

MICROBIAL ENRICHMENT OF COMPOST FOR HIGHER CROP YIELD

**A Thesis
submitted to the
Bidhan Chandra Krishi Viswavidyalaya
for the award of the Degree of Doctor of Philosophy
in
AGRICULTURAL CHEMISTRY AND SOIL SCIENCE**

**BY
MADHAB CHANDRA MANNA**

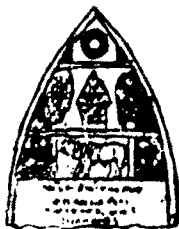
**DEPARTMENT OF AGRICULTURAL CHEMISTRY AND SOIL SCIENCE
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Dedicated
to
my loving younger Brother

BIDHAN CHANDRA KRISHI VISWAVIDYALAYA

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C E R T I F I C A T E

This is to certify that the work recorded in the thesis entitled "Microbial enrichment of compost for higher crop yield" submitted by Sri Madhab Chandra Manna for the award of the Degree of Doctor of Philosophy in Agricultural Chemistry and Soil Science of the Bidhan Chandra Krishi Viswavidyalaya, is the faithful and bonafide research work carried out under my guidance and personal supervision. The results of the investigation reported in the thesis have not so far been submitted for any other Degree or Diploma. The assistance and help received during the course of investigation have been duly acknowledged.

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Dated, Kalyani,
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Chapter I

P R E F A C E

In the event of wide spread energy crises, it has become highly desirable for making massive efforts to adopt organic recycling as a source of bioenergy as well as for enhancing soil productivity in the developing countries.

A study by Van Voorhoeve (1974) of the World Bank reported (Annexure I) that in 1971, the total theoretical production of plant nutrients from organic materials in the Developing World could be 7-8 times greater than the actual consumption of mineral fertilizers during that year (13.2 million tonnes). It has further been estimated that in 1980-81, the consumption of mineral fertilizers (N & P) in all the developing countries is likely to be about 30 million tonnes, while in the same year, the likely theoretical production of these plant nutrients from organic materials could be 80.4 million tonnes.

Another study by World Bank (1976) indicates that the cost of disposal of organic wastes from the economic point of view is about 200 billion dollars in the developing countries. Therefore, it is highly desirable to use these organic wastes for supplementation of plant nutrition for energy. Statistics in Annexure II indicate that in economic terms, the total value of this theoretical

production of plant nutrients from the organic materials in 1971 could be over \$16 billion. This clearly shows that there is good potential for organic recycling as a source of plant nutrients in the developing countries with very attractive economic implications. Even if 10-20 per cent of the potential is exploited for bioenergy and for soil productivity, organic recycling can contribute significantly in solving food and energy crises in the developing country.

Based on the available estimates, the total agricultural crop residues in India, in 1989 could be around 273.3 million tonnes, of which cereal crop residues comprised the bulk, about 196.8 million tonnes (Roy, 1989; Annexure III). In another estimate, it has been reported that about 40 million tonnes, out of total 200 million tonnes of agricultural wastes in 1975-76, was used as fuel. It has also been reported that about 70 million tonnes of cattle dung (air dried) out of total estimated production of 324 million tonnes have been burnt for energy purposes which is more than the total fertilizer consumed in agricultural production in India (Gupta, 1990). In a recent survey, Mishra et al. (1988) reported that a substantial part of cereal straw, in some parts of the country, is treated as waste and is burnt out in the field to get the land free for next cultivation. Thus, a potent source of organic matter is lost in the farm.

Another important source of organic matter is the solid wastes accumulated in the cities of the country. Swaminathan (1979), indicated that the potential available in India for the production of organic fertilizers is 10.8 million tonnes from urban wastes

and 657 million tonnes from rural wastes. The city of Calcutta itself produces about 2250 tonnes of garbage per day (Dutta Gupta *et al.*, 1986) containing 42.40 per cent compostable organic matter (CPHERI). A publication of the National Committee on Science and Technology, Govt. of India also indicates immense possibility of the use of wastes for organic recycling in India. In this connection, Mahdi (1979) reported that for the production of 125 million tonnes of food in 1978-79 in India, 13 million tonnes of plant nutrients were removed from soils when the utilization of fertilizer was only 5 million tonnes. Therefore, for further development of agriculture in India it is absolutely essential to utilize organic materials as fertilizers and to use biofertilizers on large scale. All these impressive statistics present a strong case for making massive efforts to adopt organic recycling for enhancing soil productivity, when Indian soils are being low in organic matter, caused primarily by environment (Jenny and Raychaudhuri, 1960), require regular application of manure at the rate of 20-25 tonnes per hectare (Srivastava, 1981) for the maintenance and improvement of soil fertility. There is also a global impact for organic farming through recycling of organic wastes for persistent agriculture as well as pollution free environment. Therefore, there arises the scope of developing technology for quick disposal through recycling by composting of both farm and city wastes for higher crop yield. Proper utilisation of wastes, both of farms and cities, also aims at keeping the environment clean for better human living.

Again, direct incorporation of crop residues in the field as a means of quick disposal is not always practicable due to its

own limitations of delaying the transplantation of the following crop. Moreover, direct incorporation exerts detrimental effect on the growth of the young seedlings through liberation of toxic substances and immobilization of nutrients. Therefore, appropriate technology should be developed for the management of surplus crop residues for increasing the productivity of land.

Since composting is a natural process accomplished by a variety of microbes, application of selected microbial cultures efficient in decomposing cellulosic substances may prove effective in intensifying the process of decomposition of cellulosic wastes. In that context attempts were made to use efficient cellulose decomposing cultures for rapid decomposition of cereal straw in the pit for production of good quality of compost for agricultural use.

Only rapid decomposition of cellulosic materials through composting may not fulfil the whole purpose of recycling the organic wastes. The quality of the compost should simultaneously be improved to make it more attractive to the cultivators. The quality of a compost is generally dependent on the composition of the decomposing material. Therefore, decomposition of straw and allied cellulosic wastes produce a poor quality compost due to its low nitrogen and phosphorus content. Since in humus formation by decomposition of organic residues Carbon, Nitrogen and Phosphorus are incorporated more or less in a definite proportion, straw needs supplementation of nutrients to bring down the ratios of carbon to nitrogen (C:N) and carbon to phosphorus (C:P) to round about 40 (Hajra et al.(1974) and 80 respectively which are generally

considered as the values for optimum biological conversion and production of good quality of humic substances.

As more and more humus is formed, greater amount of carbon is locked which brings the stability of humic substances and improves the quality of compost (Novak, 1972). Therefore, supplementation of an adequate amount of those inorganic nutrients and/or charging the decomposing material with easily decomposable nitrogen riched organic inputs may meet the N-requirement of the growing microorganisms leading to the formation of a good quality compost from cereal straws.

Application of inorganic N in bulk to improve the quality of compost does not prove encouraging due to loss of a substantial portion of added nitrogen at higher pH of the compost heaps.

The organic inputs for improving the quality of compost may include from a single cell bacteria (free living N-fixing organism) to a wide range of plant material of farm and agro-industrial origins like Blue-Green Algae, Azolla, Legume grasses, Legume crop plants, Agro-forestry leaves, Green manure plants, Water hyacinth, FYM, Cattle dung, Poultry manure, Slaughter house waste, Distillery waste, Wool waste, Leather waste, Paper mill waste, Biogas slurry, sewage sludge, Edible oil cakes and non-edible oil cakes of Neem, Karanz etc.

Application of suitable amount of low-cost rockphosphate may also increase the available phosphorus content of the compost by dissolution of rockphosphate during composting, especially if the process is accelerated with the help of a suitable P-solubilizing

microorganism. Free living N-fixing microorganisms may find suitable environment for their multiplication in the compost heaps and hence increase the total nitrogen of the compost and thereby improve the quality of the compost.

Another cheap mineral, pyrite, may also play useful role in arresting the loss of added/mineralized inorganic N in the compost.

Therefore, to achieve the objectives of (i) quick disposal through rapid composting of farm and city wastes, (ii) improvement of the manurial values of the composts and (iii) direct incorporation of crop residues for higher crop yield and productivity of soil, the following studies were undertaken, the results of which have been presented and discussed in the text of the thesis :

I. ✓ IMPROVEMENT OF MECHANICAL PLANT COMPOST

- a) Analysis of microbial population. Isolation, screening and identification of microorganisms from Mechanical Plant Compost at Bantaha, Calcutta.
- b) Enrichment of the compost with microbial cultures and mineral additives.

✓ II. PRODUCTION OF ENRICHED COMPOST FROM FRESH CITY GARBAGE.

✓ III. PRODUCTION OF ENRICHED COMPOST FROM FARM WASTES.

✓ IV. STUDIES ON THE DIRECT INCORPORATION OF CROP RESIDUE ON CROP YIELD AND PRODUCTIVITY OF SOIL.

- a) Effect on plant nutrient in soil.
- b) Effect on crop growth.

✓ V. USE OF REFUSE AS A SOURCE OF PLANT NUTRIENT IN SOIL. ✓

Chapter II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Since composting is a microbiological process, rapid decomposition of a particular organic material is dependent on the chemical composition and decomposability factor of the material as well as on the environmental factors acting on it. Work done in the past, on the factors responsible for rapid decomposition of municipal refuse and farm wastes, have been reviewed under the following subheads.

I. FACTORS RESPONSIBLE FOR RAPID COMPOSTING OF MUNICIPAL REFUSE AND FARM WASTES.

- i. Characteristics of the material
 - a) Carbon-Nitrogen relationship.
 - b) Size of the composting material.
 - c) Placement of material in compost heap.
- ii. Shape and size of the compost heap.
- iii. Moisture and aeration of the compost heap.
- iv. Temperature of the compost heap.
- v. Protection of compost heap.
- vi. Climatic conditions.
- vii. Reaction during composting.

viii. Period of composting.

ix. Destruction of pathogenic organisms.

x. Use of microbial inoculants.

xi. Conditions that interfere with composting.

i(a). Carbon-Nitrogen relationship :

The most important aspect of composting is C:N ratio of the decomposing material. The process of conversion is chiefly microbiological where carbon is utilized for growth of the microbes and nitrogen for protein synthesis. Since, living organisms utilize about 30 parts of carbon for each part of nitrogen (Waksman, 1938), an initial C:N ratio of 30 would seem more favourable for rapid composting (University of California, Berkeley, 1953; Waksman, 1938). Some research workers have reported optimum values from 26-35 (University of California at Berkeley, 1953; Lambert, 1931; Sinden, 1938; Acharya and Subrahmanyam, 1939; Cornfield, 1958) and a majority of investigators believed that for C:N ratios above there will be little loss of nitrogen and lower ratios cause increasing loss of N as ammonia. The University of California at Berkeley in 1953, studied the decomposition of materials with initial C:N ratios varying from 20 to 78 and with nitrogen content varying from 0.52 to 1.74 and observed that an initial C:N ratio of 30 to 35 was optimum.

Lowering of C:N ratio to 30:1 by addition of inorganic nitrogen was found to be superior by Bangar and Patil (1980) in hastening the degradation of wheat straw while 40:1 was considered optimum for rapid decomposition of wheat straw in soil by Hajra and

co-workers (1974). While composting rice straw with 0.60 and 0.15 per cent N as NaNO_3 in the laboratory Zayed et al. (1969) concluded that high dose of N were uneconomic in the composting of straw due to marked increase in denitrifying bacteria in 0.15 per cent N treated compost. On the contrary, instead of lowering the C:N, Polprasert et al. (1980) had to raise the C:N ratio of the mixture of water hyacinth and night soil to the level of 20-40 through the application of sufficient amount of leaves and to obtain most rapid decomposition at 30:1.

Knapp et al. (1983) noted enhanced rate of microbial respiration and growth during decomposition of wheat straw added with N which resulted decrease in C:N ratio from 150:1 to 48:1.

Therefore, by lowering C:N ratio of decomposing material through addition of judicious amount of inorganic nitrogen or by charging with nitrogen riched organic materials such as activated sewage sludge (University of California at Berkeley, 1953; Kochtitzky et al., 1969; Wiley and Spillane, 1962; Wiley, 1967), biogas slurry, cattle dung, legume plants, aquatic plants like water hyacinth, Azolla etc. the time of composting can be reduced.

i(b). Size of composting material :

Composting process can be accelerated if raw materials are shredded into smaller pieces to make these more susceptible to microbial attack due to exposure of greater surface area to achieve better initial aeration (University of California at Berkeley, 1953; Gotaas, 1956). Golueke et al. (1954) observed that the shredding

permitted more uniform and rapid decomposition while, unshredded developed anaerobic condition and not maintained the desirable temperature. Grinding also makes the material easier to handle and moisten. Gray and Sherman (1969) observed that grinding might double the amount of evolved CO_2 especially during the thermophilic stage. The desired size of the particle for composting is less than 2 inch. (5 cm).

i(c). Placement of the material in compost heap :

Placement of materials depends upon the type and arrangement of digest such as bins, cells, pits etc. Loose filling piles are not desirable for rapid decomposition and maintenance of optimum temperatures for destruction of pathogenic organisms. Gotaas (1956) suggested 5-6 ft. (1.5-1.8 m) as maximum height for any refuse and 3.5-5.0 ft (1-1.2 m) for municipal refuse compost. Acharya (1950) suggested composting in pits approximately 3 ft. (0.9 m) deep by a system of providing aerobic condition and high temperature for few days and then anaerobic conditions for 4-6 months.

In open heap or in large earthen pit, pile is often started with an 8" layer of carbonaceous material like straw, leaves, paper, sawdust etc. followed by a 4" layer of nitrogenous material like FYM, sewage sludge, cattle dung, biogas slurry etc. until the pile is 5 ft. high. This ratio of layer is necessary for efficient decomposition. A depression is made on the top to catch rain water. The whole pile may be covered with soil or dung to maintain heat and prevent loss of moisture.

ii. Shape and size of the compost heap :

Shape and size of the compost heap greatly influence the decomposition of the composting material. Since heat loss is proportional to surface area and heat generation is proportional to volume, the layer piles, having a smaller surface area to volume ratio, lose relatively less heat. In large piles, the temperature increases steadily with time. Yawalkar *et al.* (1962) demonstrated suitable sizes of trench, 15-20 ft. x 5-6 ft x 3-6 ft., pit (30' x 6' x 3') and for heaps a convenient length according to the material available for composting and width should be 8 ft. and height should be 4 ft.

In basic Indore method, pile is built at 7' or more in length, 7' width and 5' height. The sides are tapered so that the top is about 2 feet narrower in length and width than the base. Berkeley or Two week method (University of California at Berkeley, 1953; Rodale, 1971) produced the compost in 2 weeks having the heap size of 8' x 4' x 5'. Most successful municipal composting has been prepared with leaf windows (Randazzo, 1970; Johnston, 1971).

iii. Moisture and aeration of compost heap :

Moisture is an important parameter for compost pile. When the moisture is below 40 per cent (w/w) decomposition will be aerobic and slow. The optimal moisture is often 50-60 per cent (University of California at Berkeley, 1953; Kochtitzky *et al.*, 1969; Wiley and Pierce, 1955; Schulze, 1961; Gotaas, 1956; Kaibuchi, 1959; Teensma, 1962) but municipal refuse degrades best

at higher, 67% moisture level (Jeris and Regan, 1973). Several different aeration techniques have been utilized with varying degrees of success. Turning the materials was the most common method of aeration. Howard (1935), Scott (1952), Stovroff (1954), Westrate (1951) and others, turned the material in pits or piles for 1-4 or 5 times for a period of 1-6 months. If a long interval between turns or aeration is permitted active decomposition retarded by a change to anaerobic condition.

Wiley and Spillane (1962) found that the percentage by volume of O_2 was lower in the interior of the pile. The O_2 concentration was as high as 18.6% at 15 inches and as low as 1-2 per cent at 24 inches. An O_2 content as low as 0.5 per cent was observed inside municipal composting windrows without anaerobic symptoms (Kochtitzky et al., 1969; Schulze, 1961).

It is therefore, apparent that the rate of O_2 consumption by microorganisms during composting depends upon the moisture, temperature, particle size and the number of turnings. If a pile turns anaerobic, it may be returned to aerobic state by daily turning (University of California at Berkeley, 1953). Two to three turns per week are sufficient for aerobic decomposition of municipal refuse. Turning was done twice a week at University of California and five times a week at Jhonsen city (Kochtitzky et al., 1969). During turning and aeration, the interior aeration may drop 5-10°C. However, studies with municipal compost indicate that the pile returns to initial temperature within a few hours (University of California at Berkeley, 1953; Kochtitzky et al., 1969; Wiley and Spillane, 1962).

iv. Temperature of compost heap :

As microorganisms multiply in the decomposing mass, a rapid warming occurs. When the temperature moves above 40°C, the mesophilic stage is replaced by the thermophilic stage. This frequently occurs in 2-3 days (University of California at Berkeley, 1953; Olds, 1963). After the temperature in the middle of the pile stabilizes around 70°C, it gradually cools to ambient temperature. This pattern is typical for garden compost and municipal compost (Eastwood, 1952; Chang and Hudson, 1967; Kochtitzky et al., 1969). However, there is a longer temperature variation between the centre and surface of small heap. Decomposition is fastest in the thermophilic stage (Waksman et al., 1939). High temperature is also essential for destruction of pathogenic organisms particularly in municipal compost and weed seeds. The optimum temperature, based on oxidation of organic matter into carbon dioxide and water has been found to be 60°C by Wiley (1957), Wiley and Pierce (1955). Schulze (1961) showed a maximal temperature of 71°C as optimum, but temperature should not exceed 70°C for long because decomposition will be slowed down by a "Thermalkill" of microorganisms (University of California at Berkeley, 1953; Glathe, 1959). Greater microbial biomass and its activity at temperature below 58°C in sewage sludge compost was noted by Mckiwley and Vestal (1985). More recently, Jeris and Regan (1973) demonstrated that 59°C was optimal for composting fresh municipal refuse. Gaur et al. (1978, 1980) observed that the temperature of the compost pile did not go beyond 52°C when composting was done with high C:N ratio materials.

v. Protection of compost heap :

The compost heap should be protected from excessive rain-water and exposure to sunlight for maintaining the decomposition factor like moisture, aeration, temperature etc. under optimal conditions. Tarred cloth, Plaster layer etc. are placed around the edge to seal the cloth tightly to the pit. Open heap is covered with soil, cowdung etc. Wilson (1948) effected control of flybreeding in compost heap by placing a layer, about one foot thick, of grassy which contain no food for fly larvae.

vi. Climatic conditions :

Scott (1952) carried out a satisfactory composting in winter weather in Northern China by increasing the size of the composting mass, thereby reducing the heat loss per unit volume. During rainy weather shredding or grinding and segregation of materials should be done under cover. Van Vuren (1949) and Golueke et al. (1954) have shown that the temperature in the compost were not greatly lowered by rain.

vii. Reaction during composting :

The initial pH in compost is usually slightly acid (pH 6.0) as is the cell sap of most plants. The production of organic acids during the early stages of composting causes further acidifications (pH 4.5-5.0) but as the temperature rises the pH increases to slightly alkaline (pH 7.5-8.5) reaction (University of California at Berkeley, 1953; Gray et al., 1971; Kocktitzky et al., 1969).

