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UTILISATION OF PRESS MUD AS SOIL AMENDMENT AND ORGANIC MANURE - A REVIEW

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ABSTRACT

Pressmud is an unavoidable waste generated from sugar industries. Pressmud is rich in many plant nutrients and it also has properties to ameliorate degraded soils. For this reason pressmud is believed to be of much use in agriculture. Many research works indicate that application of pressmud improves soil fertility, nutrient uptake and yield of crops. Sulphitation pressmud can be used to amend the alkali soil whereas carbonation pressmud is useful to reclaim acidic soils. This review discusses about the prospects of pressmud utilisation in agriculture, especially with reference to soil conditioning and crop growth.

India is the largest producer of sugarcane in the world. The total area under sugarcane is 4.17 million hectares, producing 281.1 million tonnes of cane. There are 341 sugar mills in India produce annually 24 million tonnes of bagasse, 2.74 million tonnes of molasses and 2.40 million tonnes of pressmud as by products (Anonymous, 1987). A factory of about 2000 mt of cane crushing capacity produces about 60-70 tonnes of pressmud per day (Mariappan *et al.*, 1983). It is estimated that 2000-5000 tonnes of pressmud is accumulated every day, the disposal of which is a problem being faced by sugar industries due to the alarming environmental pollution it causes. Pressmud, though considered a pollutant, also contains many nutrients that are vital for improving the soil fertility and plant growth (Copper and Abu Adris, 1980; Yadavanshi and Yadav, 1990). Further, it's use as an effective soil ameliorant is also of much importance. Considering the rich nutrients and soil ameliorating possibilities, pressmud has the potential of becoming an useful product for use in agriculture and allied activities.

Composition of pressmud

Pressmud is a soft, spongy, light weight, amorphous dark brown material which can absorb moisture when dry. Pressmud contains fairly high quantities of plant nutrients that are essential for plants besides being a very effective as soil amendment. Pressmud contains appreciable amounts of nitrogen, Ca, Mg, S, trace elements and organic matter. However, it contains only a small amount of potassium. With the country facing an acute shortage of FYM and compost, use of pressmud would meet atleast partially the requirements of organics in crop production. Moreover, it can serve as soil conditioner for problem soils and can be used in controlling nematode problems in soils. It contains about 1% sugar, crude fibre, coagulated protein including cane wax, albuminoids, inorganic salts and particles (Kale and Shinde, 1986).

Pressmud contained 7.86% moisture, 2.24% nitrogen, 2.28% phosphoric acid and 0.11% potash (Chinloy *et al.*, 1953), pressmud composed 1.4% nitrogen, 12.16% phosphorus, 0.35% potassium, 20% carbon, 2.88% calcium, 0.27% sulphur and 0.03% manganese. (Agarwal and Gupta, 1958). Moisture content of the fresh pressmud reported to be 74.8% and oven dried filter cake contained 1.69% N, 0.9% total P, 0.72% available P, 0.27% total K, 0.19% available K, 1.84% Ca, 0.37% Mg, 0.19% S, 52 ppm Cu, 69 ppm Zn and 898 ppm Mn. (Alexander, 1972). Pressmud had about 0.8% N, 1% Phosphoric acid and 0.5% K. (Bangur, 1976). Pressmud from cane factories using carbonation or sulphitation process contained approximately 60 to 70% calcium carbonate (Mehta and

Gumkale, 1979). Pressmud consisted 13% moisture, 1.84% N, 7.86% P, 1.22% K, 24.6% carbon, 11.85% Ca and 3.12% Mg (Gunaseelan, 1980). Pressmud composed 1.2% N, 3.83% P and 11.1% Ca (Bawaskar, 1982). The typical composition of filter mud was 1% dry matter, 56.14% crude wax and fat lipids, 15-30% fibre, 5-15% sugar, 5-15% crude protein, 9-20% total ash, 4-10% silica, 4-10% Ca, 1-3% P and 0.5-1.5% Mg(Paturau, 1982). Pressmud had 75-85% moisture, 2 to 3% P, 1% N, 6 to 10% lipids, 30 to 35 % ash and 15 to 20% bagacillo. (Kulkarni, 1986). The amount of pressmud and its composition varies greatly with the locality, variety of cane, milling efficiency and method of clarification (Paturau, 1982). The nutrient status of pressmud could be increased after a short period of composting. Composted pressmud contained 1.98% total N, 2.7% total P, 0.99% total K, 4.56% total Ca, 3.09% total Mg, 223 ppm Zn, 133 ppm Cu, 643 ppm Fe, 422 ppm Mn, 21.6% organic carbon and 10.9 : 1 C: N ratio (Selvaraj, 1987). The pressmud also can be effectively compostec using distillery spent wash (Thopate *et al.*, 1991). This method gains more importance since two industrial wastes could be converted in a single process.

