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SOIL SCIENCE

Effect of Sludge, Woolen Carpet Waste and Press Mud on Rice Grain Quality and Soil Fertility: A Review

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ABSTRACT

Now-a-day's biodegradable organic sources are gaining global importance for the cultivation of crops specially in the rice culture. The organic wastes like digested sludge, wooden carpet waste and press mud proved equally effective in rice crop compared to other organic sources with respect to milling and cooking qualities and volume expansion ratio. The building up the total amylase and protein content in rice grain was more effective when organic sources were used in comparison to inorganic or other sources of N. The soil bulk density and electrical conductivity was reduced by the application of organic sources thereby increasing the water holding capacity and the availability of organic carbon or P, K, S and micronutrients such as Fe, Zn, Cu content of the soil.

Highlights

- The press mud and digested sludge are rich in plant nutrients particularly micronutrients therefore these wastes may be used as organic manures.
- As there is a greater requirement of quality rice globally, these organic sources of N holds great promise in the improvement of rice grain quality as well as soil fertility and productivity.

Keywords: Sludge, Carpet Waste And Press Mud, Rice, Quality, fertility

Rice is grown over an area of 44.6 million ha (Anonymous 2003) under highly diverse agro-ecological conditions ranging from below sea level in Kutanad district of Kerala to a height of 2000 meters in high hills under low temperature; parched sloppy hillocks of Rajasthan to a deep regime of 5-7 meters in West Bengal and problem soils to highly fertile soils under heavy pressure of biotic stress. Considering the heavy demand of rice and the scope of quality rice in international market, interactive research work in almost all aspects of rice is needed.

Plants require more nitrogen (N) than any other nutrient (Kimmo 1993) and N deficiency limits rice production and productivity in tropical soils (Sahrawat and Narteh 2003). Thus, it is the largest component of fertilizer used in Asian agriculture (Kimmo 1993). Nutrients supplied exclusively through chemical sources, though enhances yield initially, but the yields are not sustainable over the years. A gradual reduction occurs in overall response of applied fertilizer in terms of increase in output to applied nutrients. Furthermore, an unabated uprise in the use of chemical fertilizers can inflict irreparable damage to soil and environment (Katyal 1989). The escalating cost of chemical fertilizers warrants an efficient use of external inputs of N (Sahrawat and Narteh 2003). The unbalanced use of N fertilizers has at times led to environmental confrontations, disturbance in soil nutrient balance and depletion of soil fertility (Kimmo 1993).

Depletion of soil organic matter is the main cause of low productivity (Md Zahid Hossain 2001). The importance of managing soil organic matter (SOM) for crop production has long been recognized (Olk *et al.* 2000) and organic matter application to soils is one possible way to improve soil fertility and crop productivity (Matsumoto *et al.* 2002). In general, the composting of organic wastes and their application to improve soil fertility are well developed (Huang ShanNey and Lin JinnChing 2001). The use of organic wastes in southern Taiwan for increasing crop production, maintaining soil fertility and reducing production costs has been discussed by Huang ShanNey and Lin JinnChing (2001).

Rice is consumed commonly as a whole cooked kernel and a number of botanical, genetical, chemical, nutritional and processing features are involved in determining the quality features of rice (Govindaswami 1985). The main aspects of rice grain quality are the milling characteristics such as hulling, milling and head rice percentage; cooking characteristics such as water uptake, kernel length after cooking, volume expansion ratio and amylose content and the nutritional characteristics as crude protein content. However, most of the grain quality characters are apparently highly heritable (Webb *et al.* 1985). In many countries, milling quality that usually includes total and head rice yields from a rice sample, influences the economic value of the grain (Kunze 1985). Cooking quality in rice is mainly determined by water uptake, volume expansion ratio and kernel elongation (Tomar and Nanda 1982). Amylose and alkali value are the important characters in determining the cooking quality of rice (Ghosh and Govindaswami 1972).

