Summary and Conclusion

5 SUMMARY AND CONCLUSION

The disposal of wastes is on the increase day by day causing pollution of land and water. Therefore, effective solid waste management is important to reduce this pollution. Land application of products from organic wastes such as composts and biofertilizers is gaining importance all over the world. Microbial vermicomposting using a combination of microorganisms and earthworms is considered to be effective in the recycling of organic wastes. It is an environmentally acceptable and friendly technique of composting converting organic wastes into nutrient - rich manure.

Tapioca is a crop of great economic importance, both as human food and animal feed as well as raw material for industrial products. It is mainly used in the production of starch in India. Tamil Nadu ranks second in terms of cultivation and production of tapioca after Kerala but it stands first with respect to processing of tapioca into sago and starch throughout the country meeting about 80 percent of the country's demand. Accumulation of tapioca solid waste in and around the sago processing industries leads to unfavourable odours due to the growth of undesirable and pathogenic organisms leading to land and water pollution.

One of the promising management practices to reduce pollution by such solid wastes like tapioca waste is composting. Hence, the present study entitled 'Biocomposting of tapioca solid waste with selected earthworms and microbes' was taken up with the **objectives of**

- Studying the physicochemical characteristics of undecomposed and decomposed tapioca solid waste.

- Evaluation of enzyme activities and compost maturity in the best degraded tapioca solid waste -cow dung composts.

- Studying the efficiency of the above compost on plant growth.

The study was conducted in three phases

In Phase I, tapioca solid waste and cow dung were collected and analyzed ofr physicochemical parameters.

The results showed that pH, organic matter, organic carbon, C:N ratio, sodium, calcium and sulphur contents were significantly ($p<0.05$) high in tapioca solid waste when compared to cow dung. However, the electrical conductivity, iron, copper, zinc, molybdenum and boron levels were significantly ($p<0.05$) low in tapioca solid waste and high in cow dung. Hence cow dung was used as the bulking agent.

Different ratios (1:1, 2:1, 3:1, 4:1, 5:1 and 6:1) of tapioca solid waste were mixed with constant ratios of cow dung (bulking agent)) was composted in four different ways by using microorganisms, earthworms and a combination of microorganisms and earthworms as given below. Pilot studies showed that a high proportion of tapioca solid waste markedly decreased the survival rate of earthworms. Hence, composting was carried out by mixing tapioca solid waste and cow dung only upto 6:1 ratio. These wastes were initially precomposted for 20 days and then given the following treatments for composting.

T_1 - Natural composting (control) without any microorganisms and earthworms, T_2 - composting with microbes only, T_3 . composting with earthworms only and T_4 - composting with both microbes and earthworms.

On the 75th day, the composts obtained from the above treatments were harvested and analyzed for selected physicochemical parameters.

The results indicated that composting generally increased the pH of the substrate towards neutrality with a significantly ($p<0.05$) highest increase in the 3:1 ratio microbial vermicompost (M+V).

As regards the electrical conductivity, all the ratios of vermicomposts (V) revealed significant ($p<0.05$) increases when compared to their respective controls (C) and microbial composts (M). In the microbial vermicomposts (M+V), all the ratios showed significantly ($p<0.05$) higher values than the other treatments. In vermicomposts (V) and microbial vermicomposts (M+V) the highest percent increase was exhibited by the 3:1 ratio.

The organic matter contents of all the types of composts namely microbial composts (M), vermicomposts (V) and microbial vermicomposts (M+V), exhibited significantly ($p<0.05$) lower organic matter contents when compared to the controls (C). In all the treatments, the 3:1 ratio sample showed the maximum percent decrease in the organic matter.

The 1:1 to 4:1 ratio samples of microbial composts (M) and the 1:1 to 5:1 ratio samples of vermicomposts (V) revealed significantly ($p< 0.05$) lower organic carbon contents than the controls (C). The 1:1, 2:1, and 3:1 ratios of microbial vermicomposts (M+V) showed significantly ($p<0.05$) lower organic carbon values than all other treatments. In microbial composts (M) and microbial vermicomposts (M+V), the 1:1 ratio exhibited a high percent decrease, whereas, in vermicompost (V), the maximum percent decrease was revealed by the 3:1 ratio.

The total nitrogen contents in the 1:1 to 4:1 ratios of microbial composts (M) were significantly ($p<0.05$) higher than their controls (C). In the vermicomposts (V), the total nitrogen in all the ratios were significantly higher than their controls (C) and microbial composts (M). The 1:1 to 5:1 ratios microbial vermicomposts (M+V) expressed a highly significant ($p<0.05$) increase in the total nitrogen content when compared to other treatments. In all the treatments the 3:1 ratio exhibited the highest percent increase in the total nitrogen content.