The control of the pH in composting is seldom a problem requiring attention if the material is kept aerobic, but large amounts of organic acids are often produced during anaerobic decomposition. Ash, carbonates, lime or other alkaline substances may act as a buffer and keep the pH from becoming too low. However, the addition of alkaline material is rarely necessary in aerobic decomposition and infact, may do more harm than good because the loss of nitrogen by the evolution of ammonia as a gas will be greater at higher pH. Since the optimum pH for most organisms is around 6.5 to 7.5, it would probably be beneficial if the pH could be maintained in that range.

viii. Period of composting :

The time for "Ripening" is a function of variables such as C:N ratio, availability of carbon, shredding, shape and size of heap, moisture etc. Mostly, 1-6 month is allowed by different operators for decomposition of materials. In Berkeley (University of California at Berkeley, 1953) windrows ripened in two weeks; in the Netherlands (Gerretsen et al.^b, 1956) municipal windrows ripened in 7 weeks. In Indore process composting was done in 3 months.

ix. Destruction of pathogenic organisms :

Composting normally reduces the health hazard posed by pathogens and parasites if the minimal free-temperature conditions prevail. The requirement for windrow composting is apparently 18 to 21 days at temperature above 95°C although some pathogenic fungi survive the conditions (Golueke and McGauhey, 1970). The highest

thermal death points are appreciably lower than the maximum temperatures found inside the composting piles. A thermophilic temperature is developed after the initial aerobic stacking which is considered to be sufficient to destroy the pathogens and parasites. Scott (1952) found that atleast two turns were necessary to destroy Ent. histolytica in 12 days and three turns were required to destroy the eggs of A.lumbricoides.

✓ x. Use of microbial inoculants :

Addition of microbial inocula may be beneficial in a pile poor in microorganisms. Although this seldom occurs as has been observed in sawdust. Inoculation with spores of a cellulose decomposer and addition of ammonia, phosphoric acid and potassium sulphate shortened composting of saw dust from the usual 1-2 years to 3 months (Davey, 1953; Wilde, 1958). But recently successful results have been demonstrated in utilizing different cellulose decomposing cultures in rapid composting and phosphate solubilizing and nitrogen fixing organisms in improving the quality of composts prepared from wide C:N ratio wastes (Sadasivam et al., 1981; Goyal and Mishra, 1983; Kapoor et al., 1983; Shinde and Rote, 1983; Talashilkar, 1987; Shingte et al., 1990).

xi. Conditions that interfere with composting :

Since composting is microbiological, it requires optimal temperature, moisture, aeration, available Ca and N for growth and multiplication of microbes. Failure of a compost pile may be due to non-compliance of one or more of these essential factors.

Failure of the pile to heat may be due to the small size of the pile or due to too much or too little moisture. Occasionally in large piles the temperature may fall abruptly due to "Thermal Kill" of the microbes at temperatures above 70°C.

If the C:N is too high, sources of N can be added and for too low, sources of carbon should be added.

Pile should be large enough to retain more heat and adequately protected from loss of heat, loss of moisture, excess rain water etc.

Insufficient aeration can be solved by turning the pile.

For composting during winter, the pile should be insulated with soil, cowdung, leaves to prevent loss of heat. About choice of season, humid climatic condition during rainy season may be preferred.

II. ✓ ADDITIVES IN IMPROVING THE QUALITY OF COMPOST

Carbonaceous materials require much more time for composting and ultimately produce a low grade compost. Attempts were made for rapid composting as well as to improve the quality through application of additives.

Therefore, additives appear justified to improve the quality of compost from farm wastes of wide C:N ratios like cereal straw, saw dust, rice husk etc. Enrichment of N mineral of the compost may be enhanced by addition of N-rich organic inputs and by encouraging the growth of free living N-fixing organism and that of P by application of P-rich organic inputs and encouraging the solubilization of

added rockphosphorus by microorganisms.

Additives in composting was claimed by some investigators (Carberry and Finlow, 1928; Gadgil and Hegdekatti, 1937; McCool, 1942; Davey, 1953; Wilde, 1958) and negative results were obtained by others (Wood, 1938; Reinhold, 1938; University of California at Berkeley, 1953; Golueke et al., 1954; Rodale and Staff, 1971; Dai et al., 1972; Saito et al., 1972).

Literature accumulated on this part of study have been reviewed under the following sub-heads :

- ✓ i. Application of inorganic N and P.
- ✓ ii. Amendments of RP and P-solubilizing organism.
- ✓ iii. Application of free-living N-fixing bacteria.
- ✓ iv. Proportioning with N-riched organic inputs.

i. Application of inorganic N and P :

The organic materials having C:N ratios between 26 and 35 provide for rapid and efficient composting (Lambert, 1931; Sinden, 1938; Acharya and Subrahmanian, 1939; University of California at Berkeley, 1953; Cornfield, 1958). Lower ratios cause increasing loss of N as ammonia and higher values lead to progressively longer composting. To speed it up N can be added. Thus arises the scope of adding inorganic N when the C:N ratios of the decomposing material is too high. But preliminary results (Hankin et al., 1975) showed that when urea was added to lower C:N ratio, urease producing bacteria metabolized nearly all of it within 8 days. Most was volatilized as ammonia.

Although urea did not lower the C:N ratio for long earlier studies showed that ammonium sulphate effectively lowered the C:N ratio and improved the degradation (Poincelot and Day, 1973). While composting rice straw with 0.6 and 0.15% N as NaNO_3 in the laboratory (for 149 days) Zayed et al. (1969) observed that (i) the amount of $\text{NO}_3\text{-N}$ did not affect the activity of cellulose decomposition, non-symbiotic N-fixer, (ii) but denitrifying bacteria showed a marked increase in 0.15% N within 89 day and (iii) high doses of N were uneconomic in the composting of straw.

There is generally enough phosphate in the waste materials. Microbes need only 5-20% as much P as N (Alexander, 1961; Jeris and Regan, 1973). But several investigators have reported calcium phosphate increases the rate of decomposition and N conservation (Chekalov, 1955; Dhar et al., 1955; Dhar and Gupta, 1961). But that more than 2 per cent inhibited decomposition. Korovkin (1952) demonstrated that the addition of phosphate conserved N by decreasing the number of denitrifying bacteria. Similar results were reported by Tepla (1959). Compost is more effective when it is amended with mineral fertilizers (Honjyo, 1931; Russel, 1939; University of California at Berkeley, 1953; Reuszer, 1957; Gadzhieva, 1959; Vlamis and Williams, 1971). The addition of compost with fertilizer has been claimed to increase the availability of phosphate derived from fertilizer (Vyas and Motiramani, 1971).

Elserafy et al. (1980) composted water hyacinth mixed with ammonium sulphate, superphosphate and lime and recorded increase in protein content from 7.46% to 28.84% of dry matter after 175 days.

Bhriyuvanshi (1988) enriched the cattleshed waste and weeds with fertilizers. Phosphorus enrichment conserved N in the manure. Under field conditions, there was significant effect on yield and NPK uptake by wheat.

ii. Amendments of RP and P-solubilizing organisms :

There is generally enough phosphate in the organic wastes. Unlike nitrogen, it is not the limiting factor of composting. Microbes need only 5-20% as much as P as N (Alexander, 1961; Jeris and Regan, 1973). Several investigators have reported calcium phosphate increases the rate of decomposition and N-conservation (Chekalov, 1955; Dhar et al., 1955; Dhar and Gupta, 1961; Arzamasova and Kuzmenkova, 1962) but that more than 2% inhibited decomposition. Korovkin (1952) claimed that the addition of phosphate conserved N by decrease in the number of denitrifying bacteria. Similar results were reported by Tepla (1959). Berezova et al. (1955) claimed that N-fixation may be increased by adding phosphate. Therefore, if the added RP in compost heap is made to solubilize with the help of a P-solubilizer, the released P may be utilized by the N-fixer. Thus, the calcium phosphate plays significant role in compost pile by (i) increasing the activity of cellulose decomposer (Chang, 1939), (ii) decreasing the number of denitrifying bacteria (Korovkin, 1952; Tepla, 1959) and (iii) increasing the growth of N fixer (Berezova et al., 1955).

The investigation on chemical and microbiological solubilization of rockphosphate was carried out by Mey et al. (1986). They noted

the acidification of the medium by thiobacteria which led to the solubilization of 4% of the total phosphorus after 40 days. Addition of organic matter as a source of cellulose further increased the amount of solubilization to 5.5 per cent.

Goyal and Mishra (1983) reported the phosphatase activity and release of phosphorus during composting with fungal inoculants with Aspergillus awamori and Paecilomyces fusisporus and in the presence of phosphate. The addition of phosphate did not reduce phosphorus release in treatment without inoculation, but in inoculated samples it inhibited phosphorus release.

Thomas et al. (1985) reported the phosphate solubilizing power of different fungi, Aspergillus sp., Penicillium sp. isolated from coconut plantation soils in Kerala while Thomas and Shantaram (1986) reported the solubilization of inorganic phosphate bacteria from coconut plantation soil. Low organic matter and high temperature regime were attributed by Venkatesarlu et al. (1984) for low phosphate solubilizing organisms in aridisols where fungi were more efficient than bacteria due to production of organic acids like lactic, glucolic and succinic.

Inoculating rockphosphate amended composts with cultures of Azotobacter chroococcum and the phosphate dissolving strain, Aspergillus awamori, Sadasivam et al. (1981) reported increased total N and humus content.

Enrichment of compost by Azotobacter and phosphate solubilizing microorganisms have been claimed by Kapoor et al. (1983) for increased

N content of decomposed material and significantly increased citrate soluble P from rock phosphate.

Shinde and Rote (1983) used rockphosphate and microbial culture (Aspergillus sp., Penicillium sp. and Trichurus spiralis) for the composting of sugarcane trash by heap method and found that the superphosphate was better than bone meal or rockphosphate in these treatment combinations.

Greater dry matter yield and uptake of P resulting from increased solubilization of RP by Penicillium bilaji were recorded by Asea et al. (1988) when wheat was grown in a calcareous chernosem.

Shingte et al. (1990) reported the production of enriched sugarcane trash compost by adapting rapid composting technique and enriched with N-fixing (Azotobacter chroococcum) and phosphate solubilizing (Aspergillus awamori) cultures along with addition of 1 and 5 per cent RP as mineral additives. The available phosphorus and change of biochemical properties of chopped samples were more pronounced than unchopped compost.

✓ iii. Application of free living N-fixing bacteria :

Application of microbial inocula may be beneficial in a pile poor in that organism. Some recent studies have shown the beneficial effect of Azotobacter application in improving the quality of low grade compost (Kapoor et al., 1983; Shinde and Rote, 1983; Shingte et al., 1990). After a period of intense microbial degradation, when the heterotropic activity subsides, compost pile is treated with

Azotobacter chroococcum, both in the presence and absence of urea, Talashilkar (1987) reported the improvement in the quality of the product. During the later mesophilic stage, a yeast (Pullularia) which can fix atmospheric N was found by Nicholas (1965). This may have value in conserving or increasing N during storage of composts.

Gain of total N to the extent of 12% through nitrogen fixation during composting of cattle manure have been reported by Humbelin et al. (1980).

iv. Proportioning with N-rich organic inputs :

Composts have little nitrogen, phosphorus or potassium. The weight per cent varies for N 0.4 to 3.5, P 0.1 to 1.0 and K 0.2 to 2.0 as per following table.

Nutrient content of compost*

Type of compost	Per cent by weight of finished compost		
	Nitrogen (N)	Phosphorus (P)	Potassium (K)
Municipal ¹	0.4 - 1.6	0.1 - 0.4	0.2 - 0.6
Garden ²	1.4 - 3.5	0.3 - 1.0	0.4 - 2.0

¹Includes garbage, paper, household and yard trash.

²Includes garden wastes, fresh manure, digested sewage and soil.

Source : University of California at Berkeley, 1953 (Kortleven, 1951; Gerretsen et al.^a, 1956; Wiley and Spillane, 1962; Rodale and Staff, 1971).

It was observed that the above composition of the composts were obtained from the decomposition of a heterogenous mixture of organic wastes.

Thus the composition of the compost is dependent upon the composition of the starting material. The decomposition of straw like carbonaceous material produces low grade compost, for obvious reason of its wide C:N ratio, and there is every scope to improve its quality by proportioning with N and P rich organic inputs. Such organic inputs may include cattle dung, biogas slurry, FYM, poultry droppings, digested sewage sludge, blood meal, legume plants, water hyacinth, Azolla and even night soil. Nitrogen content and C:N ratio of some of those materials are reproduced in Annexure IV.

Not much information is available about the quantum of specific organic inputs to be added to improve the quality of straw compost to make it agronomically more viable. Since more and more N in compost is accumulated in organic forms and is released gradually, no restriction has been raised about the quality of organic inputs. Infact, alternate layers of carbonaceous and nitrogenous materials are piled for efficient composting. Sometimes, a mixture of two parts carbonaceous to one part nitrogenous materials is used but too much lowering of C:N ratios cause increasing loss of N as ammonia.

The increase in organically bound of straw mixed with cattle manure was observed by Meyer and Sticher (1983) which gradually decreased with extensive mineralization. A good quality of compost was prepared from straw, forest residue and dairy cattle manure by Hong et al. (1983) for use as a valuable acid soil conditioner.

Increased nitrogen mineralization and phosphorus immobilization during decomposition of organic materials of varying C:N and C:P ratio, were observed by Enwezor (1976). An increase in protein N from 7.46 to 28.84 per cent with concomitant decrease in C:N ratio from 40.28 : 1 to 9.5 : 1 was recorded by Elserafy et al. (1980) while composting water hyacinth with ammonium sulfate, superphosphate and lime. On the contrary, decomposition of water hyacinth with night soil demanded addition of sufficient amount of leaves to raise the C:N ratio of the mixture to 20 to 40 to obtain a most rapid decomposition at C:N ratio 30 : 1 although C:N ratio 20 : 1 contained a higher percentage of N, P and K (Polprasert et al., 1980).

Swine manures were enriched through cementkiln dust to complement the nutrient value and reduce the odour problems of swine slurries (Barrington and Mackenzie, 1989).

To obtain a high grade compost from farm wastes, Singh (1987) mixed it with a wide range of organic and inorganic inputs like dung, composts, soil including low grade rockphosphate. He noted that the cattle dung suppressed the decomposition and the inoculation of the wastes with Aspergillus awamori and Paecilomyces fuisporus was not satisfactory.

III. MICROBIAL BIOMASS AS AN INDEX OF SOIL FERTILITY

Microbial biomass is considered as active organic matter and nutrients become easily available from it. The biological stability of the compost may be an index of maturity. Investigators have correlated the microbial count and microbial biomass due to application of manures to the soil and the yield of crops (Taha et al., 1966). Rate of decomposition is also correlated with the change of microbial biomass. Decomposition of wheat straw evolved more CO₂ and higher microbial biomass (Jawson and Elliot, 1986). The proportion of total fixed ¹⁴C in the soil biomass as measured by a fumigation technique increased to a maximum value of 20% after 6 weeks in the sandy soil but decreased in clay soil from 86% at day 21 to 26% after 42 days plant growth (Merckx et al., 1985).

Microbial biomass was greatest in the organic manure plot, followed by the inorganic fertilizers plot and smallest in the no fertilizers plot (Hasebe et al., 1985) and did not find any significant relationship between the microbial biomass determined by Jenkinson's fumigation method and that by the direct counting method.

Microbial biomass was maximum in soil rich in organic matter (Dash et al., 1985) and four-fold increase in microbial population in cattle slurry treated soil (Kubista and Hons, 1977).

Incorporation of crop residues increased microbial biomass C (Carter, 1986) and greater at 40% water holding capacity of the soil (Minhoni and Cerri, 1987).

IV. DIRECT INCORPORATION OF CEREAL STRAW ON THE YIELD OF CROP AND PRODUCTIVITY OF SOIL

a) Effect on soil : Direct incorporation of crop wastes in the soil is suggested as a means of recycling of farm wastes for crop production purpose. As the process involves in situ decomposition, it requires supply of adequate amount of water besides other management practices. So far literature goes, no sound practices have come out to suggest direct incorporation of cereal straws without disturbing the growth of the following crop.

Different studies indicate that incorporation of straw maintained a higher rate of soil respiration coupled with nitrate depression throughout the period of incubation extended over 3 to 4 months duration (Waksman and Starkey, 1931; Voinova-Raikova, 1972; Debnath and Hajra, 1972; Bhardwaj and Novak, 1978). Martins and Kowald (1988) recorded decomposition to the extent of 46% and 90% after 3 months and 1 year respectively. This higher rate of soil respiration results greater loss of carbon, sometimes $\frac{3}{4}$ of the added carbon is lost as CO_2 leaving only $\frac{1}{4}$ th in the soil for building soil organic matter during 4 months decomposition (Debnath and Hajra, 1972). As the soil is left with less C for formation of humus after maintaining a definite proportion of C and N, the materials with wide C:N is likely to produce less amount of humus.

Again, direct incorporation of straw is handicapped because of the larger period of nitrate depression in soil. As means of overcoming nitrate depression and other toxic effect of reduction

Lande-Cremer (1975) suggested application of 5-7 kg N/ton of straw. Less loss of C from added straw when increasing amounts of N were added for microbial transformation in soil were also observed by Novak (1972), Hajra et al. (1974).

While studying the mineralization of phosphorus under the influence of decomposition of wide C:P ratio organic materials, rice husk and wheat straw in soil, Somani (1983) observed the immobilization of P especially during the early stage of decomposition.

Incorporation of straw increased the organic matter, humus balance, microbial activity, aggregate stability in soil (Debruck and Boguslaski, 1977).

Direct incorporation of rice straw along with N fertilizers increased negligible amount of soil organic matter but the production of phytotoxin during decomposition could be largely countered (Davies, 1982).

Continuous incorporation of straw led to increased humus content, microbial activity, a better soil structure and increase in level of K but not N and phosphorus (Debruck, 1974).