Different fertility levels also affect various quality parameters of rice grain. Application of organics along with inorganic fertilizer had the positive influence on total amylose, insoluble amylose and crude protein content of rice grain (Hattab *et al.* 1998). The cooking qualities such as amylose content and alkali index were more favorable when N was increased and P applied at mid season than at pre – plant. Improvement in head rice yields were also obtained due to inculcation of chemical fertilizers (Mukundar *et al.* 1977). There are very few evidences on cooking qualities such as water uptake and volume expansion ratio as affected by soil fertility. A lot of researches are to be done on rice grain quality in relation to soil fertility.

Dixit and Gupta (2000) have shown that yield of grain and straw of rice plant, their nutrient uptake, grain quality and soil properties can be altered greatly by using proper combination of organics with chemical fertilizers. Since the organic wastes (press mud, digested sludge and carpet wastes) are the source of primary, secondary and micronutrients to the plant growth and constant source of energy for heterotrophic microorganisms which help in increasing availability of nutrients, quality and quantity of crop produce, it can be hypothesized that the use of proper combination of these locally available organic wastes which are narrow in C:N ratio and safe to apply for agricultural purposes, is as critical as that for integrated use.

Keeping these facts in consideration, the present review for further research in these areas.

Effect of organic and inorganic on rice grain quality

Saini *et al.* (1971) reported that fertility levels had significant effect on the protein content and observed average protein content of HYV increased from 7.31 % under low fertility (60:30:30) to 8.51% under high fertility (120:60:60).

Rice protein has one of the highest nutritional qualities among the cereal proteins but occurs in relatively low amounts (Morse 1965). The crude protein content of rice is influenced by variety and environment, season of planting and soil fertility (Juliano 1965). According to Gagampang *et al*. (1966), a variety usually gives a range of protein content of 7 per cent points due to environments, e.g., BPI – 76 ranges from 9 to 16 per cent.

The percentage protein was found to be progressively elevated as N levels increased from approximately 80 to over 120 kg ha^{-1} (Juliano 1965). Kulkarni (1973) observed progressive increase in the protein content of all the six varieties due to the increasing rates of N (from 0 to 150 kg ha^{-1}). The grain protein content of rice cv. Triveni increased from 6.27 to 7.37% with increases in rates of N from nil to 120 kg/ha applied in 2 forms and by 4 methods (Abraham *et al*. 1974). N fertilizing increased the protein content of milled rice (Yamashita and Fujimoto 1974). In cv. IR8 grain protein content increased from 8.14% without applied N to 9.9% with 120 kg N/ha and in cv. IR480-5-9 grain protein content increased from 9.9% without applied N to 13% with 90 kg N/ha (Eggum and Juliano 1975). Application of N increased the number of panicles, grain yield and grain protein content (Lai *et al*. 1977). Grain crude protein content decreased with 30 kg N/ha but increased with 60 kg

N/ha from 8.19 to 9.08%. P and K had no significant effect on grain crude protein content (Bhuiya *et al*. 1979). Grain protein content and protein yield of rice was increased by increasing the N rate from 50 to 150 kg/ha (Mahajan and Nagre 1981). Grain protein content of rice cv. Tuljapur-1 increased with increases in N rates from 0 to 75 kg/ha (Tak *et al*. 1982). Agrawal *et al*. (1982) conducted a pot culture experiment to evaluate the effectiveness of Zn, Mn, Mo and Cu in different combinations on the quality of rice cultivar IR-8 and reported that maximum crude protein (13.93%) was recorded with Mn + Mo and carbohydrate (75.25%) with Cu + Zn + Mo combinations.

Average protein content (9.34%) was highest with the high fertilizer rate (Akram *et al*., 1985). Percentage protein content increased linearly from 7.31% without N to 7.96% with 120 kg N/ha (Vianna and Machado 1985). Protein content increased with increasing NPK rate from 6.87 to 7.57% in the wet season and from 6.37 to 7.91% in the dry season. Milling quality was positively correlated with protein content (Sarkar and Mittra 1987). Protein contents were improved by supply of N, independent of N source (Reddy *et al*. 1988). The increase in grain protein content was greater with higher total rates of applied N (Umetsu *et al*. 1990).