AGRICULTURAL APPLICATION OF PRESSMUD

Effect on soil properties:

a)Physical properties: Addition of pressmud to soil has been found beneficial by many scientist. The high organic matter content of pressmud was much of use in improving the tilth, favourably affecting granulation, stability of the soil particles, degree of aeration, water infiltration, drainage and water holding capacity of the soil (Lopaz *et al.*, 1953; Azzam, 1963; Alexander, 1972;Rakkiyappan, 1982; Indira Raja and Raj, 1983, Purushothaman, 1986; Kale and Shinde, 1986). Application of 154 to 174 t pressmud ha^{-1} was found to improve soil tilth (Anonymous, 1969). Application of pressmud was reported to be most beneficial in eroded and problem soils (Story, 1970). Application of pressmud to eroded soils resulted in considerable improvement in soil pore size distribution, moisture retention capacity, reduced soil compaction resulting in deeper penetration of roots (Paul, 1974; Prasad, 1976). However, Hunsigi (1993) suggested that curing of pressmud for 4-6 weeks was necessary before application to soil.

(b)Chemical properties : Incorporation of pressmud could impart a number of advantages to soil fertility, particularly in soils with low clay and organic matter content. (Pandalai *et al.*, 1953). Sugar factories employ two processes *viz.*, sulphitation and carbonation process to produce sugar. Pressmud from both the processes differ in their chemical properties. Pressmud obtained from sulphitation process is acidic in nature and hence can be applied on alkaline soils whereas, pressmud obtained from carbonation process contains lime which is useful in acidic soils (Bijay Singh and Yadvinder Singh, 1998). Application of acidic pressmud (from sulphitation process) resulted in slight increase in pH of water logged clay soils and the availability of Ca, Mg, Mn and Zn, whereas the application of the Ca rich carbonation process pressmud resulted in lowering the pH of alkaline soil from 9.5 to 8.8 (Anonymous, 1971). Substantial reduction in pH and EC was achieved due to sulphitation pressmud application @ 12.5 t ha^{-1} (Reddy *et al.*, 1973; Kumar and Mishra, 1991). In highly saline sodic soil, reduction in pH (from 9.2 to 7.25) and EC (from 5.4 to 0.18 mmhos m^{-1}) was reported due to pressmud application (Clarson, 1983). Though pressmud as such could reduce the soil pH, better results were obtained when it was added incombination with other pH reducing agents. Application of pressmud with phosphorus fertilizer decreased the pH and EC of alkaline calcareous black soil (Bawaskarr *et al.*, 1978;

Borde *et al.*, 1984). Application of gypsum added pressmud effected better pH reduction than when applied alone. Apart from decreasing the pH, this combination also significantly increased the CEC of alkali soils (Reddy *et al.*, 1973). However, pressmud + gypsum + zinc was found to be the best combination for reclaiming alkali soils with respect to pH reduction (Shivaram Shetty, 1975; Chand *et al.*, 1980; Balasubramanian and Ramasami, 1983). Application of pyrites and sulphitation pressmud to calcareous saline sodic soils also resulted in appreciable decrease in pH and EC (Singh *et al.*, 1986; Rajamannar and Sree Ramulu, 1982).