Marked improvement in soil properties including significant increase in organic C and NPK due to continuous recycling of crop residues for seven years in rice-wheat rotation has been reported by Bhat et al. (1991).

b) Effect on yield of crops : Some experimental results derived from direct incorporation of cereal straws along with fertilizers have been compiled hereunder.

Sidorenko et al. (1978) observed the biological activity and yield of rice when straw was used as a fertilizers in loamy meadow soils. The incorporation of straw from 4 to 8 tons ha^{-1} with $\text{N}_{200}\text{P}_{90}\text{K}_{90}$ increased the exchangeable $\text{NH}_4\text{-N}$, available P, exchangeable K, biological activity and yield of rice on all soils. However, in the absence of NPK the greatest increase of grain yields were obtained with 4 tons ha^{-1} straw on light meadow and with 8 tons ha^{-1} on meadow-bog soil.

The incorporation of cereal straw combined with application of N fertilizers resulted higher cereal yields than when no straw was applied and response to N was positive upto 120 kg ha^{-1} for cereals and 200 kg N for potatoes (Kurten, 1977).

Kuszelewski (1970) studied on straw as an organic fertilizers when it was incorporated along with nitrogen fertilizers. The effect of 50 q ha^{-1} straw and 40 to 100 kg ha^{-1} N was approximately the same as that of 200 q ha^{-1} FYM.

Ulman (1971) reported the effect of straw manuring on the yields of potatoes and oats in the mountain zone. Straw with mineral fertilizers could be substituted by FYM and without addition of N with straw decreased the yields of oats.

Ismunadji (1978) examined the effects of incorporation of rice straw, rice straw compost alone or with leaf mould, urine or manure;

partially decomposed straw, minimum tillage plus straw or burning of straw on the yield of succeeding crops. The effects of the date of straw incorporation prior to sowing of lowland rice were also included.

Incorporation of 20 t rice straw ha^{-1} into soil at 4 week prior to transplanting lowland rice increased rice grain yields from 2.78 to 3.06 t ha^{-1} , yields were 2.17, 2.58 and 2.66 t ha^{-1} for the untreated control, incorporation of 10 t rice straw ha^{-1} and burning of 10 t straw ha^{-1} respectively.

Soybean seed yield increased from 410 to 640, 450 and 810 kg ha^{-1} when 40 t straw ha^{-1} was incorporated into the soil, 20 t straw ha^{-1} was burnt and 20 t straw ha^{-1} was used as mulch, respectively in the 2nd year of the trial.

Wheat straw incorporation in crop rotation recorded 12.7, 6.7 and 20.4% net profit of field crops, maize, pea and sunflower respectively compared with unfertilized control treatments (Tikhonov, 1980).

Chapter III

MATERIALS AND METHODS

1. Location of the study :

Experiments of the present study were carried out in laboratory, pit and in pot. The incubation experiments were carried out in the laboratory under room temperature. The pit experiments to study the rapid decomposition as well as enrichment of composts were carried out in especially constructed cemented pits in rows of 10 m^3 in size and provided with a permanent shed on them. Pot culture experiments were carried out in an alluvial soil collected from fallow land in C-Block Farm of the Viswavidyalaya. The composition of the soil has been shown in Table 1.

2. Materials used :

a) City compost and other wastes : The processed city compost was collected from Mechanical Compost Plant at Bantala, Calcutta, West Bengal. The composition has been shown in Table 1. The other agricultural wastes like straw, cowdung, FYM and animal faeces were collected from the farm of the National Dairy Research Institute, Kalyani, Nadia. Dairy sludge was obtained from the Central Mother Dairy, Calcutta.

The chemical composition and other relevant characteristics of the organic materials have been shown in Table 1.

b) Microbial culture :

i) Phosphate solubilizing organisms : Phosphate solubilizing organisms, consisted of fungi (Penicillium sp., PFC₅) and bacteria (Bacillus sp., PBC₁, PBC₃, PBC₇) were isolated in this laboratory by S.Kole, Research Scholar, from Mechanical Plant compost at Bantala, Calcutta, W. B. Another tested and efficient P-solubilizing organism, Aspergillus awamori, was collected from the Division of Microbiology, Indian Agricultural Research Institute, New Delhi. The P-solubilizing power of the newly isolated organisms in comparison to a standard, Pseudomonas striata, was in the order : Penicillium sp., PFC₅ > Bacillus sp., PBC₁ > Bacillus sp., PBC₇ > Pseudomonas striata > Bacillus sp., PBC₃.

ii) Free living N-fixing bacteria : The specific species of nitrogen fixing bacteria, Azotobacter chroococcum, was collected from the laboratory "Survey, selection and mass production of nodule bacteria" of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal.

iii) Cellulose decomposing microorganisms : Cellulose decomposing microorganisms, Trichurus spiralis and Paecilomyces fuisporus, were collected from the Department of Bacteriology, M.P.Agricultural University, Pune and the most efficient strain, Aspergillus nidulans was a isolate of this laboratory.

c) Other amendments : The cheap quality rockphosphate (RP), Mussoorie Phos and Pyrite were collected from M/s. Pyrites, Phosphates and Chemicals Ltd., 9, Syed Amir Ali Avenue, Calcutta 17. Their relevant characteristics have been shown in Table 1.

d) Culture media used :

Composition

The following culture media were used for different microbiological estimations.

- i) Potato-Dextrose Agar (Ricker and Ricker, 1936) for maintaining and mass culturing of cellulose decomposing organism.
- ii) Thornton's Agar (Thornton, 1922) for counting total viable bacteria.
- iii) Remy's nutrient Agar (Allen, 1957) for estimating ammonifying bacteria.
- iv) Jensen's Agar (Jensen, 1942) for free living nitrogen fixing organism (Azotobacter sp.).
- v) Pikovskaia's medium (Pikovskaia, 1948) for isolating P-solubilizing bacteria.
- vi) Martin's Rose Bengal-Streptomycin Agar (Martin, 1950) for total count of fungi.
- vii) Burns and Slater medium (Burns and Slater, 1982) for isolating cellulose decomposing bacteria.
- viii) Eggins and Pugh medium (Eggins and Pugh, 1962) for isolating cellulose decomposing fungi.

e) Seeds and seedlings :

All seeds and seedlings were collected from the Research Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia.

3. Methods followed :

The methods which were followed in different experiments were as under :

A. Analyses of compost and soil :

i) pH : pH of the compost and soil samples were determined with a glass electrode pH meter using material : water in the ratio of 1 : 2.5.

ii) Organic Carbon : Organic carbon of the compost was determined by Dry Combustion in a muffle furnace at 600°C for 10-12 hours and calculating the per cent carbon following the equation : $100 - \% \text{ ash} / 1.8$ as described by Waggoner (1974) on the assumption that the dry weight per cent of the organic carbon averages 56% or $100 / 1.8$.

Soil organic carbon was determined by Walkley and Black's method as described by Jackson (1967).

iii) Total, Ammonium and Nitrate Nitrogen : 1 g dried soil or 0.25 - 0.50 g dried compost was used for determination of total N following modified Kjeldahl method. Distillate was collected in 4% boric acid with mixed indicator.

A fresh soil or compost sample of 20 g was used for the determination of ammonium and nitrate nitrogen through KCl leaching

method. MgO was used as alkali. After distilling off the ammonium nitrogen, the content of Kjeldahl flask was brought to room temperature and Devarda's alloy was added for conversion of nitrate to ammonium form. After 30 minutes reacting, second distillation was continued. Both the results have been expressed on oven dry basis at 60°C.

iv. Forms of phosphorus :

a) Water soluble phosphorus : Water soluble phosphorus of soil and compost was determined using material : water in the ratio of 1 : 20 and estimating the phosphorus by A.O.A.C. method (1980).

b) Olsen's phosphorus : Olsen's et al. (1954) extractant and estimation by Dickman and Bray's method (1940) were followed for the determination of available phosphorus of soil and compost samples.

c) Citrate soluble P : Citrate soluble phosphorus of soil and compost was determined following the method as described in A.O.A.C. (1980).

v. Estimation of soil biomass carbon : Each 50 g portion of fresh soil was taken in four separate petridishes. Two of them were fumigated with chloroform in a vacuum desiccator for 24 hours. Each soil sample was then thoroughly mixed with 1 g of original soil as inoculum and was transferred to a 500 ml Earlenmayer flask. Water was added to attain a moisture equivalent to 55% W.H.C. of the soil. The evolved CO₂ due to decomposition of biomass, at 25°C was absorbed

in a standard NaOH solution contained in a tube kept suspended inside the flask. After 10 days incubation, the tube containing NaOH solution was taken out and the excess alkali was back titrated after addition of excess BaCl_2 solution and thus the amount of CO_2 evolved was calculated. The biomass C was calculated as per following equation as described by Jenkinson and Powlson (1976). The results have been expressed on oven dry basis.

$$\text{Total microbial biomass C} = \frac{(\text{CO}_2\text{-C evolved from fumigated soil} - \text{CO}_2\text{C evolved from nonfumigated soil})}{\text{Fractionation of biomass C mineralized to CO}_2 \text{ over the 10 days incubation period (K)}} \quad (\text{F})$$

i.e. F/K . The value of K has been found to be 0.45.

vi. Water Holding Capacity : Water holding capacity was ? determined by the Keen-Raczkowski box experiment as described by WHC Piper (1950).

B. Analyses of Plant :

i) Total Nitrogen : 0.25-0.50 g portion of oven dried straw or grain was digested in H_2SO_4 -Salicylic acid mixture and the total nitrogen was determined as per procedure described by Jackson (1967).

ii) Total Phosphorus : 0.5 g portion of oven dried straw or grain sample was digested in 10 ml of tri-acid mixture of HClO_4 : H_2SO_4 : HNO_3 :: 1 : 2 : 5 (v/v) and phosphorus was estimated

colorimetrically by Vanadomolybdophosphoric yellow colour method as described by Jackson (1967).

C. Analysis of Rockphosphate :

Total P : 0.5 g rockphosphate was dissolved in 10 ml of tri-acid mixture and P of the digested extract was determined by Vanadomolybdophosphoric yellow colour method as described by Jackson (1967).

TABLE 1. Composition of the materials used in study

Materials used	C o m p o s i t i o n									
	W.H.C. (%)	pH (1:2.5)	Org.C (%)	Total N (%)	C:N	NH ₄ -N (ppm)	NO ₃ -N (ppm)	Total P (%)	Av.P (ppm)	CSP (ppm)
1. Mechanical Plant Compost, Bantala, Calcutta.	18.5	7.0	7.70	0.406	18.96	44	806	0.302	101	-
2. Pot culture soil (Indo-gangetic alluvium)	40.0	7.0	0.58	0.130	4.46	11	35	0.208	15	-
3. Paddy straw	-	-	48.72	0.516	94.00	-	-	0.074	-	-
4. Cowdung	-	-	31.96	1.176	27.00	49	21	0.490	-	-
5. Dairy sludge (Central Mother Dairy, Calcutta)	-	7.2	32.80	2.490	13.17	234	493	2.475	360	13.25
6. Rockphosphate (Mussoorie Phos)	-	-	-	-	-	-	-	17.200	-	-

CSP = Citrate soluble P.

WHC = water holding capacity

Chapter IV

EXPERIMENTS, RESULTS AND DISCUSSION

Section I

**"IMPROVEMENT OF THE QUALITY
OF MECHANICAL PLANT COMPOST"**

IMPROVEMENT OF THE QUALITY OF MECHANICAL PLANT COMPOST

As a part of National Project some Mechanical Compost Plants were installed in the cities of Ahmedabad, Bangalore, Baroda, Bombay, Calcutta, Delhi, Jaipur and Kanpur during the Fifth Five Year Plan to convert city garbage into manure. One of such plants has been installed by the West Bengal Agro-Industries Corporation at Bantala, Calcutta to convert a part of the daily accumulation of total 2,250 MT (Dutt Gupta et al., 1986) of city garbage into compost primarily to meet the growing demand of ground for further dumping and better utilization of processed compost for higher crop yield as secondary and also for maintaining the environment of Calcutta better for human living.

But the compost processed by the plant could not be made popular mainly due to, besides other factors, its low plant nutrient content. But working on the composition of Bantala compost, Dutta Gupta et al. (1986) laid much stress for utilization of city garbage for the preparation of compost for higher

crop yield. Although some improvements in the quality of mechanical plant compost due to inoculation with microbial cultures alone or in combination with inorganic fertilizers have been reported by Gaur (1987), Talashilkar (1987), Rasal et al. (1987) but its long term agronomic effect on the yield of crops, biological activity of residual soil etc. has not been evaluated. Therefore, efforts for developing appropriate technology for application of such microbial inocula during the operation of compost plant, it was found worthwhile to study the native microorganisms of the compost and to assess whether fresh application of cellulose decomposing culture is needed or not. With that object in view, (i) the total microbial population of the Mechanical Plant Compost was studied with emphasis on cellulose decomposing microorganisms in the first attempt, (ii) improvement in the quality of the compost by enrichment with microbial cultures along with mineral additives were taken up in the second phase, and (iii) evaluation of enriched mechanical plant composts by yield of successive crops were studied at the last.

I. MICROBIAL COMPOSITION OF MECHANICAL PLANT COMPOST WITH PARTICULAR REFERENCE TO CELLULOSE DECOMPOSING MICROORGANISM

Experimental :

The mature compost from Mechanical Compost Plant at Bantala was collected which has been described in Table 1. The microbial composition of the compost was studied by serial dilution pour plate technique. Total bacteria, total fungi, ammoni-

ifying bacteria, phosphate solubilizing organisms (bacteria and fungi), non-symbiotic nitrogen fixing bacteria, cellulose decomposing bacteria and cellulose decomposing fungi were isolated and studied using specific culture media as described under "Materials and Methods".

The colonies of cellulolytic fungi and bacteria developed on respective plates were transferred in agar slants containing the same medium and the isolates were purified by repeated plating following serial dilution pour plate technique. Initially 20 fungal and 30 bacterial strains were purified and were screened to four fungi and four bacteria following quantitative study of decomposition of cellulose by filter paper strips using the respective medium used for counting except the agar and cellulose. The strains were coded as 'CFC' and 'CBC' with suffix numbers for cellulose decomposing fungi and bacteria, 'PFC' and 'PBC' for P-solubilizing fungi and bacteria respectively. The selected strains were identified according to the methods followed by Gilman (Gilman, 1959) using Czapek's solution agar medium (Tuite, 1969) for fungi upto specific level and Bergey's manual (Buchanan and Gibbons, 1974) for bacteria upto generic level.

For estimating the efficiency of cellulose decomposing organisms, the experiment was divided into two sets, of which the rate of decomposition in terms of CO_2 evolution and total loss in weight were measured in first and second set respectively. A standard strain, Paecilomyces fusisporus, was taken for comparison. In the first set, each 20 g portion of dried, powdered and

partially sterilized paddy straw was mixed with rockphosphate at 1% and urea at 0.5% to enrich the straw with mineral nutrient and to lower the C:N to about 60. Fungal and bacterial inoculants were added at 0.5 g of mycelial mat suspension and 10^6 cells kg^{-1} of straw respectively and were taken in one litre conical flask after maintaining moisture at 60% WHC. The flasks were incubated at $30 \pm 1^\circ\text{C}$. A control set without inoculation was also provided. The rate of decomposition was measured in terms of CO_2 evolved at a regular interval till 90 days period as per procedure described by Debnath and Hajra (1972).

In the second set, each one kg portion of dried, unsterilized chopped straw was treated in the same way as that of first set and were taken into series of polythene bags which were placed under soil after inserting some plastic tubes for aeration. This was done with the object of utilizing the evolved heat for decomposition. Each treatment was replicated thrice. After 90 days decomposition, bags were removed, weights were recorded and samples were drawn for calculation of total loss in weight and determination of organic C by dry combustion as described by Waggoner (1974).

The phosphate solubilizing power of the isolates was determined in terms of amount of P solubilized in Pikovskaia broth from insoluble tri-calcium phosphate.

Results and Discussion :

The micro population of Bantala Plant Compost has been shown in Table 2. The number of bacteria was found to be much higher than

TABLE 2. Microbial composition of Mechanical Plant Compost .

Microorganisms	Number ($\times 10^4$) per g dry compost (average of 3 replicates)	Percentage of different micro- organisms over total bacteria/ fungi
Total bacteria	1,770	
Ammonifying bacteria	1,250	70.6
P-solubilizing bacteria	500	28.2
Cellulose decomposing bacteria	122	6.9
Non-symbiotic N-fixing bacteria	57	3.2 ?
Total fungi	10.8	— <i>Actinomyces</i>
P-solubilizing fungi	3.3	30.5
Cellulose decomposing fungi	7.5	69.4

fungi. Ammonifiers occupied more than 70% of the total bacterial population in contrast to 3.2% non-symbiotic nitrogen fixers. Cellulose decomposing fungi and bacteria contributed 69.4 and 6.9 per cent of fungal and bacterial population respectively whereas phosphate solubilizers covered 30.5 and 28.2 per cent respectively.

Among the 4 cellulose decomposing fungi, one was Penicillium varioti (CFC₈) and three were of the genus Aspergillus, of which two were A. terreus (CFC₁ and CFC₁₃) and one was A. nidulans (CFC₆). All the four cellulose decomposing bacteria were of the genus Bacillus (CBC₅, CBC₁₂, CBC₂₄ and CBC₂₇).

The efficiency of cellulose decomposing isolates was estimated in terms of the rate of evolution of CO_2 , total amount of CO_2 evolved and total loss in weight of fixed amount of paddy straw treated with selected isolates (Figs. 1 & 2; Table 3). In all the treatments, the rate of respiration was highest during 72 hours of incubation, followed by a gradual decrease which became near constant during the day 30 of decomposition. In almost all the stages of incubation, A.nidulans produced higher amount of CO_2 except the period between 20-40 days, P.varioti till day 15, whereas P.fusisporus dominated during the later stages of decomposition. Bacterial inoculants produced lower quantities of CO_2 in comparison to fungal cultures. Among the bacterial isolates, Bacillus (CBC₁₂) produced higher CO_2 in almost all the stages of incubation except at day 30, when it was dominated by another strain of Bacillus (CBC₂₇). The rate of respiration till 90 days, differed from each other and maintained the order for fungi as A.nidulans > P.fusisporus > P.varioti > A.terreus (CFC₁) > A.terreus (CFC₁₃). For bacterial strains it was in the order of Bacillus CBC₁₂ > CBC₂₇ > CBC₅ > CBC₂₄.