Chandra D. (1992) observed that protein content increased with the increase in the N levels only in Ratna; whereas with varieties Pusa 2 – 21 and Pankaj, a significant increase in protein was noted at 90 kg N ha^{-1} as compared to 30 kg N ha^{-1}. Application of S-free NPK increased grain protein content (Parida *et al*. 1994). Application of N increased grain yield as well as non-protein nitrogen and protein contents over the control (Parida *et al*. 1995). Grain protein content generally increased with increasing N rate (Andrade *et al*. 1999). Protein content increased due to increasing fertilizer rates and there was a proportional relationship between the amount of protein in a grain and the crude grain weight (Matsue and Ogata, 1999). A linear relationship between protein content in milled rice and NUE was observed (Matsuda *et al*. 2000). Applied nitrogen increased the crude protein content (Enishi *et al*. 2002).

Hattab *et al*. (1998) found that application of 25% organic N as basal and 75% inorganic as top dressing proved its efficiency in influencing the various quality parameters viz., total amylose, insoluble amylose, crude protein, lipid content, optimal cooking time and gruel loss. Among the organic sources compared, the easily degradable green manures, *Sesbania rostrata* and *S. aculeata* were observed to be the most suitable for improvement in the quality parameters of rice. Amylose content of spikelets was related to grain weight (Matsue and Ogata 1999).

Place *et al*. (1970) concluded an interaction effect between time of P application and N rates and stated that cooking qualities were more favorable when N was increased and P applied at mid season than at pre-plant.

Rhind (1962) studied the effect of N fertilizers on milling recovery of a bold grain variety (C2104Ngasein) and showed that N fertilizers increased breakage of grain significantly; while Dimyati (1969) concluded that N applications resulted in improved milling recovery, especially in varieties possessing white belly. Kulkarni (1973) reported that there was a significant difference in head rice yields between low and high N levels in varieties with bold grains showing white belly such as IR-8, IR-5 and Peta.

The evolution of suitable soil fertility and water management practices to improve the milling quality of high-yielding rice cv. Cv. IR-22 gave increased grain total mill and head rice yield with increase in N and P up to 90 kg N + 45 kg P_2O_5/ha. With 112 kg N + 50 kg P_2O_5/ha, IR-22 gave maximum grain and head rice yields of 4.56 and 3.44 t/ha, respectively (Mukundar *et al*. 1977).

Tomar and Nanda (1982) observed that water uptake was positively correlated with volume expansion, Kernel elongation, alkali value and amylose content. Volume expansion and kernel elongation also showed similar positive association with other traits.

Varieties with low amylose content become sticky on cooling (Juliano 1979). Amylose content and alkali value are the important characters in determining the cooking quality of rice (Ghosh and Govindaswami 1972).

A significant positive correlation between head rice content, milled rice protein and translucency was observed (Perez *et al*. 1996). Quality parameters like hulling percentage, milling percentage, protein and amylose contents also increased due to use of NPK fertilizers, FYM and BGA inoculation either alone or in combination (Dixit and Gupta 2000).

The quality parameters like crude protein content, bran oil content, total amylose content, hot water insoluble amylose content, percentage of milling recovery and hardness in the rice grain also improved under the treatment that received green manure plus N, P_2O_5 and K_2O at recommended levels plus gypsum at 500 kg ha^{-1} (Subbiah and Kumaraswamy, 2000).

Effect of organics and inorganic on soil fertility

Organic manure improved physico-chemical and biological characteristics of soils and resulted in greater availability of both macro and micronutrients (Biswas *et al*. 1971 and Singh *et al*. 1986).

Higher rates of application of activated sludge were necessary than with chemical fertilizer because of slower N mineralization (Higashi *et al*. 1976).

Yoneyama and Yoshida (1978) obtained that sewage sludges applied to soil could result in the accumulation of high concentrations of ammonia, nitrite or nitrate and the simultaneous application of organic matter low in N, such as rice straw, with sludge could reduce the accumulation of inorganic N as a result of its immobilization by the organic matter.

