POP) and PMC + 100 per cent NP + 50 per cent K through inorganic + 50 per cent K through IA, respectively in first (2019-20) and second season (2020-21). By this, we can clearly state that the test weight has greater role in increase in grain yield where significantly higher test weight was noticed with the treatments receiving PMC as a source of organic manure irrespective of the levels of K applied through IA.

Among the FYM treated plots only FYM + 100 per cent NPK (POP) recorded on par test weight with PMC treated plots and all other treatments treated with FYM along with varied levels of K

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TABLE 3

Effect of different sources of manures and levels of potassium through incineration ash on number of leaves of maize crop at different intervals

Treatments	Number of leaves											
	At 30 DAS			At 60 DAS			At 90 DAS			At harvest		
	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean
T_1	7.933	7.533	7.733	11.20	11.03	11.12	13.13	13.60	13.36	13.00	13.01	13.00
T_2	8.533	8.333	8.433	12.97	13.30	13.13	14.87	15.33	15.10	14.32	14.67	14.49
T_3	7.800	7.867	7.833	11.80	12.93	12.37	13.67	14.47	14.07	13.23	13.84	13.53
T_4	8.067	8.000	8.033	12.53	13.23	12.88	13.77	14.73	14.25	13.75	14.29	14.02
T_5	8.267	8.200	8.233	11.87	13.20	12.53	13.63	14.53	14.08	13.61	13.91	13.76
T_6	8.267	8.000	8.133	12.27	13.30	12.78	14.40	15.13	14.77	13.84	14.54	14.19
T_7	7.900	8.067	7.983	12.80	12.80	12.80	13.90	14.33	14.12	13.65	14.28	13.96
T_8	8.400	8.067	8.233	13.00	13.32	13.16	14.17	14.93	14.55	13.90	13.91	13.90
T_9	8.467	8.067	8.267	13.00	13.07	13.03	14.43	15.00	14.72	13.92	14.10	14.01
T_{10}	8.533	8.267	8.400	13.00	13.33	13.16	14.63	15.20	14.92	14.10	14.35	14.22
S. Em±	0.366	0.306	0.247	0.308	0.195	0.173	0.283	0.346	0.219	0.272	0.330	0.185
CD @ 5%	NS	NS	NS	0.915	0.581	0.514	0.840	1.029	0.651	0.807	0.981	0.548

Treatments Details

T_1 - Absolute control

T_2 - FYM + 100% NPK (POP)

T_3 - FYM + 100% NP + 50% K through inorganic + 50% K through IA

T_4 - FYM + 100% NP + 25% K through inorganic + 75% K through IA

T_5 - FYM + 100% NP + 100% K through IA

T_6 - FYM + 100% NP + 125% K through IA

T_7 - PMC + 100% NP + 50% K through inorganic + 50% K through IA

T_8 - PMC + 100% NP + 25% K through inorganic + 75% K through IA

T_9 - PMC + 100% NP + 100% K through IA

T_{10} - PMC + 100% NP + 125% K through IA

Note: FYM: Farmyard Manure (10 t ha-1) PMC: Pressmud Compost (2.5 t ha-1) IA: Incineration Ash

TABLE 4

Effect of different sources of manures and levels of potassium through incineration ash on test weight, harvest index and yield of maize crop