The efficiency of the microorganisms, when considered in terms of total CO_2 evolved in 90 days period, was found to be in the order, A.nidulans > P.varioti > P.fusisporus > Bacillus sp. CBC₁₂ > CBC₂₇ > CBC₅ > A.terreus (CFC₁₃) > A.terreus (CFC₁) > Bacillus sp. CBC₂₄. In fact, the microorganisms which remain more active during the initial period of decomposition is considered more suitable so far as rapid composting is concerned and in

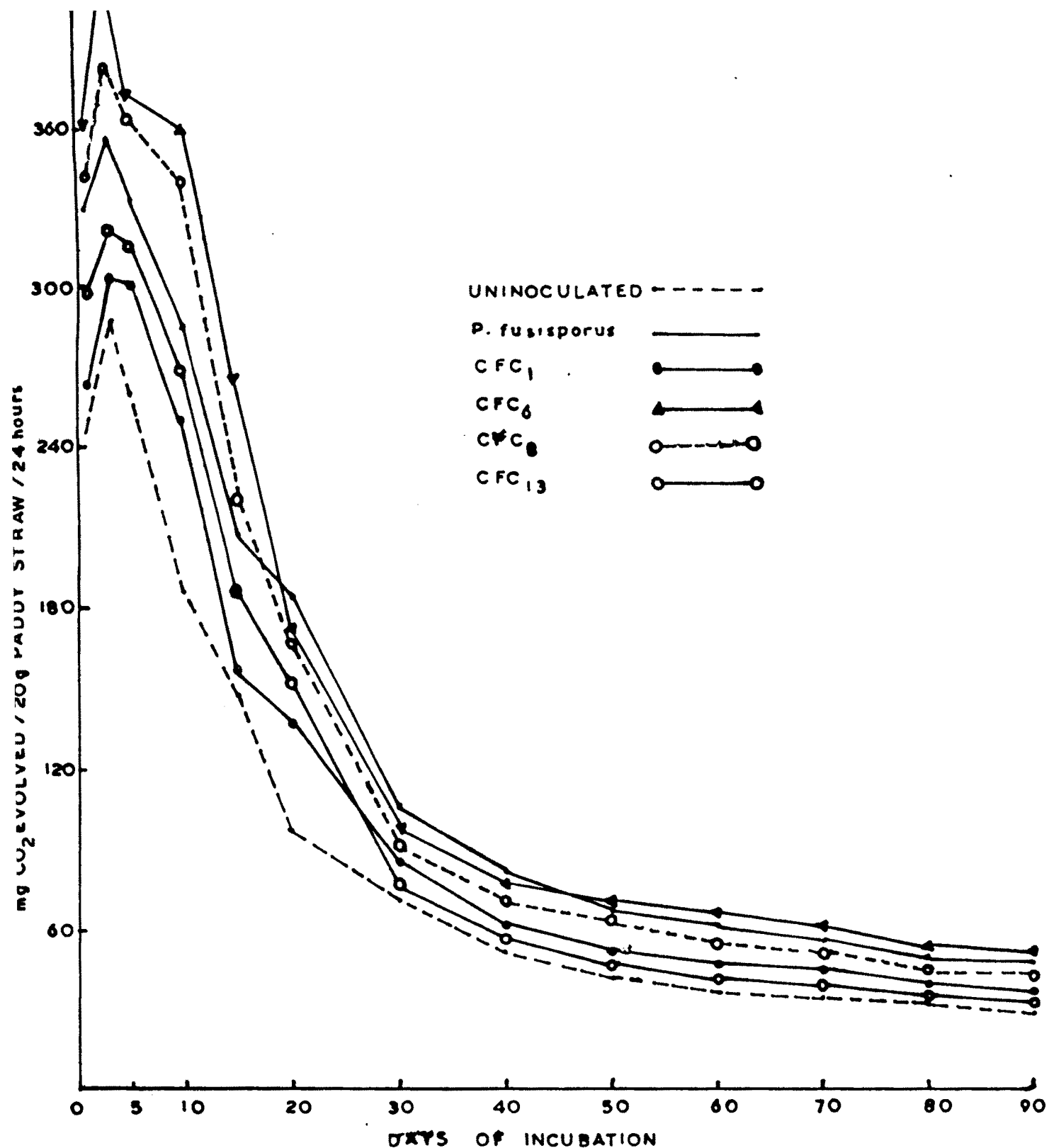


FIG.1 : RATE OF CO₂ EVOLUTION DURING DECOMPOSITION OF PADDY STRAW WITH FUNGAL INOCULANTS

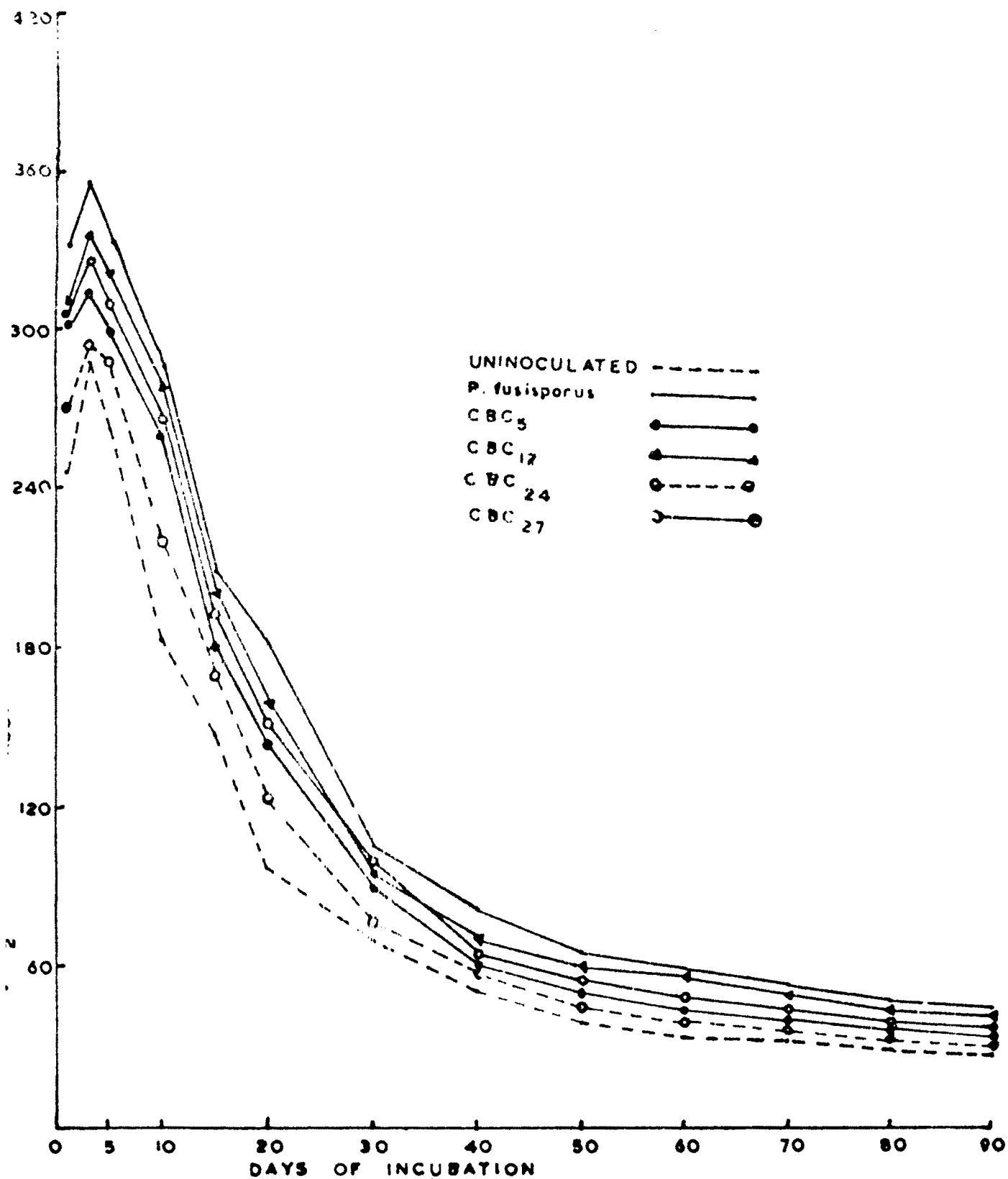


FIG.2 : RATE OF CO₂ EVOLUTION DURING DECOMPOSITION OF PADDY STRAW WITH BACTERIAL INOCULANTS

TABLE 3. Composting of rice straw by the use of selected microbial inoculants (isolated from Bantala compost) at 90 days incubation. Organic carbon of fresh straw = 49.6%. Compost samples were dried at 80°C. (Data average of three replications).

Code number	Organism Name	Total CO ₂ evolved/ ² 20 g straw (mg)	Decomposition (%)	Organic C (%)
Uninoculated control		6577	52.0	36.3
CFC ₁	<u>Aspergillus terreus</u>	7772	56.9	34.0
CFC ₆	<u>A.nidulans</u>	10908	69.7	31.2
CFC ₈	<u>Penicillium varioti</u>	9979	64.7	32.5
CFC ₁₃	<u>A.terreus</u>	8099	64.5	32.8
CBC ₅	<u>Bacillus</u> sp.	8211	63.6	34.2
CBC ₁₂	<u>Bacillus</u> sp.	9268	64.0	33.0
CBC ₂₄	<u>Bacillus</u> sp.	7631	62.3	34.6
CBC ₂₇	<u>Bacillus</u> sp.	8766	63.0	33.5
<u>Paecilomyces fusisporus</u> (standard)		9806	64.5	32.7

that context the new isolates of A.nidulans and P.varioti were considered much more effective than the standard culture of P.fusisporus.

The per cent loss in original weight due to inoculation of rice straw with selected cellulolytic cultures and decomposition for 90 days has been shown in Table 3. Per cent decomposition varied from 56.9 to 69.7 compared to control of 52.0. This variation in decomposition is attributed to the efficiency of microbial inoculants. Application of culture enhanced the decomposition leading to greater loss in weight, ranging from 12-17 per cent over control for fungal inoculants and 10-12 per cent for bacterial inoculants with concomitant decrease in organic carbon ranging from 31.2 to 34.2 per cent from initial value of 48.9 per cent. This is possible, as the enhanced rate of decomposition resulted greater loss of organic carbon. Thus the efficiency of inoculants were graded in the order : A.nidulans > P.varioti > P.fusisporus > A.terreus (CFC₁₃) > Bacillus sp. (CBC₁₂). Here also fungi were more efficient than bacteria. It is noteworthy that A.terreus (CFC₁₃) although not prominent in the laboratory condition but it was as active as P.fusisporus in compost system at natural field condition. A significant negative correlation between organic C and Total CO₂ evolved, decomposition and organic C of the compost and a positive correlation between decomposition and total CO₂ evolved were obtained (Table 4).

The efficiency of P-solubilizing microorganisms isolated from mechanical plant compost has been shown in Table 5. Their efficiency was estimated in terms of amount of P-solubilized in

TABLE 4. Interrelationship between magnitude of decomposition, organic C and total CO₂ evolved after 90 days decomposition. Values are significant at 1% level(*).

Relationship between	Correlation coefficient
Organic C and total CO ₂ evolved	-0.924*
Decomposition and total CO ₂ evolved	0.846*
Decomposition and organic C	-0.889*

TABLE 5. P-solubilizing power of isolated microorganisms at 30 days.

Organisms	ug P solubilized/ 15 g insoluble P *
PBC ₁ <u>Bacillus</u> sp.	589.0
PBC ₃ <u>Bacillus</u> sp.	506.6
PBC ₇ <u>Bacillus</u> sp.	585.0
PFC ₅ <u>Penicillium</u> sp.	628.4
<u>Pseudomonas striata</u> (standard)	546.5

* 75 mg Ca₃(PO₄)₂/0.15 g sucrose.

Pikovskaia broth from tricalcium phosphate in comparison to a standard organism, Pseudomonas striata. It is observed from the data that the P-solubilizing power of the isolates were in the order : PFC₅ (Penicillium sp.) > PBC₁ (Bacillus sp.) > PBC₇ > (Bacillus sp.) > Pseudomonas striata > PBC₃ (Bacillus sp.).

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Therefore, the present study show that the city compost processed at Bantala was infested with a number of efficient cellulolytic organisms and for obvious reason application of fresh culture is not required so far as rapid composting is concerned. Moreover, the present study lead to the identification of a few more efficient fungal strains, mainly Aspergillus nidulans and Penicillium varioti which offered scope for their culturing and use as inoculants in the rapid composting of farm waste material.

II. ENRICHMENT OF MECHANICAL PLANT COMPOST WITH P-SOLUBILIZING AND N-FIXING ORGANISMS ALONGWITH MINERAL ADDITIVES AND ITS EVALUATION.

A. Enrichment :

Each 40 kg portion of mechanical compost was taken in cemented pit and was treated as per following schedule of treatment.

- T₁ = Mature compost (MC)
- T₂ = MC + Rockphosphate (RP)
- T₃ = MC + Azotobacter (Azot.)
- T₄ = MC + RP + Azot.
- T₅ = MC + RP + Azot. + P-sol. I (PFC₅)
- T₆ = MC + RP + Azot. + P-sol. II (PBC₇)
- T₇ = MC + RP + Azot. + P-sol. III (PBC₃)
- T₈ = MC + RP + Azot. + P-sol. IV (PBC₁)
- T₉ = MC + RP + Azot. + P-sol. II + N (1%) + Pyrite (5%).

Rockphosphate, pyrite and urea-N were added @ 1, 5 and 1 per cent

respectively of the material. All the microbial cultures and mineral supplements were added at the start of the experiment. The microbial inoculants were consisted of selected cultures of fungi, PFC₅ (Penicillium sp.) and bacteria, PBC₁, PBC₃ and PBC₇ (Bacillus sp.) and all were efficient in solubilizing rockphosphate. Nitrogen fixing organism was Azotobacter chroococcum. Bacterial cultures were added @ 10^6 viable cells kg^{-1} of compost whereas fungal cultures were added @ 500 g mycelial mat ton^{-1} of material. Moisture was maintained at 50% WHC of the compost throughout the period of 6 weeks decomposition. At the end, whole material was removed from the pit, mixed thoroughly and samples were drawn for analyses of total N, $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, available P and total P as per procedure described by Jackson (1967). Organic C and biomass C were determined following the methods as described by Waggoner (1974) and Jenkinson and Powlson (1976) respectively.

Results and Discussion :

i) Changes in chemical nutrients : The chemical composition and biomass C of the enriched city compost at six weeks decomposition have been shown in Table 6.

It is observed from the data that the organic C of the treated composts including control (T_1) decreased from the initial value possibly due to further decomposition of six weeks period. Those decrease in carbon might be due to further mineralization of compost after receiving adequate moisture along with microbial inoculants and supplements of minerals through rockphosphate and pyrite.

TABLE 6. Chemical composition and Biomass of Enriched Compost

Treatments	pH	Org. C (%)	Total N (%)	C:N	NH ₄ -N (ppm)	NO ₃ -N (ppm)	Total P (%)	C:P	Av. P (ppm)	Biomass C (g/40 kg compost)
Original compost	7.0	7.70	0.406	19.0	44	806	0.302	25.5	101	-
T ₁ Compost alone (C)	7.2	7.00	0.455	15.4	28	554	0.300	23.3	133	50.66
T ₂ C + RP	7.3	6.77	0.455	14.9	21	589	0.350	19.3	144	73.47
T ₃ C + Azot.	7.3	7.15	0.490	14.6	46	734	0.295	24.2	161	98.32
T ₄ C + RP + Azot.	7.3	7.25	0.500	14.5	36	775	0.315	23.0	150	102.24
T ₅ C + RP + Azot. + PS I (PFC ₅)	7.2	6.89	0.540	12.8	48	895	0.327	21.0	180	112.00
T ₆ C + RP + Azot. + PS II (PBC ₇)	7.2	6.77	0.560	12.0	40	967	0.327	20.7	166	130.54
T ₇ C + RP + Azot. + PS III (PBC ₃)	7.2	7.43	0.537	13.8	38	910	0.382	19.5	142	135.60
T ₈ C + RP + Azot. + PS IV (PBC ₁)	7.3	7.48	0.518	14.4	40	965	0.345	21.7	153	130.64
T ₉ C + RP + Azot. + PS II+N+Pyrite	7.4	7.77	0.682	11.4	431	792	0.317	24.5	155	132.76
CD at 5%	0.86	0.86	0.065		16.808	48.65	0.005		6.22	23.26

Total N of the treated composts increased ranging from 7.7 to 49.9 per cent over control while the increase due to Azotobacter in presence of rockphosphate and P-solubilizing cultures was in the range of 13.84 to 23.07 per cent. Kapoor et al. (1983) also observed increase in N content when Azotobacter was inoculated into already decomposed material. The maximum increase was recorded in treatment T₉ where combination of treatments were applied along with inorganic N and Pyrite. Among the P-solubilizers, bacterial cultures effected greater increase than fungal cultures, possibly through greater production of microbial biomass at above neutral pH of the compost.

Those decrease of org. C and increase in total N with decomposition resulted a lower C:N ratio in all the treatments as also noted by Gaur (1987). Barring maximum reduction in C:N in treatment T₉ where inorganic N was applied, the next greater reduction was effected in the treatment T₆ where Azotobacter was applied in combination with rockphosphate and bacterial culture of P-solubilizer.

Both NH₄-N and NO₃-N of the treated composts increased significantly over respective control except in treatment T₂. Those increases in NO₃-N were to the extent of 6.31 to 74.54 per cent over control and 10.79 to 19.97 per cent over initial value in treatments T₅ to T₈. The decreases in NH₄-N and NO₃-N over their respective initial values might be due to their immobilization by enhanced microbial activity. Those losses in NO₃-N were possibly overcome in treatment T₅ to T₈ by the combined activity of

Azotobacter and P-solubilizing cultures through higher production of microbial biomass and subsequent addition of $\text{NO}_3\text{-N}$ through mineralization of microbial biomass protein.

With the increase in total P, the C:P ratio was brought down from 25.5 to 19.3. Available P of the treated composts increased significantly with maximum record in treatment T_5 followed by T_6 where combined cultures were applied along with rockphosphate possibly through higher rate of mineralization of compost. Increase in citrate soluble P was noted by Kapoor et al. (1983) when compost material was inoculated with Aspergillus awamori along with rockphosphate.