Tolerance to cadmium is highly crop specific: Spinach, soybean, curly cress and lettuce are sensitive, whereas tomato, squash, cabbage and rice are tolerant and experiments show Cd to be more phytotoxic than Cu, Ni and Zn in a sludge amended acid soil plus or minus lime (Bingham 1979). Bingham *et al*. (1980) observed that the parameters influencing grain yields to be only soil pH and the Cu addition rate (combining the unlimed and limed sludge amended soil experiments) and disregarding the high Ni treatment, the Cd content of rice grain was dependent upon the Cd addition rate and soil pH only; additions of Cu, Ni and Zn had no significant effect on Cd uptake and accumulation in rice grain.

Iwata *et al*. (1982) reported that application of 90 per cent soil weight of sludge to the pots increased P absorption in the soil causing phosphoric acid deficiency of rice even in the presence of normal P_2O_5 fertilizer and high rates of P_2O_5 in equilibrium to 5 per cent of the phosphate absorption coefficient of the soil increased grain yields by 130 – 173 per cent.

Imagawa *et al*. (1986) found that the sludge increased the C, N, total and exchangeable P and exchangeable Ca levels in the soil but lowered the Mg level with increased water holding capacity of the ploughed layer.

Gupta and Narwal (1988) reported that ammonical N decreased and nitrate N increased with increasing periods of incubation at all the levels of N from sludge and sources of N. Application of sludge and N increased the content of ammonical and nitrate N at all the periods of incubation with both the sources of N.

Gambrell *et al*. (1989) observed that under reducing conditions, Cu was retained by various organic phases, but a marked transformation to the reducible (hydrous iron oxide) phase occurred with increasing redox potential and there was a trend for dissolved exchangeable and chelate extractable Cu to increase with increasing redox potential. There was a weak trend for dissolved and exchangeable Zn to increase with increasing redox potential, and the highest levels were at pH 5.

Prasad[2] *et al*. (1989) found the DTPA – extractable Fe due to applications of different Fe – enriched organic wastes (sewage sludge, municipal wastes, press mud, poultry manure and farmyard manure) and $FeSO_4$. Mn, Zn and Cu were readily available from both the sludge and the refuse compost and availability of Fe, however, decreased with increased sludge application rates (Chung *et al*. 1992).

Hernandez *et al*. (1991) found higher total N and extractable N and P contents and nearly constant extractable K in soil amended with sludge. Through sludge application, the levels of Cu, Zn and Pb increased and the Fe content decreased. The extractability of Fe, Cu, Mn, Zn and Pb increased as compared to the control.

Maiti *et al*. (1992) reported continuous application of sewage effluents make the soil alkaline and increase the salt contents. Not withstanding the high nutrient content of sewage effluents and sludge, they opined to make serious consideration regarding toxic levels of micronutrients and heavy metals before their application in soils. Organic C content and Olsen extractable P of post harvest soil samples increased with the application of the sewage sludge. But P application increased only Olsen's P and soil C remained unaffected as reported by Gupta *et al*. (1993).

Malarvizhi *et al*. (1993) observed that increased availability of sulphur in soil was attributed to the addition of S through natural sources such as irrigation water, rain etc. in addition to the application of S and at a rate of 100 kg S ha^{-1}, available S in the soil was significantly increased from tillering to the post harvest stage in both seasons. However, application of S showed a non-significant relationship with P and K status in the soil.

Soni and Singh (1994) reported that mineralized N increased with increasing temperature from 15 to 35^0 C and decreased at 45° C. Mineralized N was higher in the sludge treated soil than in untreated ones at each temperature. Rate of nitrification was fastest at field capacity followed by 50 per cent field capacity and wetting and drying.