Treatments	Number of leaves											
	Test weight (g)			Harvest index (HI)			Grain yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean	2019-20	2020-21	Pooled mean
T_1	26.44	25.31	25.88	0.412	0.390	0.401	6277	5709	5993	8924	8910	8917
T_2	28.19	29.46	28.83	0.409	0.427	0.418	7882	8112	7997	10862	11343	11102
T_3	26.50	26.35	26.43	0.392	0.417	0.405	6901	7190	7046	10054	10677	10365
T_4	26.84	27.15	27.00	0.407	0.422	0.414	7484	7605	7531	10475	11015	10745
T_5	26.45	26.92	26.69	0.390	0.421	0.406	7018	7578	7312	10429	10966	10697
T_6	26.99	26.99	26.99	0.397	0.425	0.411	7499	7933	7716	10718	11340	11029
T_7	28.12	28.79	28.46	0.409	0.443	0.426	7548	8187	7867	10269	10986	10627
T_8	29.31	29.34	29.33	0.409	0.423	0.416	8199	8257	8228	11204	11763	11484
T_9	29.77	29.95	29.86	0.414	0.426	0.420	8418	8649	8533	11632	11925	11779
T_{10}	31.85	31.91	31.88	0.413	0.424	0.418	8473	8956	8715	12125	11974	12050
SEm±	1.399	1.179	1.017	0.014	0.016	0.009	348.2	401.4	300.1	453.3	399.9	282.7
CD @ 5%	4.156	3.502	3.022	NS	NS	NS	1034.4	1192.7	891.7	1347.0	1188.3	840.0

Treatments Details

T_1 - Absolute control

T_2 - FYM + 100% NPK (POP)

T_3 - FYM + 100% NP + 50% K through inorganic + 50% K through IA

T_4 - FYM + 100% NP + 25% K through inorganic + 75% K through IA

T_5 - FYM + 100% NP + 100% K through IA

T_6 - FYM + 100% NP + 125% K through IA

T_7 - PMC + 100% NP + 50% K through inorganic + 50% K through IA

T_8 - PMC + 100% NP + 25% K through inorganic + 75% K through IA

T_9 - PMC + 100% NP + 100% K through IA

T_{10} - PMC + 100% NP + 125% K through IA

Note: FYM: Farmyard Manure (10 t ha^{-1}) PMC: Pressmud Compost (2.5 t ha^{-1}) A: Incineration Ash

using IA recorded lower test weight which is also confirmed with lower yield in the respective treatments. In case of pooled data the statistically on par test weight was only with the T_8, T_9 and T_{10} treatments which clearly indicated that even in PMC treated plots lower level of K (50%) through IA and also FYM + 100 per cent NPK (POP) treated plots could not able to maintain the similar test weight compared to 75,100 and 125 per cent K through IA.

Moreover, presence of comparatively higher amounts of major, secondary and micronutrients in PMC might have contributed in increasing the yield parameters of maize compared to FYM applied treatments irrespective of the levels of K applied through IA. In addition as potassium mainly helped in translocation of photosynthates to the sink (grain) it increased the yield in maize when it was applied at higher levels. Bhagya lakshmi *et al*. (2010) reported that sulphur fertilization in sandy clay loam increased the yield parameters of maize like cob length and test weight. Similar results were also reported by Sakal *et al*. (2001) and Dwivedi *et al*. (2002) who reported that yield parameters of maize increased with increase in levels of sulphur application.

Harvest Index

The data regarding the harvest index (Table 4) was found to be statistically non significant in both the seasons as well as in the pooled data, however numerically higher value of 0.426 was recorded in the treatment with PMC + 100 per cent NP + 50 per cent K through inorganic + 50 per cent K through IA (T_7). However, it can be noticed that the higher harvest index in the second season compared to first season indicating the residual effect of sources of organic manures as well as potassium source might resulted in higher harvest index.

Grain and Stover Yield

Increase in yield parameters with increase in levels of K applied through IA was more when PMC is used in combination as a source of organic manure in comparison with FYM as depicted in Table 4.