The microbial biomass C of the enriched city compost increased markedly ranging from 1.45 to 2.68 fold of the control. The highest gain was recorded in one of the combined culture receiving treatments, T_7 . Increased production of microbial biomass predict the possibility of greater dissolution of rockphosphate by P-solubilizing organisms and simultaneous utilization of the same by Azotobacter. The effect was found to be more pronounced with bacterial culture of P-solubilizer than fungal one, possibly due to increased activity of bacterial culture at higher pH of the compost. The combined inoculant survived significantly over the uninoculated control. Thus, the amount of biomass C present in a biologically stable compost plays an important role in determining the quality of the compost.

Therefore, it is observed that the cheaper sources of mineral rockphosphate and pyrite are the prospective amendments

which in association with the compatible microbial cultures may contribute greatly to the quality of compost prepared from city organic wastes.

B. Evaluation :

The enriched compost was evaluated by yield of crops, uptake of nutrients and fertility status of the residual soil in a pot culture experiment.

The soil used in the experiment was a gangetic alluvium, collected from the fallow land of the C-Block Farm of the Viswavidyalaya whose composition has been shown in Table 1.

Each 4 kg portion of the processed soil was thoroughly mixed with the requisite amount of fresh enriched compost calculated on dry weight basis @ 20 ton ha⁻¹ for each treatment with three replications. Higher rate of compost was applied to assess the persistent effect of enriched compost on the growth of successive crops. A soil control (T₀) without addition of compost was also run side by side.

Three crops, rice (IR 8), rice (MW 10) and urad (T 9) were grown in three consecutive Rabi-Kharif-Rabi seasons of 1988-90. The soil of the pot was inoculated with respective cultures through water after harvest of second crop as the residual soil carbon was sufficient to feed the further dose of microbes. After harvest of each crop at maturity soil samples were drawn for analyses.

Results and Discussion :

i) Dry matter yield of crop plants : The dry matter yield of three successive crops have been presented in Table 7.

It is observed from the data that the enriched composts effected higher dry matter yield of first, second and third crops ranging from 42.41-140.63, 44.93-114.01 and 0 to 100.75 per cent respectively over their soil control values. In general, city compost responded very well to the growth of all the three crops possibly due to the fact that the tested soil was a virgin one and did not receive any fertilizer nor any cultural practice since long past. More increase in yield was reported by Kortleven (1956) when compost was used on light sandy soil and soil low in nitrifying activity (Inamatsu, 1970). The highest yield of all the crops were recorded in treatment T_9 which also exhibited highest pool of available nutrients (Table 6) and sustained the highest significant yield till third crop. The second best treatment in increasing the dry matter yield was T_8 for first and third crops and T_6 for second crop whereas T_7 was third best for all the three crops. The better effect of the other treatments were almost at par with each other. The effect of T_4 and T_2 in third crop came down to the level of soil control presumably rendering no effect of added compost. Thus the treatment T_9 receiving combined cultures along with rockphosphate, inorganic N and pyrite exhibited most effective influence in increasing the dry matter yield of three successive crops followed by T_8 for first and third crops and T_6 for second crops.

TABLE 7. Effect of Enriched Compost on Dry Matter Yield of Crops.

Treatments	Dry matter yield (g/pot)		
	1st crop (Rice, Rabi)	2nd crop (Rice, Kharif)	3rd crop (Urad, Rabi)
T ₀ Soil alone (S)	12.33	11.06	5.33
T ₁ S + Compost (C)	18.00	16.03	8.63
T ₂ S + C + RP	18.00	16.42	5.93
T ₃ S + C + Azot.	18.83	16.42	10.00
T ₄ S + C + RP + Azot.	21.06	16.75	5.33
T ₅ S + C + RP + Azot. + PS I (PFC ₅)	18.50	16.18	7.50
T ₆ S + C + RP + Azot. + PS II (PBC ₇)	17.56	18.01	9.30
T ₇ S + C + RP + Azot. + PS III (PBC ₃)	22.00	17.10	10.30
T ₈ S + C + RP + Azot. + PS IV (PBC ₁)	22.73	16.86	10.50
T ₉ S + C + RP + Azot. + PS II + N + Pyrite	29.67	23.67	10.70

CD at 5%	4.207	2.519	3.094

ii) Content and uptake of N and P : Concentration of N and uptake by grain and straw of the three successive crops as influenced by application of different forms of enriched mechanical plant compost have been shown in Tables 8 and 9 respectively.

The effect on concentration was found to be nonsignificant although the concentration was higher in third crop in comparison to former two cereal crops (Table 8).

Application of enriched composts increased the uptake of N (Table 9) by 50.05-167.63 per cent in first crop, 56.21-144.33 per cent in second crop and 43.8-105.28 per cent in third crop over their respective soil control (T_0). Total uptake decreased in second crop possibly due to exhaustion of N from the soil which was recouped in the third crop which was a leguminous one. Thus, uptake of N by the third crop was higher than the second crop (Rice) and at par with the first crop (Rice). Among the treatments, T_9 was most effective in increasing the uptake of total N by all the three crops followed by T_8 for first and second crops and T_7 for third crop. The third best treatment was T_7 for first crop, T_6 for second and T_8 for third crop. Better effect of other treatments in effecting the higher uptake of N was persistently noticed till the harvest of the third crop.

Content of P and uptake by grain and straw of three successive crops have been shown in Tables 10 and 11 respectively.

It is observed from the data (Table 10) that the content of phosphorus of the straw was effected significantly whereas that of

TABLE 8. Effect of Enriched Compost on N content (%) of grain and straw of rice-rice-urad.

Treatments	N content (%)					
	1st crop (Rice, Rabi)		2nd crop (Rice, Kharif)		3rd crop (Urad, Rabi)	
	Grain	Straw	Grain	Straw	Grain	Straw
T ₀ Soil alone (S)	0.967	0.532	1.134	0.512	2.667	1.387
T ₁ S+Compost (C)	1.148	0.528	1.153	0.551	2.753	1.353
T ₂ S + C + RP	1.139	0.508	1.264	0.551	2.772	1.337
T ₃ S + C + Azot.	1.157	0.532	1.106	0.555	2.716	1.317
T ₄ S+C+RP+Azot.	1.064	0.560	1.087	0.579	2.757	1.337
T ₅ S+C+RP+Azot.+ PS I (PFC ₅)	1.092	0.527	1.115	0.575	2.753	1.313
T ₆ S+C+RP+Azot.+ PS II (PBC ₇)	1.092	0.550	1.084	0.574	2.772	1.343
T ₇ S+C+RP+Azot.+ PS III (PBC ₃)	1.193	0.551	1.068	0.579	2.753	1.343
T ₈ S+C+RP+Azot.+ PS IV (PBC ₁)	1.101	0.560	1.070	0.538	2.758	1.320
T ₉ S+C+RP+Azot.+ PS II+N+Pyrite	1.185	0.562	1.100	0.611	2.778	1.330
CD at 5%	NS	NS	NS	NS	0.058	NS

TABLE 9. Effect of Enriched Compost on uptake of N by successive crops

Treatments	Uptake of N (mg/pot)									
	1st crop (Rice, Rabi)		2nd crop (Rice, Kharif)		3rd crop (Urad, Rabi)					
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Total
T ₀ Soil alone (S)	53.5	36.4	89.9	31.8	40.9	72.4	31.1	57.8	88.9	
T ₁ S+Compost (C)	89.9	53.7	143.6	47.6	65.5	113.1	59.6	87.9	147.5	
T ₂ S+C+RP	94.9	48.9	143.8	62.3	63.4	125.7	35.2	62.4	97.6	
T ₃ S+C+Azot.	94.8	56.7	151.5	63.6	60.2	123.8	45.3	109.7	155.0	
T ₄ S+C+RP+Azot.	81.5	75.1	156.6	57.2	65.2	122.4	27.7	57.8	85.5	
T ₅ S+C+RP+Azot.+ PS I (PFC ₅)	92.6	54.2	146.8	53.8	63.6	117.4	52.3	73.5	125.8	
T ₆ S+C+RP+Azot.+ PS II (PBC ₇)	80.3	56.4	136.7	58.6	70.5	129.1	63.8	94.0	157.8	
T ₇ S+C+RP+Azot.+ PS III (PBC ₃)	102.6	73.4	176.0	65.9	62.3	128.2	70.6	103.9	174.5	
T ₈ S+C+RP+Azot.+ PS IV (PBC ₁)	99.8	76.9	176.7	64.5	66.2	131.6	69.3	104.1	173.4	
T ₉ S+C+RP+Azot.+ PS II+N+Pyrite	144.2	96.4	240.6	78.8	98.1	176.9	77.8	104.7	182.5	
CD at 5%	35.74	19.8	28.704	18.68	11.27	15.78	29.1	34.66	38.24	

TABLE 10. Effect of Enriched Compost on P concentration (%) of grain and straw of successive crops.

Treatments	P concentration (%)					
	1st crop (Rice, Rabi)		2nd crop (Rice, Kharif)		3rd crop (Urad, Rabi)	
	Grain	Straw	Grain	Straw	Grain	Straw
T ₀ Soil alone (S)	0.372	0.162	0.375	0.160	0.377	0.185
T ₁ S + Compost (C)	0.375	0.185	0.372	0.185	0.377	0.208
T ₂ S + C + RP	0.377	0.189	0.377	0.190	0.399	0.202
T ₃ S + C + Azot.	0.380	0.195	0.380	0.195	0.382	0.202
T ₄ S+C+RP+Azot.	0.372	0.187	0.372	0.187	0.395	0.208
T ₅ S+C+RP+Azot.+ PS I (PFC ₅)	0.385	0.187	0.385	0.187	0.377	0.208
T ₆ S+C+RP+Azot.+ PS II (PBC ₇)	0.370	0.182	0.370	0.184	0.397	0.202
T ₇ S+C+RP+Azot.+ PS III (PBC ₃)	0.382	0.190	0.383	0.190	0.384	0.220
T ₈ S+C+RP+Azot.+ PS IV (PBC ₁)	0.382	0.175	0.382	0.175	0.399	0.206
T ₉ S+C+RP+Azot.+ PS IV+N+Pyrite	0.375	0.187	0.375	0.137	0.399	0.212
CD at 5%	NS	0.015	NS	0.038	NS	0.013

TABLE 11. Effect of Enriched City Compost on Uptake of P by successive crops.

Treatments	Uptake of P (mg/pot)									
	1st crop (Rice, Rabi)		2nd crop (Rice, Kharif)		3rd crop (Urad, Rabi)					
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	
T ₀ Soil alone (S)	20.5	11.1	31.6	10.7	14.1	24.8	4.4	7.6	12.0	
T ₁ S + Compost (C)	29.4	18.9	48.3	15.3	20.2	35.5	8.2	13.5	15.3	
T ₂ S + C + RP	31.4	18.3	49.7	18.9	19.2	38.1	5.1	9.4	14.5	
T ₃ S + C + Azot.	31.0	20.7	51.7	22.2	13.5	40.7	6.4	16.8	23.2	
T ₄ S+C+RP+Azot.	28.5	25.1	53.6	20.1	20.0	40.1	3.9	9.1	13.0	
T ₅ S+C+RP+Azot.+ PS I (PFC ₅)	31.4	19.4	50.8	19.4	24.7	44.1	7.2	11.7	18.9	
T ₆ S+C+RP+Azot.+ PS II (PBC ₇)	27.1	18.7	45.8	21.4	27.8	49.2	9.1	14.1	23.2	
T ₇ S+C+RP+Azot.+ PS III (PBC ₃)	33.1	25.3	58.4	22.6	20.0	42.6	9.9	17.0	26.9	
T ₈ S+C+RP+Azot.+ PS IV (PBC ₁)	34.4	23.9	58.3	23.5	19.5	43.0	10.5	16.2	26.7	
T ₉ S+C+RP+Azot.+ PS IV + N + Pyrite	45.6	32.1	77.7	29.1	38.9	68.0	11.2	16.8	28.0	
CD at 5%	8.69	6.55	8.41	7.14	6.46	6.64	5.25	5.25	5.54	

grain was nonsignificant.

Phosphorus uptake (Table 11) by different crops were effected by the application of different enriched composts. Increases over their respective soil control varied within the range of 44.93-145.88 per cent for first crop, 43.19-174.19 per cent for second crop and 8.33-133.33 per cent for third crop. Amount of total uptake decreased gradually with crop harvests. Treatment T_9 exerted most significant beneficial effect in mobilizing greater uptake of P by all the three crops followed by T_7 in first and third crops and T_6 in second crop. The third best treatment was T_8 for first and third crops and T_5 for second crop. Effect of other treatments were marginal in all the crops and were almost at par with each other during respective crop growth.

iii) Organic C and biomass C of the harvested soil : Organic C and biomass C of the soil decreased gradually with the number of crop harvest. The compost treated soils maintained 48-81, 63-92 and 60-95 per cent higher organic C over control for respective harvesting of first, second and third crop and for biomass C the increases ranged from 26-52, 10-40 and 25-35 per cent respectively (Table 12). As the mechanical compost was significantly mature and biologically stable due to its old age, it might have acted, besides other basic contributions, as a good carrier for added microbial inoculants and sustained its influence till third harvest. The significant decrease in organic C in T_9 treated soil was caused possibly due to increased activity of the soil leading to maximum

TABLE 12. Organic C and Biomass C of Soil after Harvest of each Crop.

Treatments	Organic C (%)			Biomass C (g/pot)		
	Crops			Crops		
	1st	2nd	3rd	1st	2nd	3rd
T ₀ Soil alone (S)	0.33	0.27	0.23	6.56	5.99	5.49
T ₁ S + Compost (C)	0.60	0.52	0.43	8.26	7.17	6.85
T ₂ S + C + RP	0.58	0.49	0.43	8.64	7.48	7.00
T ₃ S + C + Azot.	0.57	0.52	0.44	8.59	7.55	7.40
T ₄ S + C + RP + Azot.	0.56	0.51	0.45	9.99	7.17	6.62
T ₅ S + C + RP + Azot. + PS I (PFC ₅)	0.54	0.46	0.41	9.85	8.40	7.00
T ₆ S+C+RP+Azot. + PS II (PBC ₇)	0.59	0.46	0.37	8.66	7.42	6.59
T ₇ S+C+RP+Azot. + PS III (PBC ₃)	0.60	0.50	0.45	9.81	8.41	7.10
T ₈ S+C+RP+Azot. + PS IV (PBC ₁)	0.58	0.53	0.45	9.35	7.88	7.23
T ₉ S+C+RP+Azot. + PS II + N + Pyrite	0.49	0.44	0.35	8.88	6.59	6.02
CD at 5%	0.08	0.05	0.05	3.91	1.01	1.44

return of dry matter of crops with consequent decrease in organic C of the soil.

It is evident from the foregiven evidences that the mechanical compost prepared from city garbage enriched with compatible microbial cultures along with minerals and inorganic N may contribute greatly in maintaining the potential of environment of soil for higher crop yield.

III. PREPARATION OF ENRICHED COMPOST FROM FRESH CITY GARBAGE

Calcutta City generates 2250 tonnes of garbage per day (Dutta Gupta et al., 1986). This accumulation is increasing day by day. Municipal authority is faced with the problem of its disposal, particularly the new dumping ground not far away from the city.

On the otherhand, Central Public Health Engineering Research Institute, Nagpur reported (1977) that Calcutta City garbage contain about 42.40 per cent decomposable organic matter having 24.5% organic C, 0.69% N, 0.855% P_2O_5 and 0.435% K_2O . Thus, an equivalent amount of 15.52 tonnes of N, 19.28 tonnes of phosphate and 9.78 tonnes of potash is wasted daily which could have been recycled by composting for higher crop yield.

Considering the above, an attempt was made to prepare enriched compost directly from the unprocessed city garbage after application

low-cost microbial enrichment technique along with other additives. It was envisaged, if the technology was found suitable, the local Municipal Authority would be advised for its implementation for the preparation of compost from the municipal garbage.

Experimental :

Trucks of fresh city garbage were taken to the cemented floor of the mechanical compost plant at Bantala, Calcutta. Heaps of 500 kg each were treated as per following schedule of treatment and were allowed to decompose on the floor with a cover of polythene sheet on each of them.

- T₁ = City garbage (C)
- T₂ = C + Rockphosphate (RP) @ 1% + Microbial inoculants(MI).
- T₃ = C + RP + MI + Urea-N @ 1%
- T₄ = C + RP + MI + N + Pyrite @ 5%

Microbial inoculants were consisted of cellulose decomposing culture, Paecilomyces fuisporus, phosphate solubilizing culture, Aspergillus awamori and free living N-fixing bacteria, Azotobacter chroococcum. Former two cultures along with minerals and fertilizer N were added at the start of the experiment and the later was added during third turning at 30 days decomposition. Rate of application was the same as followed in the earlier experiment (No. I). Garbage was consisted of waste vegetables, sal leaves, banana leaves, fruits, flowers, straws, cloths, papers etc. Addition of water was restricted to the amount required for application of

microbial cultures alongwith minerals. Cover was provided throughout the decomposition of 60 days period. Four turnings were given on 7, 15, 30 and 45 days. Decomposition was completed within sixty days period when samples were drawn for analyses after thorough mixing of the material.

Results and Discussion :

Chemical composition of the enriched composts has been shown in Table 13. It is evident from the data composting of city garbage caused the lowering of organic C and increase in total N with consequent effect on decrease of C:N in all the compost piles including control. Organic C and C:N ratio of the composts were nearer to that of humic substance. These indicate that the desired decomposition of the garbage was completed by 60 days decomposition period.

An appreciable increase in total N due to inoculation of garbage pile with mixed microbial inoculum along with free living N-fixing organisms in presence of rockphosphate (T_2) indicate the suitability of applying the low cost microbial enrichment technique in improving the quality of compost prepared from city garbage. Increase in total N might have been possible due to (i) increase in the activity of cellulose decomposer (Chang, 1939); (ii) decrease in the number of denitrifying bacteria (Korovkin, 1952; Tepla, 1959) and increase in the growth of free living N-fixing bacteria (Berezova et al., 1955). Role of calcium phosphate in conserving the N in compost pile have been recognised by Chekalov (1955), Dhar et al.

TABLE 13. Composition of enriched compost from city garbage.