Apart from the favourable pH reduction role played by sulphitation pressmud in alkali soils, they also add to the build up of essential plant nutrients to the soil. In Lousiana (USA), application of pressmud @ 80 t ha^{-1} increased soil N and extractable P, K, Ca and Mg (Golden, 1975). Pressmud application also increased the organic carbon, N, P and K levels, but reduced the total soluble salts of soil (Bawaskar, 1982). Sulphitation pressmud contributes to greater increase of organic carbon in soil than carbonated pressmud (Gupta *et al.*, 1986; Virendra Kumar and Misha, 1991). Patil and Kale (1983a) reported that pressmud application @ 25 t ha^{-1} to soil increased the organic carbon, total N, available P and K, but slightly decreased the C:N ratio. However, Hagihara (1974) reported decreased N content in soils due to pressmud application.

In sandy soils also, pressmud application increased the available P and K substantially (Prasad, 1976). Application of pyrites and sulphitation pressmud to calcareous saline sodic soils resulted in appreciable decrease in ESP and increase in available P of soil (Singh *et al.*, 1986; Rai *et al.*, 1980). Combined application of gypsum at 50% requirement and pressmud @ 12.5 t ha^{-1} significantly reduced ESP and pH in alkali soil (Gaul and Dargan, 1978; Duraisamy *et al.*, 1986). The replacement of Na by Ca ions during the decomposition of pressmud must have lead to the reduction in soil ESP. Incorporation of pressmud @ 12.5 t ha^{-1} + Zn @ 50 kg ha^{-1} was found to be highly effective in reducing the sodium content of soil (Jayamani, 1992). Pressmud was also reported to be effective in removing the carbonates and bicarbonate ions from percolated soils than that of gypsum and pyrites (Patel and Bhajan Singh, 1991). Water soluble anions like CO_3^{2-}, HCO_3^-, Cl and SO_4^{2-} decreased with increased pressmud addition, but the exchangeable cations like Ca_2^+ and K^+ recorded increased values (Kumar *et al.*, 1991). Increased CEC was recorded in sodic soil due to pressmud addition (Paramasivam, 1979). Clarson (1983) recorded an increase in CEC values from 0.85 to 8.13 m.e.$100g^{-1}$ of soil due to the application of pressmud. Pressmud application to soil have an impact on the trace element composition as well. The availability of iron did not increase after pressmud application but the available aluminium content was reduced below toxic level (Chinloy *et al.*, 1953; Prasad, 1976). Limestone application along with pressmud to soil resulted in significant reduction of zinc and iron to deficiency levels in soil (Datta and Gupta, 1984).

(c)Biological properties : Application of pressmud greatly increased bacterial and fungal population of soil (Owen, 1954). Pressmud application was responsible for a large increase in the number of non-spore forming bacteria and various fungi including *Neurospora crassa, Trichoderma viride, Aspergillus sp.* and *Penicillium sp.* but pathogenic fungi such as *Fusarium* and *Pythium* were absent (Anonymus, 1968). An increase in the spore forming *Bacillus* and Actinomycetes, which have a positive influence on soil aggregate stability was observed in the final stage during composting of pressmud (Roth, 1971). Control of nematodes in soil also was reported due to pressmud application (Anonymous, 1971; Alexander, 1972).

Effect on crop growth

(a) Sugarcane : Application of pressmud to sugarcane has been proved successful in increasing the cane yield. Increased yield in sugarcane was observed due to varying levels of pressmud application (Song *et al.* 1959; Patil *et al.*, 1979; Rai *et al.*, 1980; Rao, 1980; Patil and Kale, 1983b; Anonymous, 1984; Hunte, 1984; Jafri *et al.*, 1985; Singh *et al.*, 1986). Addition of 5 - 7 t of pressmud to one hectare of soil resulted in significantly higher cane yield (Sharma and Sani, 1962; George, 1982). Sugarcane responded to pressmud application upto 10 t ha^{-1} by yielding higher dry matter, cane and sugar (Bhupal Raj and Suryanarayana Reddy, 1992). Application of pressmud @ 175 - 200 t ha^{-1} to sugarcane field provided more than enough P for the ratoon crop and gave an appreciable increase in cane yields upto 37.5 t ha^{-1} (Anonymous, 1969). Basal dressing with pressmud (25 t ha^{-1}) in cane varieties CO 419 and CO 449 resulted in increased cane yield by 7.5 t and sugar yield by about 2.5 t ha^{-1} compared to control (Rao *et al.*, 1970). Nema *et al.* (1995) estimated that continuous application of pressmud @ 6 t ha^{-1} results not only in increased, but also sustained cane yield.