Grain Yield

The variability in grain yield was observed in the first season (2019-20), second season (2020-21) and pooled data. In the first season, significantly higher grain yield of 8473 kg ha^{-1} was recorded with the application of PMC + 100 per cent NP + 125 per cent K through IA (T_{10}). However, it was on par with all other treatments except T_5 (7018 kg ha^{-1}), T_3 (6901 kg ha^{-1}) and T_1 (6277 kg ha^{-1}) which received FYM + 100 per cent NP + 100 per cent K through IA, FYM + 100 per cent NP + 50 per cent K through inorganic + 50 per cent K through IA and control treatment, respectively. But in the second season this irregularity gets somewhat clear where significantly higher yield was recorded in the same way in T_{10} (8956 kg ha^{-1}) treatment and was on par with all other treatments except T_1 (5709 kg ha^{-1}), T_3 (7190 kg ha^{-1}), T_4 (7605 kg ha^{-1}) and T_5 (7578 kg ha^{-1}) which received control, FYM + 100 per cent NP + 50 per cent K through inorganic + 50 per cent K through IA, FYM + 100 per cent NP + 25 per cent K through inorganic + 75 per cent K through IA and FYM + 100 per cent NP + 100 per cent K through IA, respectively. Here it can be clearly seen that all the PMC treated plots were statistically on par with each other. These treatments were also on par with the higher level of K applied through IA along with FYM and 100 per cent N and P and also the package of practice treatment indicating the effect of levels of K as well as chemical fertilizers also play a greater role in increasing the yield.

In pooled data, all the treatments receiving PMC as a source of organic manure irrespective of the levels of K applied through IA were statistically on par with each other, stating that PMC plays a greater role in increasing grain yield over FYM treated plots when these were applied along with IA. Though package of practice treated plot was also statistically on par this PMC treated plots, numerically it recorded lower yield whereas, control treatment recorded very low yield in comparison with all other treatments.

Stover Yield

Similar to grain yield, in the first season (2019-20) significantly higher stover yield was recorded in the treatment T_{10} applied with higher level of K through IA along with recommended dose of N and P with PMC as a source of organic manure to an extent of 12125 kg ha^{-1} and was on par with the T_9 (11632 kg ha^{-1}), T_8 (11204 kg ha^{-1}) and T_2 (10862 kg ha^{-1}) which were applied with PMC + 100 per cent NP + 100 per cent K through IA, PMC + 100 per cent NP + 25 per cent K through inorganic + 75 per cent K through IA and FYM + 100 per cent NPK (POP). From this, it can be opined that irrespective of the levels of K applied through IA, PMC treated plots were able to maintain significantly higher yield compared to FYM treated plots except FYM + 100 per cent NPK (POP).

During 2020-21, this variability gets reduced wherein all the treatments were statistically on par with each other except control and FYM + 100 per cent NP + 50 per cent K through inorganic + 50 per cent K through IA (T_3) by recording a lower stover yield of 8910 and 10677 kg ha^{-1}, respectively.

In the pooled mean, the variation in stover yield was similar to that of first season, but in this even the FYM + 100 per cent NPK (POP) treatment could not able to maintain the higher yield similar to that of PMC treated plots indicating the efficiency of PMC over FYM as a source of organic manure. In addition, increased yield in the second season was observed compared to the first season irrespective of the sources of organic manures and levels of K applied through IA except control and the one which received PMC with higher level of K applied treatment (T_{10}). From these results we can clearly conclude that PMC can be substituted well for the FYM in and around the areas of sugar industry that too with only 2.5 t ha^{-1} compared to 10 t ha^{-1} of FYM, when IA was used as a source of potassium.

Owing to increase in growth parameters *i.e.*, plant height and number of leaves and yield parameters *i.e.,* cob length, number of rows per cob, number of grains per row, number of grains per cob and test weight in PMC treated plots irrespective of the levels of K (upto 125% K_2O) applied through IA compared to FYM treated plots with varied levels of K through IA might resulted in increased grain and stover yield in maize.

The results of the study proved that locally available resources like by-products of sugar industries such as pressmud compost and incineration ash could be used as a organic manure due to their good nutrient composition. The pressmud compost is a rich sources of essential plant nutrients along with higher organic carbon content in comparison with FYM and proved to be beneficial in maintaining the soil fertility as well as maize productivity. However, its efficacy was higher when incineration ash was used as a source of potassium with higher levels. Therefore, we can conclude that combined application of PMC and incineration ash was found to be effective for increasing growth and yield of maize compared to FYM along with different level of K through IA and package of practices.

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