Treatments	Org. C (%)	Total N (%)	C:N	NH ₄ -N (ppm)	NO ₃ -N (ppm)	Total P (%)	Av. P (ppm)
T ₁ City garbage (C)	10.00	1.092	9.2	255	1021	0.106	230
T ₂ C + Rockphosphate (RP) @ 1% + Micro- bial inoculants(MI)	9.44	1.275	7.4	138	1092	0.215	234
T ₃ C + RP + MI + Urea-N @ 1%	9.56	1.386	6.9	129	1450	0.391	344
T ₄ C + RP + MI + N + Pyrite @ 5%	9.44	1.484	6.4	99	1508	0.306	235
CD at 5%	0.973	0.216	1.271	30.459	43.919	0.0201	34.243

(1955), Arzamasova and Kuzmenkova (1962). Further increase in total N in T_3 was possibly due to addition of inorganic N and that in T_4 suggests that the application of pyrite might have played a very significant role in conserving the total N in compost pile. Thus, the treatment combination consisting of combined microbial inoculants along with rockphosphate, inorganic N and Pyrite was much more effective in increasing the total N of the city compost.

There was lesser abundance of NH_4 -N and greater accumulation of NO_3 -N in the microbe inoculated pile in presence and absence of urea N. That trend in the accumulation of mineral nitrogen also indicate that the respective pile attained its maturity within 60 days decomposition. As decomposition proceeds compost microorganisms metabolize both organic and inorganic N and among the inorganic N, preferably in the form of ammonium and nitrate begins to form at the expense of soluble organic N at the later stages of composting (Hoyle and Mattingly, 1954; Knuth, 1969). Hoyle and Mattingly (1954) also reported that the percentage of soluble N in straw composts containing ammonium sulfate decreased during the first 50 days but increased gradually during the next 450 days.

Total P increased significantly in the rockphosphate treated pile. Available P (Olsen P) did not show much increase possibly due to immobilization of the same except in treatment T_3 .

Therefore, it is evident from the above study that the combined microbial inoculants along with rockphosphate, inorganic N and pyrite was more effective in rapid decomposition as well as in the preparation of a good quality compost from unprocessed city garbage.

Section II

"PRODUCTION AND EVALUATION OF ENRICHED COMPOST FROM FARM WASTES"

PRODUCTION AND EVALUATION OF ENRICHED COMPOST FROM FARM WASTES

It has earlier been noted that in some parts of the country straw is treated as waste which is left over on the field and ultimately burnt out to get the land free for next cultivation (Mishra et al., 1988). But that organic wastes could have otherwise been recycled through composting to obtain sustained productivity from the ecosystem (Michell, 1979; Nagar, 1981). Again, mere composting of straw may not fulfil the whole purpose of recycling. Compost should be a good quality one without giving any harm to the growth of the young seedling. Nitrogen is the main determining factor of the quality of a compost. Increase in N content of the compost may be ensured by (i) addition of N-rich inputs and (ii) encouraging the growth of free living N-fixing organism; and that of P by (i) addition of P-rich organic inputs and (ii) encouraging the solubilization of mineral rockphosphate by microbial cultures. The beneficial role of rockphosphate in the production of good quality compost has been observed in the

earlier studies. Several investigators have reported calcium phosphate increases the rate of decomposition and N conservation (Chekalov, 1955; Dhar et al., 1955; Dhar & Gupta, 1961; Arzamasova and Kuzmenkova, 1962) but that more than 2 per cent inhibited decomposition.

Application of cattle manure as stimulant in rapid composting of municipal wastes has been recognised by Sir Albert Haward (1935) but its appropriate dose and specific contribution in improving the quality of compost has not been evaluated. Therefore, in this part, studies were initiated to evaluate (i) the effect of higher application of rockphosphate in influencing the rapid composting of straw by microbial inoculants and (ii) cattle dung as substitute of microbial inoculum for rapid composting of straw and evaluation of composts by (i) dry matter yield of crops in comparison to 50 and 100 per cent recommended dose of inorganic fertilizer, and (ii) the biological activity of harvested soil.

EFFECT OF MICROBIAL INOCULUM AND CATTLE DUNG SLURRY ON THE PRODUCTION OF ENRICHED COMPOST FROM STRAW AND ITS EFFECT ON DRY MATTER YIELD OF CROPS.

A. Production of enriched compost :

Waste straw was chopped to 5-6 cm in size. Each 30 kg portion was put into cemented pit of 1 m³ in size. Urea N was added to lower the C:N to 60:1. Mussoorie rockphosphate was added at the rate of 0.2 and 1 per cent P₂O₅ basis. The cellulose decomposing cultures, Trichurus spiralis and Paecilomyces fuisporus in the

ratio of 1:1 were used at the rate of 500 g of mycelial mat ton^{-1} of material. Aspergillus awamori was used as P-solubiliser which was also added at the same rate. In another treatment, fresh cowdung was applied at the rate of 50 per cent of the material on fresh weight basis. Fresh cowdung was made into slurry with water and mixed with straw.

Fungal mats were homogenized and were mixed in required amount of water to attain moisture of the final material at 100 per cent level. Rockphosphate was also added to the culture mixture and mixed uniformly with 30 kg portion of straw before putting into pit as per following design of the experiment.

- T_1 = Straw alone (control)(S).
- T_2 = S + RP @ 0.2% P_2O_5 basis + Microbial inoculants (MI).
- T_3 = S + RP @ 1% P_2O_5 basis + Microbial inoculants (MI)
- T_4 = S + RP 1% + Cowdung (CD) @ 50% of the material on fresh weight.

Pits were covered with polythene sheet to minimise the loss of moisture due to evaporation.

Nitrogen-fixing organism, Azotobacter chroococcum, was applied at the rate of 10^6 cells/ml after one month decomposition. All together five turnings were given during four months decomposition. Each treatment was replicated thrice. At the end, whole material was mixed thoroughly before taking sample for analyses of org.C, total N, $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, water soluble P, citrate soluble P and total P as per procedure mentioned under "Materials and Methods".

Results and Discussion :

Composition of compost at the end of four months decomposition showing per cent loss in weight, org. C, total N, C:N ratio, $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, water sol. P, cit.sol. P and total P has been shown in Table 14.

i) Decomposition : Per cent loss of straw due to decomposition over four months varied from 59.30-63.13. It is observed from the data that the loss due to decomposition was slightly retarded (0.36%) when straw was amended with lower rate of rockphosphate (T_2) but the effect was significantly higher at higher level of RP application (T_3 and T_4) both in microbial inoculated (3.41%) and cattle dung treated pile (3.83%). Several investigators reported calcium phosphate increases the rate of decomposition (Chekalov, 1955; Dhar and Gupta, 1961) but that more than 2% inhibited decomposition. Suppression of decomposition by cattle dung has also been noted by Singh (1987) who reported that microbial culture was not satisfactory when composting was done with wide range of organic and inorganic inputs. Lower loss of carbon during second half of decomposition of straw in presence of inorganic N has been reported by Novak (1972), Hajra et al. (1974). Thus, it is very likely that as humus formation starts in compost pile in presence of an adequate amount of N and P, more and more C is locked resulting lower loss of C. But it is interesting to note that there was significant decrease in organic C at higher application of RP both in microbe inoculated and cattle dung treated piles.

TABLE 14. Composition of enriched straw compost after 4 months decomposition.

Treatments	Loss (%)	pH	Org. C (%)	Total N (%)	C:N	NH ₄ -N (ppm)	NO ₃ -N (ppm)	W.S.P. (%)	C.S.P. (%)	Total P (%)
T ₁ Straw only (S)	63.13	7.1	29.44	1.33	22.1	129	178	0.029	0.205	0.288
T ₂ S + RP @ 0.2% P ₂ O ₅ basis + MI	62.77	7.2	29.16	1.54	18.9	240	245	0.033	0.289	0.546
T ₃ S+RP @ 1% P ₂ O ₅ basis+ MI	59.72	7.1	26.41	1.75	15.1	236	586	0.040	0.775	1.475
T ₄ S+RP @ 1% P ₂ O ₅ basis + CD	59.30	6.9	25.83	1.91	13.5	265	888	0.092	0.834	1.656
CD at 5%	3.141		1.751	NS	4.973	19.207	458.336	0.070	0.019	0.216

W.S.P. = Water soluble P; C.S.P. = Citrate soluble P; RP = Rockphosphate; MI = Microbial inoculants; CD = Cattle dung .

ii) Mineral transformation : Total N of the composts ranged between 1.59-1.91 per cent in treated piles as against 1.33 per cent of control pile. The maximum increase in cattle dung treated pile might be due to higher N content (1.176%) of the cattle dung itself. Although lower decomposition at higher application of RP in microbe inoculated pile (T_3) was noted but it increased N more than lower level of RP in T_2 . Thus, it may be presumed that lower RP encourages cellulose decomposer while higher application encourages N-fixer or discourages denitrification as claimed by Korovkin (1952). Conservation of N by addition of calcium phosphate in composts have been reported by Chekalov (1955), Dhar et al. (1955), Dhar and Gupta (1961), Arzamasova and Kuzmenkova (1962). Increases in total N and humus content in RP amended compost inoculated with cultures of N-fixing and P-solubilizing organisms have been reported by Sadasivam et al. (1981), Kapoor et al. (1983).

Decrease in organic C and increase in total N resulted significant decrease in C:N ratio in higher RP treated piles (T_3 and T_4).

There were significant higher accumulation of both $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ in all the treated piles; maximum increases in both the fractions were noted in cattle dung treated pile. Generally, compost organisms prefer $\text{NH}_4\text{-N}$ (Jansson et al., 1955) and $\text{NO}_3\text{-N}$ begins to form at the expense of soluble organic N and did not increase significantly for first 120 days (Hoyle and Mattingly, 1954; Knuth, 1969). They reported decrease in soluble N during the first 50 days but increased gradually during the next 450 days of straw decomposition.

Application of rockphosphate caused significant increase in water soluble, citrate soluble and total P fractions of compost enriched with cattle dung. Increases of all those forms of P were maximum at higher application of rockphosphate along with cattle dung in T_4 possibly due to further addition of those P-riched inputs.

There is generally enough phosphate in waste material. Microbes need only 5-20 per cent as much P as N (Alexander, 1961; Jeris and Regan, 1973), still calcium phosphate application to the compost pile finds its justification due to its role in encouraging cellulose decomposing organisms (Chang, 1939) and conservation of N by decreasing the number of denitrifying bacteria (Korovkin, 1952; Tepla, 1959). The increasing amount of citrate soluble P in T_3 suggest the possibility of increasing solubilization of RP by P solubilizing organism and subsequent utilization of the same by microbes including N-fixing organism and that of T_4 might be due to addition through cattle dung.

Therefore, from the above observations, application of RP at 1 per cent P_2O_5 basis may be suggested for getting an overall improvement in the quality of compost prepared from straw. Cattle dung inoculum is considered more effective in improving the quality of compost and may be suggested for its wider application in composting straws and allied wastes in farm house.

B. Evaluation of enriched compost :

For evaluation of enriched composts a pot culture experiment was conducted. The soil used was a gangetic alluvium collected

from fallow land of C-Block Farm of the Viswavidyalaya whose composition has been shown in Table 1.

Each 4 kg portion of the processed soil was thoroughly mixed with the requisite amount of fresh compost calculated on dry weight basis at the rate of 10 ton ha^{-1} for each treatment with three replications. Two treatments were also included to compare the efficiency of the enriched compost with 50 and 100 per cent recommended dose of inorganic fertilizer. A soil control T_0 , without addition of compost was also run side by side.

Two crops, rice (MW 10) followed by Urad (T 9) were grown during kharif and rabi season of 1990. After harvest at maturity of first crop, soil samples were drawn. The residual soil was again treated at the same rate of respective compost which were since then kept under dried condition in the laboratory. After harvest of second crop, soil samples were drawn for analyses as per procedure detailed under "Materials and Methods".

Results and Discussion :

i) Effect on dry matter yield of crop plants : Dry matter yield of rice and urad have been shown in Table 15.

It is observed from the data that application of compost irrespective of treatment effected the increase in dry matter yield of rice over soil control. The increase in yield varied within the range of 24.17-79.12 per cent (T_1 - T_4), the maximum increase was recorded in cattle dung enriched compost (T_4). Crop response was found to be higher which was attributed to the virgin nature of the

TABLE 15. Effect of enriched straw compost on dry matter yield of crops.

Treatments	Dry matter yield (g/pot)	
	1st crop (Rice, Kharif)	2nd crop (Urad, Rabi)
T ₀ Soil alone	8.19	8.93
T ₁ Control compost	10.17	12.00
T ₂ Straw + RP 0.2 + MI	10.33	14.16
T ₃ Straw + RP 1 + MI	12.67	15.00
T ₄ Straw + RP 1 + Cattle dung	14.67	15.50
T ₅ 50% NPK	12.69	10.70
T ₆ 100 % NPK	19.33	12.43

CD at 5%	3.168	2.515

soil as also observed in earlier study with mechanical plant compost (Expt. I). Among the composts, cattle dung enriched one (T₄) effected maximum yield followed by microbially enriched compost with 1 per cent P₂O₅ as RP (T₃) which in turn was at par with 50% NPK fertilization (T₅). The effect of cattle dung enriched compost was significantly higher over control compost. Thus, the microbially enriched compost with 1% P₂O₅ saved 50% NPK fertilizer requirement of rice although the yield of cattle dung enriched compost was much higher than that and the highest yield among the treatments was obtained at 100% NPK fertilization (T₆). Other microbially enriched compost with 0.2% P₂O₅ (T₂) did not show better effect over control compost (T₁) possibly due to continuation

of decomposition under submerged condition. Thus, in effecting the dry matter yield of rice, the composts may be graded in comparison to fertilizer in the order : 100% NPK > cattle dung compost > 50% NPK > microbial enriched compost with 1% P_2O_5 > microbial enriched compost with 0.2% P_2O_5 > control compost > soil control.

Composts, in general, influenced the dry matter yield of the second crop, urad very effectively. The increase in yield ranged from 34.37-73.57 per cent over soil control. The crop responded significantly to the application of compost irrespective of enrichment while the effect of the fertilizer at 100% level was at par with control compost indicating low response of inorganic fertilizer to this leguminous crop. Microbiologically enriched compost with 0.2% P_2O_5 (T_2) exhibited its better effect unlike to the first crop in increasing the dry matter yield over control. Cattle dung enriched compost (T_4) recorded maximum significant dry matter yield followed by microbially enriched compost with 1% P_2O_5 (T_3). The phosphate enriched compost thus greatly influenced the dry matter yield possibly through slow and steady release of P required by this leguminous crop in contrast to fully soluble inorganic fertilizer which might have been transformed fully to other forms rendering less availability to the growing plant.

Thus, the effect of the compost in comparison to inorganic fertilizer in influencing the dry matter yield of second crop, a leguminous one, was in the order : cattle dung compost > microbial enriched compost with 1% P_2O_5 > microbial enriched compost with 0.2% P_2O_5 > 100% NPK > control compost > 50% NPK > soil control.

Therefore, the cattle dung enriched compost was found to be superior to microbially enriched compost so far as its effect on dry matter yield of the crops was concerned.

ii) Effect on uptake of N and P by crop plants : The effect of enriched straw compost on the uptake of N and P by crops plants has been shown in Table 16.

Application of compost increased the uptake of N ranging from 35.62-101.03 per cent by rice and 47.03-94.41 per cent by urad in comparison to recommended dose of fertilizer (T_6) recording 183.31 and 53.69 per cent respectively over respective soil control values (Table 16). Among the composts, cattle dung enriched one (T_4) induced the maximum uptake followed by microbially enriched compost (T_3) in both the crops. Thus, the enriched composts were superior to inorganic fertilizer in mobilizing greater uptake of N by urad which is a leguminous crop.

Application of compost also mobilized greater uptake of P ranging from 51.58-120.37 per cent by rice and 40.92-81.70 per cent by urad in comparison to recommended fertilizer showing 204.91 and 52.14 per cent respectively over soil control values. Among the composts, cattle dung enriched (T_4) showed maximum uptake of P followed by microbially enriched compost (T_3) in both the crops and composts were superior to inorganic fertilizer in inducing greater uptake of P by urad.

TABLE 16. Effect of enriched straw compost on the uptake of N and P by crop plants.

Treatments	Uptake of N (mg/pot)		Uptake of P (mg/pot)	
	1st crop (Rice, Kharif)	2nd crop (Urad, Rabi)	1st crop (Rice, Kharif)	2nd crop (Urad, Rabi)
T ₀ Soil alone	53.33	105.06	17.08	34.77
T ₁ Control compost	72.33	154.47	25.89	49.00
T ₂ Straw+RP 0.2+ MI	73.36	179.66	26.57	60.00
T ₃ Straw+RP 1+ MI	95.87	191.00	33.20	60.00
T ₄ Straw+RP 1 + Cattle dung	107.24	204.25	37.64	63.18
T ₅ 50% NPK	93.92	140.42	34.23	42.95
T ₆ 100% NPK	151.09	161.47	52.08	52.90
CD at 5%	27.729	47.395	3.574	10.547

iii) Effect on org. C and biomass C of the residual soil : Organic C and biomass C of the residual soil after harvest of first and second crops have been shown in Table 17.

It is observed from the data that the application of composts irrespective of enrichment maintained significant higher org.C and biomass C of the soil as estimated after harvest of first and second Crops
(excepting the biomass C after second harvest when it dropped to the level of control. However, at this stage fertilizer treated soil maintained higher biomass C over the others. Highest significant biomass C was recorded in the treatment T₂ which received compost

amended with lower rate of RP, 0.2% P_2O_5 basis, unlike the other two treatments, T_3 and T_4 which received enriched composts amended with higher rate of RP, 1% P_2O_5 basis. It may be presumed that higher rate of RP, applied through compost, might have rendered harmful effect on the biological population of the soils. Korovkin (1952), Chekalov (1955), Dhar *et al.* (1955), Tepa (1959) reported that calcium phosphate more than 2% inhibited cellulose decomposer as well as denitrifier in compost pile.

But the above trend in biomass C was no longer existed as estimated after the harvest of next crop which was a leguminous one. On the contrary, the fertilizer treated soil exhibited higher biomass C over the others although the amount was reduced to almost half of the earlier one.

TABLE 17. Organic C and Biomass C of residual soil.

Treatments	After first harvest		After second harvest	
	Org.C (%)	BiomassC (g/pot)	Org.C (%)	Biomass C (g/pot)
T_0 Soil alone	0.31	8.4	0.29	4.7
T_1 Control compost	0.54	9.4	0.44	4.9
T_2 Straw+RP 0.2+ MI	0.53	11.5	0.43	4.8
T_3 Straw+RP 1+ MI	0.53	10.6	0.45	5.0
T_4 Straw+RP 1+ Cattle dung	0.50	10.4	0.48	4.6
T_5 50% NPK	0.46	9.0	0.42	5.4
T_6 100% NPK	0.39	8.4	0.41	5.7
CD at 5%	0.033	1.093	0.027	NS

Section III

"TO DEVELOP TECHNOLOGY FOR DIRECT
INCORPORATION OF SURPLUS CROPS
RESIDUES ON YIELD OF CROPS AND
PRODUCTIVITY OF LAND"

TO DEVELOP TECHNOLOGY FOR DIRECT
INCORPORATION OF SURPLUS CROP
RESIDUES ON YIELD OF CROPS AND
PRODUCTIVITY OF LAND

Direct incorporation of crop residues into the soil is another way of recycling of organic wastes for higher crop yield and increasing the productivity of land. But direct incorporation has got its own limitations of (i) deferred sowing and (ii) prolonged immobilization of plant nutrients.