Pressmud when applied along with fertilizer N greatly enhances the cane yield than when applied alone. Yaduvanshi and Yadav (1993) reported that combined application of pressmud and fertilizer N improved the yield of millable cane in the second ratoon. Mixing of biological agents with pressmud also yielded fruitful results. When applied along with Azotobacter @ 5 kg ha^{-1}, pressmud recorded higher cane yield and soil available N (Tiwari *et al.*, 1998). The leaf moisture content and the growth of aerial portion of cane were also found to increase upon pressmud application to sugarcane crop (Jafri *et al.*, 1985). Pressmud from sulphitation process was found to increase the germination percentage, length and girth of millable cane than that from carbonation process. Reduced tiller mortality to a level of 26.4% with SPM and 27.6% with CPM was recorded by Yaduvanshi and Yadav (1990). SPM and CPM when applied @ 26 t ha^{-1} increased the cane yield by 15.6 and 9.5% respectively in comparison to 3.3% by 150 kg N ha^{-1}.

Similarly, quality of cane juice, N : P ratio, mineral matter content of juice were increased due to pressmud application (Patil and Shingte, 1981; Bawaskar, 1982). Higher cane and sugar yield with better juice quality was obtained by Patil and Kale (1983b), when they applied pressmud cake @ 12.5 t ha^{-1}. The cane yield and quality were significantly increased by the supplementation of Zinc (Zn), Iron (Fe) with pressmud (Kumaresan *et al.*, 1985). The higher calcium content in pressmud also helped in increasing the sodium content of cane juice (Rajamannar, 1983). Apart from increasing the cane yield, pressmud also helps in reducing the cost of cultivation by way of substituting fertilizer. Chinloy *et al.* (1953) reported that pressmud application @ 25 t ha^{-1} could replace 18% super phosphate to obtain an equal yield of sugarcane. Application of 20 pressmud ha^{-1} (fresh weight basis) resulted in a saving of 25% of the recommended inorganic fertilizers in wheat, sugarcane, rice, maize and soybean crops (Jurwaker, *et al.*, 1995). Yaduvanshi and Yadav (1990) found that a combination of 10 t ha^{-1} SPM and 75 kg N ha^{-1} produced cane yield which was equal to that obtained from application of 150 kg N ha^{-1}. Substantial reduction in fertilizer N, P and K requirement due to pressmud application also was observed by Selvakumari *et al.* (1996).

(b)Other crops : Pressmud application to many field and horticultural crops has been found to yield positive results. The yield of rainfed groundnut was reported to increase due to pressmud addition @ 10 t ha^{-1} besides improving the available macro-nutrient status of soil (Mayalagu *et al.*, 1983; Kumaresan *et al.*,1984).Application of pressmud @ 5 t ha^{-1} and P_2O_5 @ 22 kg ha^{-1} proved superior in terms of number of pods $plant^{-1}$, number of filled pods and pod weight in groundnut (Trivedi *et al.*, 1995). In acid soil, application of pressmud @ 5 t ha^{-1} increased the yield of maize and decreased the soil hardness compared to soils that did not receive pressmud. Application of pressmud @ 12.5 t ha^{-1} significantly increased the dry matter production (DMP), N content and nutrient uptake of maize (Sherly Zacharis, 1995). Effective dose of pressmud was 20 t ha^{-1} producing yield increase of 129.4 and 65.2% in maize and wheat crops respectively over the control (Bijay Singh and Yadvinder Singh, 1998). Combined application of pressmud 75% and 25% gypsum recorded higher grain yield in maize crop raised in sodic soil (Paramasivam and Rani Perumal, 1983).