Mukherjee *et al*. (1995) concluded from the experiment conducted in the microplots to investigate the effect of different organic additives and inorganic fertilizer on the nutrient status of soil that neem cake was the most effective in increasing total N, and 60 days following the application of sludge inorganic N content reached maximum values and neem cake, sludge, mustard cake and farmyard manure also significantly increased P availability in soil. The integrated use of green manures and organic manures with chemical fertilizers built up available nutrient and was much more effective than that of chemical fertilizer alone in augmenting crop productivity and nutrient availability in calcareous soils. Use of organic manure held a great promise in rice-wheat cropping system not only for securing high productivity levels but also against emergence of multiple nutrient deficiencies and amelioration of soil health (Prasad *et al*. 1995).

The effect of sewage sludge composts were studied in volcanic ash soil in Japan applied twice a year for 17 years for growing summer maize and winter barley. The results showed: (1) the average concentrations of Zn and Cu in compost of sewage sludge mixed with rice husks were 628 and 112 mg kg^{-1}, respectively, while those of compost (compost of sewage sludge mixed with saw dust) were 606 mg Zn kg^{-1} and 184 mg Cu kg^{-1}; (2) long-term application of sewage sludge compost increased the concentration of Zn in the surface soil; (3) most of the Zn applied to the soil remained at both soil depths; (4) most Zn added to the soil with sewage sludge was retained in the surface soil layer for atleast 13 years following the application, although an eventual slight decrease in Zn concentration of the surface soil layer was noticed; and (5) the concentration of total Cu in the surface soil less than that of Zn since the concentration of Cu in the sewage sludge was not so much greater than that of the original soil (Goto *et al*. 1997). Sewage sludge compost is a better source of phosphorus (Sugito *et al*. 2001). When sludge fertilizer was tested against others on the market, no difference could be found in the heavy metal content of the rice and rice stems. Therefore, sludge fertilizer can be assumed to be safe and effective for agriculture (Xie QingLin *et al*. 2001).

Pyrites and Sulphitation press mud applied to calcareous saline-sodic soils of North Bihar resulted in appreciable decrease in pH, E.C., ESP and increase in available phosphate of soil as reported by Singh *et al*. (1986). Prasad[1] *et al*. (1989) found that the effect of various sources (poultry manure, compost, press mud, biogas slurry, sewage sludge and $ZnSO_4$) and levels of Zn on DTPA extractable Zn differed significantly and the residual effect of Zn application through these organic sources of Zn persisted even after the harvest of the fourth crop of wheat and rice. The DTPA extractable Zn decreased in succeeding crops of wheat and rice and biogas slurry and other organic wastes maintained higher levels of available Zn (1.75 ppm) in Zn deficient calcareous soil than $ZnSO_4$ (0.89 ppm). Prasad[2] *et al*. (1989) studied the influence of Fe enriched organic wastes on the availability of applied Fe in calcareous soil and reported that the highest DTPA extractable Fe was in the treatment of sewage sludge (14.8 ppm), followed by municipal wastes, press mud, poultry manure, farmyard manure and $FeSO_4$ (7.6 ppm).

Kumar and Mishra (1991) confirmed that in the soil, pH increased and available P decreased by application of the carbonation press mud whereas no change in the soil pH occurred and available P content increased by addition of the sulphitation press mud. Both types of press mud increased organic C and available K content of the soil but the effects of sulphitation press mud were greater than those of carbonation press mud.

Application of inorganic fertilizer or their combined use with the organic manures increased the organic carbon status of the soil. The NPK fertilizer at 100 per cent recommended levels or more and their combined use with organic N sources also increased the available N and P by 5 – 22 kg and 0.8 – 3.8 kg ha^{-1}, respectively, over their initial values (Bhandari, 1992).

Kant and Kumar (1992) found reduced pH, E.C. and ESP and increased organic C and CEC of the soils by the application of press mud as compared to control under salt affected soil of Faizabad. Narwal *et al*. (1993) confirmed that the NH_4^+ - N increased due to addition of N and sulphitation press mud. The NO_3^- N also increased with the increase in incubation period of N with press mud.

Patel and Singh (1993) reported that cumulative removal of CO_3^{-} + HCO_3^- was higher with press mud (from sugar factories) treatment than with gypsum or pyrites in a sodic silty loam soil and the reduction in pH, ESP and the increase in the exchangeable Ca and Mg in soil were due to gypsum, press mud and pyrites among which gypsum was more effective.