It has been recorded in earlier studies (Expt. No. I) the effective role of microbial inoculants in shortening the period of decomposition as well as in improving the quality of compost. It was, therefore, found worthwhile to apply the same technology for management of surplus crop residues through direct incorporation into the field soil. The present study was aimed at developing ways and means of direct incorporation of straws alone and in combination with other amendments including microbial culture to suitably ameliorate the effect of prolonged immobilization of nutrients in soil.

EFFECT OF DIRECT INCORPORATION OF PADDY STRAW TREATED WITH MICROBIAL CULTURES AND MINERAL ADDITIVES ON THE YIELD OF CROPS AND PLANT NUTRIENT OF THE SOIL.

Experimental :

A pot culture experiment was conducted in an alluvial soil (Table 1) as per following schedule of treatment.

- T₁ Soil alone (control).
- T₂ Microbial culture + Rockphosphate (RP)
(applied on the date of sowing)
- T₃ Microbial culture + RP
(applied 21 days before sowing)
- T₄ Straw (applied on the date of sowing)
- T₅ Straw + Microbial culture + RP
(applied on the date of sowing)
- T₆ Straw + Microbial culture + RP
(applied 21 days before sowing)

The experiment was carried out in two sets. In first set, calculated amount of chopped paddy straw (2-3 cm), at the rate of 1% of C of soil weight basis, was inoculated with the cultures of cellulose decomposing microorganism, Aspergillus nidulans, P-solubilizing microorganism, PBC₇, a bacterial culture, N-fixing bacteria, Azotobacter chroococcum and rockphosphate, Mussoorie Phos, at the usual rate as applied in earlier experiment (Expt. No. II). The inoculated straw was then thoroughly mixed in each 5 kg portion of processed soil. The treated pot was then left in the green house for three weeks of initial decomposition of the incorporated straw at moisture equivalent to 50% WHC of the soil. Each treatment was

replicated thrice. A control set without straw was also provided.

In second set, soil was treated with inoculated straw in the same manner as in the first set on the day of transplantation.

Each pot was transplanted with four seedlings of rice (var. MW 10) as first crop on 4.9.89. Crop plant was uprooted at maturity on 20.12.89 and soil samples were taken for analyses.

A second crop, wheat (var. Kalyan sona) was grown on the same soil without any further input during 28.12.89 to 22.3.90. At second harvest, whole soil was thoroughly mixed before taking sample for analyses as per methods described under "Materials and Methods".

Results and Discussion :

i) Dry matter yield of crops : Dry matter yield of first and second crops grown on succession on the same soil have been shown in Table 18.

It is observed from the data that the direct application of straw irrespective of amendment and time of application in T_4 , T_5 , T_6 badly effected the dry matter yield of first crop, rice over their respective soil control treatments (T_1 , T_2 , T_3). Dry matter yield of rice was seriously effected possibly due to injurious effect of decomposition under submerged condition. Decomposition of straw under submergence continued as evidenced by evolution of gases throughout the period of crop growth. Application of straw in T_4 alone thus decreased significantly the yield over soil control(T_1).

Adverse effect of direct incorporation of rice straw on yield of wheat crop and of wheat straw on yield of rice crop have been reported by Sidhu and Beri (1989). But the injurious effect of direct incorporation on dry matter yield was slightly overcome when was treated with microbial cultures along with RP applied either on the date of sowing (T_5) or 21 days prior to sowing (T_6).

Residual effect of direct incorporation, however, induced 68, 89 and 62 per cent greater yield of the second crop, wheat in T_4 , T_5 and T_6 respectively over their respective soil control values. Thus, the beneficial effect of straw application was found to be highly significant in increasing the dry matter yield of the following crop. However, microbial inoculation in T_5 and T_6 effected 10 per cent greater yield over uninoculated control (T_4).

ii) Change in plant nutrient of the soil : Change in plant nutrient of the soil as influenced by direct incorporation of straw and simultaneous growing of rice followed by wheat crop have been shown in Table 19.

It is observed from the data that the application of straw maintained higher organic C of the soils (T_4 - T_6) ranging from 0.67-0.72 per cent as against control of 0.47-0.53 per cent as recorded after harvest of first crop. Maximum increase in organic C was noted when straw treated with combined microbial cultures was added 21 days before sowing. Significant increase in organic C of the soils when crop residues were incorporated over seven years in rice-wheat rotation was observed by Bhat et al. (1991). Therefore, it was

TABLE 18. Effect of direct application of straw on the dry matter yield of successive crops.

	Treatments	Time of application	Dry matter yield (g/pot)	
			1st crop (Rice, Kharif)	2nd crop (Wheat, Rabi)
T ₁	Control (Soil alone)		5.26	3.59
T ₂	Microbial culture + RP	On the date of sowing	5.33	3.43
T ₃	Microbial culture + RP	21 days before sowing	5.26	3.98
T ₄	Straw	On the date of sowing	4.34	5.98
T ₅	Straw + Microbial culture + RP	On the date of sowing	4.46	6.50
T ₆	Straw + Microbial culture + RP	21 days before sowing	4.85	7.00
CD at 5%			NS	2.482

TABLE 19. Effect of direct application of straw on crop growth and plant nutrient of the harvested soil.

Treatments	Organic C (%)		Biomass C (%)		NH ₄ -N (ppm)		NO ₃ -N (ppm)		Available P (ppm)	
	1st harv-est	2nd harvest	1st harv-est	2nd harv-est	1st harv-est	2nd harv-est	1st harv-est	2nd harv-est	1st harv-est	2nd harv-est
T ₁ Soil alone	0.47	0.39	2.57	2.77	4.13	2.33	8.83	6.00	3.77	2.00
T ₂ MI + RP ¹	0.51	0.40	2.47	2.73	6.00	2.67	9.83	5.67	2.83	2.17
T ₃ MI + RP ²	0.53	0.38	3.20	2.76	5.83	3.00	11.17	5.67	3.27	2.17
T ₄ Straw ¹	0.67	0.44	3.97	4.37	7.67	4.57	13.53	7.00	5.43	2.17
T ₅ Straw+MI+RP ¹	0.67	0.46	3.17	3.90	10.20	7.00	20.16	9.00	5.80	2.33
T ₆ Straw+MI+RP ²	0.72	0.46	4.60	3.47	12.63	5.33	20.00	9.33	5.23	2.83
CD at 5%	0.056	0.043	1.331	0.806	3.093	1.527	4.177	2.387	0.949	NS

MI = Microbial inoculants; RP = Rockphosphate; 1 = applied on the date of sowing;

2 applied 21 days before sowing.

quite apparent that the significant higher organic C maintained higher soil respiration throughout the growing period from 4.9.89 to 20.12.89 i.e. 103 days and badly effected the dry matter yield of rice grown under submerged condition. Higher soil respiration coupled with nitrate depression for prolonged period during decomposition of added straw have been noted in different studies by Waksman and Starkey (1931), Voinova-Raikova (1972), Bhardwaj and Novak (1978). Debnath and Hajra (1972) reported loss of 3/4th of the added C in 120 days decomposition of added straw in an alluvial soil.

Organic C of the soils decreased subsequently almost to the level of control as recorded at the end of 28.12.89 to 22.3.90 i.e. 85 days of second crop growth. Thus, the total period of interaction of the straw in soils was 4.9.89 to 22.3.90 i.e. 200 days and there were little or no added carbon left in the soil irrespective of treatment. Martins & Kowald (1988) recorded decomposition to the extent of 46 and 90 per cent after 3 months and 1 year respectively.

Biomass C of the soils recorded increase with the application of straw alone or in combination with cultures. Highly significant increase after harvest of first crop was recorded in treatment, T_6 where culture treated straw was applied 21 days before sowing whereas that after second harvest was recorded in treatment, T_4 where straw was applied alone. In the former, intense microbial activity due to application of straw along with cultures started its functioning 21 days prior to sowing and possibly attained

maximum in biomass C earlier than the others. In the latter one, decomposition was extended over longer period by native soil microorganisms recording highest biomass C at latter stage, as recorded after second harvest.

Application of straw alone or in combination with cultures maintained significant increase in $\text{NH}_4\text{-N}$ of the soils as recorded after harvest of each of the crops. However, highest $\text{NH}_4\text{-N}$ was recorded in T_6 after first harvest and in T_5 after second harvest. Significant increase in $\text{NO}_3\text{-N}$ was also recorded excepting in T_4 where straw was applied alone. But both the forms after second harvest were decreased to the half of the first harvest. Although significant increase in available P was observed after harvest of first crop but no difference over control was noted after harvest of second crop. Significant increase in available and total forms of NPK of the soil have been reported by Bhat et al. (1991). Improvement of the soil nutrient status inspite of adverse effect of long-term incorporation of rice straw on yield of wheat crop and of wheat straw on yield of rice crop have also been reported by Sidhu and Beri (1989).

Therefore, it is observed from the above study that the better effect of direct application of straw may be derived if straw can suitably be treated with microbial cultures along with minerals and applied to the soil about few weeks prior to sowing.

Section IV

**"USE OF REFUSE AS SOURCE OF
PLANT NUTRIENT IN SOIL"**

USE OF REFUSE AS A SOURCE OF PLANT NUTRIENT IN SOIL

Mother Dairy, Calcutta has been facing the problem arising out of the disposal of sludge produced from the effluent as well as the spoiled milk at their main processing plant at Dankuni. The present attempt was made to suggest if (i) the sludge can be utilized by its application to the field as an organic amendment and (ii) to increase its efficiency by treating with N-fixing and P-solubilizing organisms along with rockphosphate (RP). The samples received under two distinct physical conditions, were analysed with respect to their plant nutrient content which have been shown in Table 20. The material was found to be rich in N and P.

EFFECT OF DAIRY SLUDGE ON CROP YIELD AND SOIL PROPERTIES

Experimental :

A pot culture experiment was carried out in an alluvial soil (chemical composition in Table 1) with maize (Zea mays) as test crop.

TABLE 20. Chemical composition of the dairy sludge from Mother Dairy, Calcutta.

(Data on oven dry basis at 80°C)

Properties	Granular	Muddy
1. Moisture	19.16	43.06
2. pH (1:2.5)	7.2	6.8
3. Organic C (% , Dry combustion)	32.80	34.44
4. Total N (%)	2.49	3.28
5. C:N ratio	13.17	10.50
6. $\text{NH}_4\text{-N}$ (ppm-N)	234	-
7. $\text{NO}_3\text{-N}$ (ppm-N)	493	-
8. Total P (%)	2.475	2.75
9. C:P ratio	13.25	12.52
10. Available P (Olsen's P, ppm)	360	380

Each pot was filled up with 5 kg portion of processed soil which received treatment as follows :

- T₁ Control (Soil alone)
- T₂ Sludge @ 2.5 ton/ha.
- T₃ Sludge @ 5.0 ton/ha
- T₄ Sludge @ 2.5 ton/ha + RP @ 50 Kg P₂O₅/ha basis.
- T₅ Sludge @ 5.0 ton/ha + RP @ 50 Kg P₂O₅/ha basis.
- T₆ Sludge @ 2.5 ton/ha + RP @ 50 Kg P₂O₅/ha basis +
Microbial inoculants (MI).
- T₇ Sludge @ 5.0 ton/ha + RP @ 50 Kg P₂O₅/ha basis +
Microbial inoculants (MI).
- T₈ Fertilizer @ 50% of recommended dose.
- T₉ Fertilizer @ 100% of recommended dose.

Sludge was applied @ 2.5 ton and 5.0 ton ha⁻¹ basis alone or in combination with N-fixing and P-solubilizing cultures along with rockphosphate. Microbial inoculants were consisted of Aspergillus awamori, a fungal strain efficient in solubilizing Mussoorie rockphosphate and Azotobacter chroococcum, a N-fixing bacteria. All were applied at the rate as followed in the earlier studies (Expt. No I & II). Rockphosphate (Mussoorie Phos) containing 17.2% P₂O₅ was added @ 50 kg P₂O₅ ha⁻¹ basis as recommended dose of P for the crop.

Calculated amount of sludge was first treated with microbial inoculants which in turn were mixed with a handful of soil and ultimately with each 5 kg portion of soil. Above treatment combinations were compared with 50 and 100 per cent dose of inorganic

fertilizer recommended for maize. A soil control without sludge was also included. Each treatment was replicated thrice. Four germinated maize seeds (var. Vijay composite) were sown on 13.4.91 and plants were harvested at flowering stage on 13.6.91. After thorough mixing, soil samples were drawn for analyses including estimation of biomass as per procedure described under "Materials and Methods".

Results and Discussion :

i) Dry matter yield :

Dry matter yield of maize has been shown in Table 21. It is observed from the data that the dry matter yield was greatly influenced by the application of sludge alone or in combination with other inputs. The yield was increased by 1.88 to 3.03 times over soil control possibly due to virgin nature of soil which did not receive any fertilizer nor any cultural practice since long past.

Application of sludge at lower rate, 2.5 ton ha^{-1} (T_2) effected significant higher increase in dry matter yield of test crop over soil control (T_1). Amendment of RP in T_3 helped in increasing the dry matter yield, while microbial inoculum induced further increase of the same in T_6 which was equivalent to the yield recorded in 50% inorganic fertilizer recommended for the crop in T_8 . Therefore, application of sludge at 2.5 ton ha^{-1} basis along with RP and microbial cultures could save 50% fertilizer recommended for maize.

TABLE 21. Influence of dairy sludge on the dry matter yield and uptake of N and P by maize (Zea mays).

(Data average of three replications)

Treatments	Dry matter yield (g/pot)	N (%)	Uptake of N (mg/pot)	P (%)	Uptake of P (mg/pot)
T ₁ Soil alone (S)	9.00	0.477	42.97	0.100	8.97
T ₂ S+Sludge 2.5	17.00	0.501	85.21	0.143	24.28
T ₃ S+Sludge 5.0	23.33 ✓	0.501	116.76	0.162	37.60
T ₄ S+Sludge 2.5 + RP 50	21.70	0.539	116.77	0.173	37.32
T ₅ S+Sludge 5.0 + RP 50	24.67 ✓	0.548	135.17	0.180	44.40
T ₆ S+Sludge 2.5+RP 50 + MI	22.33	0.539	120.43	0.179	39.98
T ₇ S+Sludge 5.0+RP 50 + MI	27.33 ✓	0.553	151.32	0.203	55.40
T ₈ Fertilizer 50% recommended dose	23.00	0.506	116.32	0.180	41.47
T ₉ Fertilizer 100% recommended dose	27.00	0.558	150.62	0.193	52.20
CD at 5%	7.095	0.012	38.026	0.012	12.673

Further, when sludge was applied at higher rate (5.0 ton ha^{-1}) alone (T_3) or in combination with RP (T_5) and along with microbial cultures (T_7) effected further increase in yield over their respective lower level of applications in treatments T_2 , T_3 and T_6 respectively. The dry matter yield obtained at higher application of sludge along with RP and microbial cultures was equivalent to the yield recorded with 100% NPK fertilization.

Therefore, considering the dry matter yield of test crop, application of dairy sludge may be suggested to the agricultural field at an appropriate rate and if possible along with RP and microbial cultures to save the fertilizer recommended for the crop.

ii) Uptake of N and P : Uptake of N and P by maize were greatly increased by the application of sludge alone or in combination with RP and microbial cultures (Table 21). Amount of uptake was however, proportional to the amount of its application. Uptake of N were increased by 1.98 to 3.52 times whereas that of P by 2.70 to 6.17 times over their respective soil control values. Sludge was rich in N and P, presumably in organic form. It was very probable that those nutrients were readily mineralised by greater microbial activity due to their fresh application leading to higher uptake of N and P by the high fertilizer consuming maize plant. Thus, maximum uptake of both the nutrients were recorded at higher application of sludge along with RP and microbial cultures (T_7) which were almost at par with 100% inorganic fertilizer application in T_9 .

Chapter V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

In the event of wide spread energy crises it has become highly desirable for making massive efforts to adopt organic recycling as a source of bioenergy as well as for enhancing soil productivity in the developing countries.

Recycling through composting may be one of the most effective ways in utilizing the organic wastes of our farm and city origin. The purpose can more effectively be served if such composts can be enriched with nutrients like N and P.

Therefore, in the present study attempts were made (I) to improve the quality of composts of both farm and city origin; (II) recycling of organic wastes through direct incorporation into the soil for higher crop yield and soil productivity, and (III) use of refuse as a source of plant nutrient.

✓
I. The study on improvement of the quality of the composts included

- i) Mechanical Plant Compost;
- ii) Compost prepared from fresh city garbage;

iii) Compost prepared from farm waste.)

The improvement of the above compost was carried out by the application of low cost microbial enrichment technique along with the application of cheap quality of minerals like rockphosphate, pyrites etc. The extent of enrichment was evaluated by (i) chemical composition of the compost, (ii) effect on dry matter yield of test crops, (iii) uptake of major plant nutrients like N and P by test crops, and (iv) the residual effect on the soil with respect to nutrients and biomass.

i) In the event of improving the quality of the Mechanical Plant Compost it was found worthwhile to know the microbial composition of the compost with particular emphasis on cellulose decomposing microorganisms.

It was found that the city compost processed at Bantala was infested with a number of efficient cellulolytic microorganisms and for obvious reason, application of cellulolytic organism was not required so far as rapid composting was concerned. Moreover, the study lead to the identification of a few efficient fungal strains, namely Aspergillus nidulans and Penicillium varioti which offered a scope for their culturing and use as inoculants in the rapid composting of farm wastes.

Therefore, the studies for improving the quality of mechanical plant composts were carried out by fresh application of P-solubilizing and N-fixing microorganisms along with rockphosphate, pyrite and mineral nitrogen.

The chemical composition of the enriched mechanical plant compost recorded an increase of both total N and $\text{NO}_3\text{-N}$ ranging from 7.7-49.9 and from 6.31-74.54 per cent respectively over their respective control when compost heaps were amended with Azotobacter chroococcum, rockphosphate and P-solubilizing cultures of Penicillium sp. and Bacillus sp. Available P of the treated composts increased significantly with maximum record with fungal cultures of P-solubilizer. Bacterial culture of P-solubilizer in association with Azotobacter recorded a maximum gain in biomass C, 2.68 fold of the control treatment.