Similarly, pressmud application gave increased yield in black gram (Indira Raj, 1978; Indira Raja and Raj, 1983; Shanmugam *et al.*, 1996). Yield of greengram was also observed to increase by 20 to 30% due to pressmud application (Borde *et al.*, 1984) The integrated use of 600 kg ha^{-1} SPM with 25 kg P_2O_5 ha^{-1} produced more yield in greengram than that obtained with 50 kg P_2O_5 ha^{-1} on a silty clay soil (Datta and Gupta, 1983a). Rice crop was also found to benefit from pressmud application. Application of biodigested pressmud @ 10 t ha^{-1} along with recommended N increased the grain yield and uptake of nutrients in short duration rice to the tune of 33.1% over recommended N alone (Kapur, 1995; Subramanian and Wahab, 1997). Vermicomposted pressmud (prepared using pressmud, maize and sunflower stalks) when applied with raw pressmud resulted in higher grain yield than that of the recommended N, P and K in rice (Jeyabal *et al.*, 1998). Molasses application alongwith pressmud was also reported to reclaim saline and alkaline soils for subsequent paddy cultivation (Chumichev and Dutev, 1961). However, Giridharakrishna (1983) found that pressmud application in combination with MRP and SSP to rice crop did not influence the soil reactions and crop yield. In soybean also, pressmud application was found to lessen the seed yield as compared to gypsum @ 250 kg ha^{-1}, enriched FYM @ 750 kg ha^{-1} + recommended P_2O_5 applied fields (Ramasamy, 1997). The seed yield, protein content registered higher values when pressmud was applied alongwith recommended fertilizers (Jafri and Tiwari, 1995).

Various horticultural crops like pomegranate, pineapple, tomato and turmeric were also reported to benefit from pressmud application. Application of pressmud @ 20 t h^{-1} along with recommended NPK recommended significantly increased the rhizome yield of turmeric over application of recommended NPK alone (Selvakumari and Baskar, 1998). Pressmud application increased the marketable yield of tomatoes grown in a low humus sandy clay soil besides improving the texture of soil (Azzam, 1963; Azzam and Samuel, 1964). In pomegranate, application of pressmud @ 75% of gypsum requirement significantly increased the plant height and stem diameter (Gurbachan Singh *et al.*, 1999). The yield of pineapple was also reported to increase due to pressmud application (Samuels and Landrau, 1955). Seed inoculation with bioinoculants have also been observed to be successful, when applied along with pressmud. Application of pressmud along with seed bioinoculant *Bradyrhizobium japonicum* registered significantly higher grain yield in soybean and greater number of root nodules over their individual addition and control in acid soil (Prabakaran and Ravi, 1996). Ramasamy (1997) also reported positive effects due to phosphobacteria addition @ 600 g as seed inoculant + pressmud. In Punjab, application of carbonation pressmud used alone or incombination with fertilizers improved crop yields in saline-alkali soils (Kanwar and Bhumbla, 1961; Kanwar *et al.*, 1987; Uppal, 1995).

(c)Nutrient uptake : Enhanced nutrient uptake in plants due to pressmud application was well established. Increased P uptake by black gram (Indiraraja and Raj, 1983), N, P and K uptake by greengram (Bordè *et al.*, 1984), N and Zn uptake by maize (Gupta *et al.*, 1986). N, P and K uptake by sugarcane (Yaduvanshi and Yadav, 1990) and S uptake by mustard (Patil and Kale, 1983b; Narwal *et al.*, 1991) were earlier reported. The content and uptake of N, P and K by sugarcane was also increased by the residual effect of SPM (applied last season) upto 25 t ha^{-1} (Patil and Kale, 1983a). Long-term application of sulphitation pressmud increased the concentration of Cu, Fe and Zn in sugarbeet leaves while carbonation pressmud exerted no effect at an application dose of 20 t ha^{-1} (Kapur and Kanwar, 1989). A progressive raise in calcium content in wheat and maize tissues was observed due to application of pressmud (Datta and Gupta, 1984). The calcium content in cane was reported to increase due to pressmud application. However, Mn content in root, shoot and grain of wheat and maize grown on acid soils was observed to decrease with increasing rates of SPM (Datta and Gupta, 1985).