Sinha and Sakal (1993) showed that the application of pyrite with FYM and press mud improved the physical and chemical properties of soil. More (1994) studied the effect of various combination of press mud, dried biogas slurry, FYM and wheat straw in rice-wheat cropping system on sodic vertisol and found that in general, all the treatments, particularly, FYM + press mud decreased the pH and ESP and increased the contents of organic C, available N, P and K in soil. The infiltration rates also increased due to application of organic wastes and manures.

Chauhan (1995) reported that the pH of the degraded sodic soil was lowered to 8.6 from 10.5 after the second rice crop when 50 per cent of calculated gypsum requirement was applied as pyrites, or gypsum with 15 t press mud ha^{-1}. Devarajan and Oblisami (1995) conducted field trials irrigated with sugar factory waste water or treated distillery effluent (spent waste) at 50, 40, 30, 20 and 10 fold dilutions. Sub plots received farmyard manure @ 12.5 t ha^{-1} , with recommended levels of N, P and K, or 12.5 t ha^{-1} press mud, composted coir waste or 5 t ha^{-1} gypsum, with the recommended levels of N and P. The effluent irrigations significantly increased the soil available N, P, K, Ca, Mg and micronutrients contents, soil pH, soil EC and soil organic matter content.

Dang and Verma (1996) found that increase in organic C, available P, K and Zn in soil were more pronounced from the sulphitation press mud cake (SPMC) than from the carbonation press mud cake (CPMC). However, the use of CPMC showed slight increasing trend in pH and $CaCO_3$ contents.

Raman *et al*. (1996) studied the efficacy of gypsum, press mud and fly ash @ 6 t ha^{-1} in absence and presence of rice straw @ 5 t ha^{-1}. Fly ash and press mud did not have any effect on soil pH and E.C. The organic carbon content significantly increased due to press mud application. Although application of all the three materials enhanced the infiltration rate and increased the water stable aggregates significantly, but press mud was found to be the best.

Shanmugam *et al*. (1996) reported that soil pH was increased by press mud and lime, whereas soil hardness was only slightly affected by treatments. Soil available N and P were unaffected by treatments whereas available K was increased by farmyard manure. There was a residual effect of lime, rice husk and press mud on the following black gram crop.

Subramaniyan and Wahab (1997) reported that in post harvest soil available nutrient status (N, P and K) were favorably influenced by the application of bio-digested press mud (filter cake) @ 10 t ha^{-1} along with the recommended rates of fertilizer nitrogen of 150 and 120 kg N ha^{-1} for medium and short duration rice cultivars, respectively.

Ram *et al*. (2000) showed that use of 30 or 60 kg. N from organic sources (farm yard manure, press mud or water hyacinth [*Eichhornia crassipes*]) out of total application of 120 kg N decreased soil pH and increased soil fertility.

CONCLUSION

Exceptionally the carpet waste (CW) contains 12.5% nitrogen, 1.65% sulphur and 56% organic carbon and is negligible of other nutrients. However, the press mud (PM) and digested sludge (DS) are rich in plant nutrients particularly micronutrients. Therefore these wastes may be used as organic manures.

The total plant nutrient contents in all the three sources were in the decreasing order such as NPK content (CW>DS>CW), S content (CW>PM>DS), Fe, Mn, Zn, and Cu content (PM>DS>CW) and C : N ratio [PM (14.36) > OS (5.03) > CW (4.52)] from the research reviews so far it may be concluded that if recommended dose of N is to be applied through these organics such as DS, PM or CW there is a possibility of reduction in yield in comparison to recommended doses of chemical fertilizer by 10 percent approximately. However, the indications are that in the present day context of organic farming and greater requirement of quality rice globally, these organic sources of N holds great promise in the improvement of rice grain quality as well as soil fertility and productivity. These review will certainly help those Agricultural Scientist who have stated undertaking research on organic farming in various crops.

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