Inoculation of combined cultures along with rockphosphate, inorganic N and pyrite exhibited the most effective influence in increasing the dry matter yield and uptake of N and P by three successive crops.

Thus, the cheaper sources of mineral rockphosphate and pyrite/ Δ were the prospective amendments which in association with the compatible microbial cultures contributed greatly to the quality of compost prepared from city organic wastes.

ii) Above microbial enrichment technique followed by rapid decomposition by selected cellulose decomposing cultures was applied for the preparation of enriched composts directly from the unprocessed garbage of Calcutta City. ?

Combined microbial inoculants along with rockphosphate, inorganic N and pyrite was found to be much more effective in rapid decomposition as well as in increasing the N of the composts

processed from city garbage. Thus, the low cost microbial enrichment technique was tested to be a viable one in improving the quality of composts of different origins.

iii) In the next study, (a) efficiency of low cost microbial inoculation technique was compared with the age-old practice of using the cattle dung for the production of good quality of compost from farm waste like paddy straw; (b) the effect of higher application of rockphosphate in influencing the rapid composting of straw by microbial inoculants was also compared. /

Higher application of RP was found to inhibit significantly the decomposition of paddy straw but increased total N. There were significant higher accumulation of $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, av. P in cattle dung treated pile. In effecting the dry matter yield of first crop, rice, composts could be graded in the order : 100% NPK > CD enriched compost > microbial inoculants enriched compost with 1% P_2O_5 > 50% NPK >> microbial enriched compost with 0.2% P_2O_5 > control compost > soil control, whereas for the second crop, a leguminous one it was in the order : cattle dung (CD) enriched compost > microbial enriched compost with 1% P_2O_5 > microbial enriched compost with 0.2% P_2O_5 > 100% NPK >> control compost > 50% NPK > soil control.

Thus, cattle dung enriched compost was found to be superior to microbially enriched compost so far as its effect on dry matter yield of the crops was concerned. Microbially enriched compost with lower RP, 0.2% P_2O_5 basis, maintained highest significant biomass C in the soils estimated after harvest of first crop.

Therefore, application of RP at 1 per cent P_2O_5 basis may be suggested for an over-all improvement of the quality of compost prepared from straw. Cattle dung inoculum is considered more effective in improving the quality of compost and may be suggested for its wider application in composting straws and allied wastes in farm house.

✓
II. The attempt to develop technology for quick disposal of crop residue through direct incorporation into the soil was aimed at developing alternative technology as a means of recycling of straw waste for higher crop yield and productivity of land. Straw was inoculated with the combined cultures of cellulose decomposing, P-solubilizing and N-fixing organisms along with RP and were incorporated into the soil (i) on the date of sowing and (ii) 21 days before sowing to assess their effect on (a) the dry matter yield of crops and (b) plant nutrient including biomass of harvested soil.

It was found that -

- a) Irrespective of amendment and time of application direct incorporation of straw seriously effected the dry matter yield of rice grown as first crop under submerged condition.
- b) Dry matter yield of the next crop, wheat, was greatly increased ranging from 68-89 per cent over their respective soil control values. However, microbial inoculation effected 8-17 per cent greater yield over uninoculated control.

c) Application of straw induced significant increase in the plant nutrient of the soil.

✓
III. (A study was also undertaken to suggest if the dairy sludge produced out of the effluent as well as the spoiled milk at the main processing plant of Mother Dairy, Calcutta can be utilized as an organic amendment for field use.)

A pot culture experiment was carried out with two rates of sludge application, 2.5 and 5.0 ton ha⁻¹ basis alone or in combination with combined microbial cultures along with minerals and in comparison with 50 and 100 per cent recommended dose of inorganic fertilizer for the test crop, maize (Zea mays).

Application of sludge at lower rate, 2.5 ton ha⁻¹ along with combined microbial cultures and RP saved 50% fertilizer recommended for maize, while the dry matter yield obtained with higher application of sludge (5 ton ha⁻¹) was equivalent to the yield recorded by 100 per cent NPK fertilizer.

Chapter VI

FUTURE SCOPE OF RESEARCH

FUTURE SCOPE OF RESEARCH

The investigation embodied in the present thesis "Microbial enrichment of compost for higher crop yield" includes the results of research carried out on enrichment of composts with different amendments of different origins. The enriched composts have been evaluated by their effect on dry matter yield of crops in Pot culture experiment. Therefore, it may not be wise to draw a sweeping conclusion based on the results of those pot culture experiments. To draw a definite conclusion in these directions it is suggested that the investigation should be extended in the following lines :

1. Studies for rapid decomposition of mixed organic municipal wastes, straws of wide C:N ratios, etc. with more efficient cellulolytic and lignolytic organisms should be continued. /
2. Optimum dose of cattle-dung inoculum, rockphosphate, pyrite etc. for the production of enriched composts should be worked out on priority basis.
3. Enrichment of composts with other wastes, rich in N and P, should simultaneously be undertaken.

4. Enrichment experiments should be extended to the composts of different origins.
5. Studies for in situ decomposition and efficient management of left over crop stubbles with the help of cellulose decomposing cultures along with P-solubilizing, N-fixing organisms and minerals may be undertaken.
6. Attempts may be undertaken for microbial enrichment of manures which are already available in the market as "Organic manure".
7. Evaluation of enriched composts should be carried out in field experiments with sufficient number of replications.

Chapter VII

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Chapter VIII

LIST OF PUBLICATION

EFFECT OF NITROGEN FIXING AND PHOSPHATE SOLUBILIZING MICROORGANISMS ON THE ENRICHMENT OF CALCUTTA MECHANICAL PLANT COMPOST

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Abstract

Both Total N and $\text{NO}_3\text{-N}$ of the enriched compost recorded an appreciable increase ranging from 7.7 to 23.1 and from 61.0 to 74.5 per cent respectively over control when compost heaps were amended with *Azotobacter chroococcum*, rockphosphate and P-solubilizing cultures of *Penicillium* sp. and *Bacillus* sp. Available phosphorus (Olsen P) increased remarkably when amended with fungal culture of P-solubilizer. Bacterial culture of P-solubilizer in association with *Azotobacter* recorded a maximum gain in biomass C (2.58 times).

Introduction

One mechanical compost plant has been installed by West Bengal Agro Industries Corporation at Bantala near Calcutta during Fifth Five Year Plan to prepare manure from Calcutta City garbage for agricultural use. Government of India emphasised in Sixth Five Year Plan, 1980-85, the need for popularising extensively organic recycling in the country. Contrary to this, the status report of ICAR (Bhardwaj, 1984) about functioning of the mechanical compost plants installed in the cities of Ahmedabad, Bangalore, Baroda, Bombay, Calcutta, Delhi, Jaipur and Kanpur for the purpose of conversion of city garbage to a useful product, is not much encouraging. The product is not popular to the farmers. But working on the composition of Bantala compost, Dutta Gupta *et al.* (1986) laid much stress for utilization of city garbage for the preparation of compost for higher crop yield. In view of the above, it was felt that the product brought out by the mechanical compost plant at Calcutta should be improved qualitatively. With that object in view, the present study was initiated if any improvement could be made in the material by enriching it with rockphosphate and microbial inoculants to make it agronomically more viable and economically more acceptable to the farmers.

Materials and Methods

The compost material processed earlier by the plant was used in the

present experiment. The initial composition of the material was : pH 7.00, WHC 18.5%, Org. C 7.90%, Total N 0.406%, $\text{NH}_4\text{-N}$ 44 ppm, $\text{NO}_3\text{-N}$ 806 ppm, Total P 0.302% and Av. P 101 ppm.

Each forty kg portion of mechanical compost was taken in cemented pit and was treated as per following Schedule of treatment :

T_1 —Nature compost (MC)

T_2 —MC+Rockphosphate (RP)

T_3 —MC+*Azotobacter* (Azot.)

T_4 —MC+RP+Azot.

T_5 —MC+RP+Azot.+P-sol. I (PFC₅)

T_6 —MC+RP+Azot.+P-sol. II (PBC₇)

Rockphosphate (Mussoorie Phos, 100 mesh) containing 17.2 per cent P_2O_5 was added @ 1 per cent as preliminary investigations (Hajra, 1988) indicated that this level of phosphate could suffice to stimulate the process of composting. All the microbial cultures and mineral supplements were added at the start of the experiment. The microbial inoculants consisted of the effective cultures of selected fungi, PFC₅ (*Penicillium* sp.), and bacteria PBC₇ (*Bacillus* sp.), efficient in solubilizing rockphosphate and efficient nitrogen fixing organism, *Azotobacter chroococcum*. Bacterial cultures were added @ 10^6 viable cells per Kg of compost whereas fungal cultures were added @ 500 g mycelial mat per ton of material. All the strains were isolated in the laboratory. Moisture was maintained at 50 per cent WHC of the compost throughout the period of 6 weeks decomposition. At the end, material was removed from the pit, mixed thoroughly and samples were drawn for analysis of Total N, $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, Av.P as per procedure described by Jackson (1967). Total organic carbon was estimated after dry combustion of compost at 600°C for 6 hours and calculating the per cent C following the equation : $\frac{100 - \% \text{ ash}}{1.8}$ as described by Waggoner (1972) on the

assumption that the dry weight % of organic carbon averages 56% or $100/1.8$.

Total biomass of enriched compost was estimated by fumigation with chloroform vapour followed by incubation for determination of total CO_2 evolved as described by Jenkinson and Powlson (1976). Total microbial biomass C has been calculated from the difference between the amounts of CO_2 evolved during incubation by fumigated and unfumigated samples as per follows :

$$\frac{(\text{CO}_2 \text{ evolved from the fumigated sample}) - (\text{CO}_2 \text{ evolved from unfumigated sample})}{\text{incubation period}} = \frac{F}{K}$$

Fraction of biomass C mineralized to CO₂ over the 10 days

Where the value of K is 0.45 as determined by Jenkinson and Powlson (1976). They concluded that this flush of decomposition (CO₂ evolution) in large measure was the result of the decomposition of microbial cells killed by the fumigation and pointed out that the measurement of this flush in respiration could indicate the approximate size of biomass.

Results and Discussion

The chemical composition and biomass content of the enriched compost at six weeks decomposition have been shown in Tables 1, 2 & 3.

The organic content of compost decreased significantly after six weeks, decomposition in all the treatments from the respective initial value which supports the earlier observation (Rasal *et al.*, 1987).

Total N increased in all the treatments (Table 1). This increase in N was remarkable (19.0 to 23.1%) in the treatments where *Azotobacter* was applied in combination with P-solubilizing cultures. Among the P-solubilizers, bacterial effected greater increase than fungal culture, possibly through greater production of microbial biomass at neutral pH of the

TABLE 1. *Changes in carbon, nitrogen and C : N ratio during incubation of enriched compost*

Treatment	Organic Carbon (%)		Total Nitrogen (%)		C : N	
	Period of incubation		Period of incubation		Period of incubation	
	(Weeks)		(Weeks)		(Weeks)	
	0	6	0	6	0	6
T ₁	7.88	7.00	0.422	0.455	18.69	15.40
T ₂	7.80	6.77	0.413	0.455	18.92	14.97
T ₃	7.85	7.15	0.413	0.490	19.06	14.63
T ₄	7.90	7.25	0.415	0.500	19.20	14.52
T ₅	7.88	6.89	0.420	0.540	18.83	12.81
T ₆	7.80	6.77	0.434	0.560	17.99	12.08
CD at 5%	0.31		0.047		1.73	

TABLE 2. *Changes in $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$ and available P during incubation of enriched compost*

Treatment	$\text{NH}_4\text{-N}$ (ppm)		$\text{NO}_3\text{-N}$ (ppm)		Available P (ppm)	
	Period of incubation (Weeks)		Period of incubation (Weeks)		Period of incubation (Weeks)	
	0	6	0	6	0	6
T ₁	39	28	792	554	104	133
T ₂	29	21	805	589	110	144
T ₃	48	46	806	734	110	161
T ₄	46	36	810	775	110	150
T ₅	58	48	810	893	110	180
T ₆	48	40	807	967	112	166
CD at 5%	9.02		30.52		12.85	

TABLE 3. *The biomass content of enriched compost 6 weeks, calculated from the increase in CO_2 evolution caused by fumigation with CHCl_3*

Treatment	$\text{CO}_2\text{-C}$ evolved (mg/50 g compost)		Biomass	Biomass
	Fumigated compost	Unfumigated	mg C/50 g	g C/40 Kg
	(x)	compost (y)	compost $x - y \times k$	compost
T ₁	54.50	26.00	63.33	50.664
T ₂	56.00	14.67	91.84	73.472
T ₃	88.77	33.47	122.90	98.320
T ₄	81.50	24.00	127.78	102.240
T ₅	86.37	23.34	140.00	112.000
T ₆	92.50	19.00	163.30	130.640
CD at 5%	6.56	5.31	17.94	

compost heaps. The decrease in carbon might have been possible due to further mineralization of compost after receiving adequate moisture along with microbial inoculants and supplements of minerals through rock phosphate. This decrease of carbon and increase in nitrogen with progress in decomposition resulted a lower C : N ratio in all the treatments. Greater reduction in C : N ratio was obtained when *Azotobacter* was applied in combi-

nation with P-solubilizing cultures, the bacterial strain, *Bacillus* sp, recorded the highest reduction (12.08).

Both NH_4 - N and NO_3 - N recorded a decrease in all the treatments (Table 2) excepting the later in T_5 and T_6 where it was increased ranging from 61.0 to 74.5 per cent over control. This loss of NO_3 - N might be due to its denitrification at comparatively higher pH of the compost. This loss was overcome in T_5 and T_6 by the combined effect of *Azotobacter* and P-solubilizing cultures through greater production of microbial biomass (Table 3) and subsequent release of NO_3 - N through mineralization. Increased production of microbial biomass might have been possible due to the combined effect of utilization of "solubilized P" from rockphosphate by P-solubilizing organisms and simultaneous utilization of the same by *Azotobacter*. The effect was found to be more pronounced with bacterial strain of P-solubilizer than fungal one possibly due to increased activity of bacteria at higher pH of the compost. *Azotobacter* alone or only in combination with rockphosphate could not bring any positive effect on NO_3 - N of the compost.

A marked increase in available P was observed in all the treatments possibly due to further mineralization of compost. A greater increase was recorded in the treatments where combined culture of *Azotobacter* and P-solubilizers, *Penicillium* sp. (T_5) and *Bacillus* sp. (T_6) were added along with rockphosphate.

The microbial biomass carbon of the enriched compost was significantly increased ranging from 1.45 to 2.58 times of the control (Table 3). The increase in biomass was in the order : $T_6 > T_5 > T_4 > T_3 > T_2 > T_1$, the maximum value (2.58 times) was recorded in the treatment, T_6 , where the cultures were added in combination. The combined inoculants survived significantly over the uninoculated control. Thus, the amount of biomass present in a compost sample may be considered as an important parameter in determining the quality of compost.

Therefore, it is observed from the present study that the addition of mineral materials of comparatively cheap quality is one of the prospective amendments which in association with the compatible microbial cultures may contribute to the quality of compost prepared from city organic wastes.

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Chapter IX

ANNEXURE

Annexure I

Total Annual Production of Soil Nutrients (N, P, K) through Organic Wastes in the Developing World.

1971 (Actual) and 1980 (Estimated)*

Source	Year	N (Million metric tonnes of nutrients)	P	K
Human	1971	12.25	2.87	2.61
	1980	15.26	3.57	3.25
Cattle	1971	17.80	4.91	12.12
	1980	22.25	6.14	17.65
Farm compost	1971	9.54	3.34	9.54
	1980	11.93	4.18	11.93
Urban compost	1971	0.48	0.38	0.57
	1980	0.60	0.48	0.71
Urban sewage	1971	1.43	0.29	0.86
	1980	1.79	0.36	1.08
Other ⁺	1971	6.63	4.44	11.35
	1980	8.29	5.55	14.19
Total	1971	48.13	16.23	39.05
	1980	60.12	20.28	48.81

*Excludes Central America and Oceania, but includes Socialist Asia.

⁺Bone-meal, poultry litter, bagasse, sheep/goat litter, oilcake, pressmud (Several other sources were not included due to small potential for the developing world).

Reproduced from "Energy crisis, Food crisis, Desertification and Organic Recycling" by B.R.Nagar published in Journal of Scientific and Industrial Research, Vol. 40, March 1981, pp. 147-153.

Annexure II

Values of N, P and K Found in Wastes of the Developing World
Compared to Chemical Fertilizers

[at 1973 world f.o.b. prices in millions of 5]

		N	P	K	Total
Organic	1971	9626	4058	2499	16183
	1980	12024	5070	3124	20218
Chemical	1971	7000	5597	1246	13843
	1980	11380	7775	1638	20793

Reproduced from "Energy crisis, Food crisis, Desertification and Organic Recycling" by B.R.Nagar published in Journal of Scientific and Industrial Research, Vol. 40, March 1981, pp. 147-153.

Annexure III

Total annual availability of various solid wastes in India (1989)

Solid waste category	Quantity (approx.) million tonne/year
Agricultural crop residues :	
(a) Cereal	196.8
(b) Pulses	14.4
(c) Oil seeds	5.8
(d) Plantation crops	34.4
(e) Fibre crops	17.4
(f) Fruits and vegetables	4.5
Sub total = 273.3	
Agro-industrial wastes :	
(a) Rice husk	18.0
(b) Jute Mill waste	0.5
(c) Cotton dust	0.3
(d) Sugarcane	5.3
(e) Saw dust	2.1
Sub total = 26.2	
Animal and Poultry wastes :	
(a) Wet cattle dung	860.0
(b) Sheep and Goat wastes	45.0
(c) Poultry wastes	1.0
Sub total = 906.0	
Sewage sludge and Marine wastes :	
(a) Community wastes	150.0
(b) Fisheries and Marine wastes	1.4
Sub total = 151.4	
Grand total = 1356.9	

Reproduced from "Biogas from solid waste" by G.K.Roy published in Science Reporter, June 1989, pp. 267-271.

ANNEXURE IV

Nitrogen content and C:N ratio of various organic inputs

Material	%C	%N	C:N
Cattle dung	31.96	1.17	27 : 1
FYM	28.77	1.77	16 : 1
Activated sludge	3.03	0.45	6.74 : 1
Water hyacinth	44.33	2.29	19 : 1
Legume plants	46.15	2.48	19 : 1