CONCLUSION

A review of scientific research on pressmud indicated it's richness of major and minor plant nutrients. Many crop plants recorded increased yield due to pressmud application, especially when applied along with recommended fertilisers. The fairly good concentration of N, P and K makes pressmud, a potential role player in enhancing the soil fertility and crop productivity. The acidic and alkaline nature of sulphitation and carbonation pressmud respectively will be of much interest in the reclamation of alkaline and acidic soils. Neutralisation of pH in any soil is the primary requirement for better crop production. Research works on this line so far indicated significant alteration of soil pH by pressmud. The increased cane and juice quality also is an encouraging result. All these indicate the potential of pressmud in promoting crop growth, soil fertility and soil amelioration.

Future focus

(1)Effect of pressmud application to different soils in the long run is yet to be studied in detail.

(2)Amount of application, either for crop production or for soil reclamation has to be precisely quantified. The amount of FYM and/or chemical fertilizer it can substitute is also to be quantified. Research on the effect of pressmud application to different types of soil is also mandatory, since sugarcane is widely cultivated across the country.

(3)Effect pressmud application to different cropping systems has to be studied.

(4)Possibility of using pressmud in integrated nutrient supply system is to be evaluated.

(5)Residual effect of pressmud application has to be studied in different soils.

REFERENCES

Agarwal, R.R., and Gupta, R.N. (1968). *ICAR Tech. Bull.*, 15:30-32.
Alexander, K.E.F. (1972). *South Africa Sug. J.*, 56:71-77.
Anonymous. (1968) *South Agr. Sug. Assoc.*, p.44-45.
Anonymous. (1969). *Producers Rev.*, 59:27.
Anonymous. (1971). *Handbook of Manures and Fertilizers.* ICAR, New Delhi. p:253-274.
Anonymous. (1984) *BSES. Bull.*, 6:16.
Anonymous (1987) *Co-op. Sug.*, 18:327-337.
Azzam, H. (1963). *Carribbian Agric.*, 1: 223-230.

Azzam, H. and Samuels, (1964). *J. Agric. Univ. P.Rico.*, 48:55-59.
Balasubramanian, K. and Ramaswami, P.P. (1983) In: Proc. National Seminar on utilization of organic wastes & AC & RI, Madurai. p.79-80.
Bangur, N.G. (1976). *Indian Sug.*, 25:909-910.
Baswarkar, V.S. (1982). *Maharashtra Sug.*, 7:37-40.
Bawaskar, V.S. *et al.* (1978). *Indian Sug.*, 27:807-810.
Bhupal Raj, G. and Reddy, M. Suryanarayan (1992). *Bharatiya Sugar*: 49-50
Bijay Singh and Singh, Yadvinder (1998) *Bull. Indian Inst. Soil Sci.*, 2: 46-58.
Borde, N.K.*et al.* (1984). *J. Indian Soc. Soil Sci.*, 32: 516-518.
Chand, M. *et al.* (1980). *Pl. Soil*, 55:17-24.
Chinloy, T. *et al.* (1953). *J. Agric. Sci.*, 43:1-11.
Chumichev, A.S. and Dutev, P.N. (1961). *Sakh. Prom.*, 10:48-49.
Clarson, D. (1983) M.Sc (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.
Cooper, B.R. and Abu Adris, B.C. (1980). In: Proc. Cong. Int. Soc. Sugarcane Technol., 1: 200.
Curbachan Singh, *et al.* (1999). *J. Indian Soc. Soil Sci.*, 47: 345-352.
Datta, M. and Gupta, R.K.(1983a). *J. Indian Soc. Soil. Sci.*, 31: 511-516.
Datta, M. and Gupta, R.K. (1983b) *J. Indian Soc. Soil. Sci.*, 31:635-637.
Datta, M. and Gupta, R.K. (1984). *J. Indian Soc. Soil Sci.*, 32: 180-182.
Datta, M. and Gupta, R.K. (1985). *J. Indian Soc. Soil. Sci.*, 33:715-717.
Duraisamy, P. *et al.* (1986) *Madras Agric. J.* 73: 129-133.
Gaul, B.L. and Dargan, K.S. (1978). *Agron. J.*, 23: 104.
George, J.F. (1982). In: Proc. 40th Ann. Conv. Sugar Tech. Assoc. p: 131-140.
Giridharakrishna, S. (1983) M.Sc (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.
Golden, L.E. (1975). *Sug. Bull.*, 53:12-19.
Gunaseelan, G. (1980). M.Sc (Ag) Thesis. Tamil Nadu Agricultural University, Coimbatore.
Gupta, A.P. *et al.*, (1986). *J. Indian Soc. Soil. Sci.*, 34: 810-814.
Hagihara, H.A. (1974): In : Meeting of Hawaiian Sugar Tech. Rept., p:55-59.
Hunsigi, G. (1993) In: Fertilizer Management in Commercial Crops. (H.L.S.Tandon ed.) FDCO, New Delhi. p:1-25.
Hunte, S.C. (1984). In: Proc. 2nd Ann. Conf. Barbodos Sug. Technol. Assoc., p:8.
Indiana Raja, M. and D. Raj (1983). In: Proc. National Seminar on Utilization of Organic wastes. Tamil Nadu Agricultural University, Coimbatore -641 003.
Indira Raja, M. (1978). M.Sc (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.
Jafri, S.M.R. *et al.* (1985). *Maharashtra Sugar*, 10 (4) : 47-53.
Jain, R.C and Tiwari, R.J. (1995) *Crop Res.*, (Hisar), 9: 215-217.
Jayamani, R.S. (1992). M.Sc. (Ag) Thesis, Tamil Nadu Agricultural University, Coimbatore.
Jeyabal, A. *et al.* (1998) *Madras Agric. J.*, 85:148-149.
Jurwarkar, A.S. *et al.* (1995). In: RAPA publication 12. P. 87.
Kale, S.P. and Shinde, B.N. (1986) *Bharatiya Sug.*, 11:63.
Kanwar, J.S. and Bhumbla, D.R. (1961). Annual Report. PAU, Ludhiana.
Kanwar, R.S. and Kapur, J. (1987). *Indian Sugar Crops J.*, 13(4):1-5.
Kanwar, R.S. *et al.* (1987). *Indian Sugar Crop J.*, 13(2): 17.
Kapur, M.L. (1995). *J. Indian Soc. Soil Sci.*, 43: 63.
Kapur, M.L. and Kanwar, R.S. (1989). *Biological Wastes*, 29:233-238.
Kulkarni, D.P. (1986). *Bharatiya Sug.*, 11:9.
Kumar, R. *et al.* (1991). *Indian J. Agric. Sci.*, 61 : 139-142.
Kumar, V. and Mishra, B. (1991). *J. Indian Soc. Soil. Sci.*, 39:109-113.
Kumaresan, K.R. *et al.* (1984). *Madras Agric. J.*, 71: 783-786.
Kumareasn, K.R. *et al.* (1985). *Madras Agric. J.*, 72: 701-705.
Lopez, L. *et al.* (1953). *J. Agric Univ. P. Rico.*, 37:213-223.
Mariappan, M. *et al.* (1983) In : Proc. National Seminar on Utilization of Organic Wastes. Tamil Nadu Agricultural University, Coimbatore. p : 68-72.
Mayalagu, K. *et al.* (1983). In : Proc. National Seminar On Utilisation of Organic Wastes, Agricultural College Research Institute, Madurai. p: 110-116.
Mehta, V.C. and Gumkale, S.D. (1979). *Chem. Eng. World*, 11:63-67.
Narwal, R.P. *et al.* (1991). *J. Indian Soc. Soil. Sci.*, 39:324-327.

Nema, G.K. *et al.* (1995). *J. Soils Crops,* **5** : 129.
Ownen, W.L. (1954). *Int. Sug. J.*, **56**:212-213.
Pandalai, K.M. *et al.* (1953). *Indian Cocon. J.*, **7**:20-25.
Paramasivam, P. (1979). M.Sc. (Ag) Thesis, Tamil Nadu Agricultural University, Coimbatore.
Paramasivam, P. and Rani Perumal. (1983). *Madras Agric. J.*, **70** : 827-831.
Paramasivam, P. (1979). M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.
Patel, K.P. and Bhajan Singh (1991). *J. Indian Soc. Soil Sci.*, **39**: 154-159.
Patil, S.P., *et al.* (1979). *Indian Sug.*, **27**:711-714.
Patil, S.P. and Kale, S.P. (1983a). *Indian Sug.* **33**: 905-908.
Patil, S.P. and Kale, S.P. (1983b). *Indian Sug.* **33**: 91-95.
Patil, V.D. and Shingte, A.K. (1981). *Maharashtra Sug.*, **6**:45.
Paturau, J.M. (1982). By products of the Cane Sugar Industry. Elsevier Scientific Publishing Company, New York. p.366.
Paul, C.L. (1974). *Tropc. Agric.*, **51**:288-292.
Prabhakaran, J. and Ravi, K.B. (1996). *Madras Agric. J.*, **83** : 132-133.
Prasad, M. (1974): In:Proc. Int. Soc. Sug. Technol., 15th Cong., 2:568-575.
Purushothaman, D. (1986). *Natn. Acad. Sci. Lett.*, **9**:257-259.
Raj, J. *et al.* (1980). *Indian Sug.*, **30**: 241-244.
Rajamannar, A. and Ramulu, U.S. Sree (1982) The Hindu. 16.6.1982.
Rajamannar, A. (1983) In: Proc. Natn. Seminar on Utilization of Organic Wastes, AC & RI, Madurai.
Rakkiyappan, P. (1982). In: Proc. 4th Sugarcane Research and Development Workers Meeting, July 23-24.
Rakkiyappan, P. *et al.* (1986) In: Proc. 36th Ann. Conv. DSATA. P: 433-442.
Ramasamy, M. (1997). Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore.
Rao, M.S. (1980). *J. Am. Soc. Sug. Beet Technol.*, **39**:223-237.
Rao, T.K.G. *et al.* (1970). In:Proc. 2nd Conv. South Indian Sugarcane and Sug. Technol. Assoc., P:50-52.
Reddy, R.V. *et al.* (1973). *Madras Agric. J.*, **60**:854-858.
Roth, G. (1971). In:Proc. 45th Cong. South Africa Sug. Technol. Assoc., p:142-148.
Samuels, G. and Landrau, P. (1955). *Sug. J.*, **18**:30-34.
Selvakumari, G. and Baskar, M. (1998). *Bull. Indian Inst. Soil sci.*, **2**: 152-155.
Selvakumari, G.R. *et al.* (1996). In:Proc. National symposium on Use of Distillery and Sugar Industry Wastes in Agriculture. OCT. 28-27.
Selvaraj, P. (1987). M.Sc (Ag) Thesis, Tamil Nadu Agricultural University Coimbatore .
Shanmugam, M. *et al.* (1996). *Madras Agric. J.*, **83** : 24-26.
Sharma, J.M. and Sani, S.S. (1962). *Indian Sug.*, **12**:191-192.
Sherly Zacharis (1995). M.Sc (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.
Shivaram Shetty, K. (1975). *Indian J. Agric. Chem.*, **8**: 253-256.
Singh, O.K.D.N. *et al.* (1986). *J. Indian Soc. Soil Sci.*, **34**:152-154.
Song, P. *et al.* (1959). *Rept. Taiwan Sug. Exp. Stn.*, **26**:39.
Story, G.G. (1970). *Cane Grow. Q. Bull.*, **33**:129-131.
Subramanian, K. and Wahab, K. (1997). *Madras Agric. J.*, **84**: 78-80.
Thopate, A.M. *et al.* (1991). In : Proc. Ann. Conv. of DSTA, part 1.p:312-315.
Tiwari, R.J. *et al.* (1998). *J. Indian Soc. Soil Sci.*, **46** : 243-245.
Trivedi, B.S. *et al.* (1995). *J. Indian Soc. Soil. Sci.*, 43:627-629.
Uppal, H.L. (1995). *Indian J. Agric. Sci.*, **25**:211.
Virendra Kumar and Mishra, B. (1991). *J. Indian Soc. Soil Sci.*, **39** : 109-113.
Yadav, D.V. (1992). *Indian J. Sugarcane Technol.*, **7**:1-16.
Yaduvansh, N.P.S. and Yadav, D.V. (1973). In : Final Report of Project No.C.16.1.1., IISR, Lucknow.
Yaduvanshi, N.P.S. and Yadav, D.V. (1990). *J. Agric. Sci.*, **114** : 259-263.