The C:N ratio should lie between 10:1 to 20:1 for having a positive effect on the growth of plants. The C:N ratios in the 1:1, 2:1 and 3:1 samples of vermicomposts (V) and 2:1, 3:1 and 4:1 samples of microbial vermicomposts (M+V) showed values in the range of 10:1 to 20:1 which are known to have stimulatory effects on plant growth.

The phosphorus contents in 2:1 and 3:1 ratio microbial composts (M) were significantly ($p<0.05$) higher than in the control (C). The vermicomposts (V) formed from 2:1 and 3:1 ratio samples expressed values significantly ($p<0.05$) higher than their respective controls (C) and microbial composts (M). In the microbial vermicomposts (M+V), upto the 3:1, ratio the phosphorus contents were highly significant ($p<0.05$) when compared to other treatments. Among all the ratios, the 3:1 samples of all the treatments revealed the highest percent increase.

The total potassium in the 3:1 ratio microbial compost (M), was significantly ($p<0.05$) higher than in the control (C). In the vermicomposts (V), the 1:1 ratio marked significant ($p<0.05$) increases as compared to their controls (C). The 1:1 2:1, 3:1 and 5:1 ratios of microbial vermicomposts (M+V) expressed significantly ($p<0.05$) higher levels of total potassium content, when compared to control (C), microbial composts (M) and vermicomposts (V). The maximum percent increase was found in the 3:1 ratio samples of all the treatments.

The available nitrogen contents in all the microbial composts (M) were significantly ($p<0.05$) higher than the contents in the controls (C). In the case of vermicomposts (V) also, the available nitrogen content in all the ratios were significantly ($p<0.05$) higher than in the controls (C) and microbial composts (M). In the microbial vermicompost (M+V) all the ratios expressed significantly ($p<0.05$) higher available nitrogen contents than their corresponding controls (C), microbial composts (M) and vermicomposts (V).The percent increase was high in the 3:1 ratio microbial composts (M) and microbial vermicompost (M+V), whereas, in vermicompost (V) the 4:1 ratio showed the highest percent increase.

All the samples of microbial composts (M), 1:1 to 3:1 ratios of vermicomposts (V) and microbial vermicomposts (M+V) recorded significant ($p<0.05$) increases in the available nitrogen contents on comparison with the controls (C). But in the microbial vermicomposts (M+V), the available phosphorus levels in all the ratios were significantly ($p<0.05$) higher than in the controls (C) and microbial composts (M). Here the 6:1 ratio microbial compost (M) and 3:1 ratio vermicompost (V) and microbial vermicompost (M+V) revealed the highest percent increase in the available phosphorus content.

All the ratios of microbial composts (M) and vermicomposts (V) revealed significantly ($p<0.05$) higher levels of available potassium, when compared to the controls (C) and microbial composts (M) respectively. The available potassium levels in the 1:1 to 3:1 ratios of microbial vermicomposts (M+V) were significantly ($p<0.05$) higher than the controls (C), microbial composts (M) and vermicomposts (M+V). The percent increase was high in the 3:1 ratio vermicompost (V) and microbial vermicompost (M+V), whereas, in microbial composts (M) the 4:1 ratio showed the highest percent increase.

The microbial degradation (M) of tapioca solid waste did not alter the sodium content of the composts. All the ratios of vermicomposts (V) and microbial vermicomposts (M+V) marked significant ($p<0.05$) decreases in the sodium contents when compared to their controls (C) and microbial composts

(M). It was found that in vermicomposts (V) and microbial vermicomposts (M+V) the 3:1 ratio showed the highest percent decrease in the sodium content.

The calcium contents in the 2:1 and 3:1 ratios of microbial composts (M) were significantly ($p<0.05$) higher than their respective controls (C). The 1:1 to 5:1 ratios of vrmicomposts (V) and all the samples of microbial vermicomposts (M+V) expressed significantly ($p<0.05$) higher values than the controls (C) and microbial composts (M). The calcium content in the 3:1 ratio microbial vermicompost (M+V) alone was significantly ($p<0.05$) higher than those of the controls (C), microbial composts (M+V) and vermicomposts (V). In all the treatments the 3:1 ratio expressed the highest percent increase in the calcium content.

The magnesium contents in 1:1 to 3:1 ratios of microbial composts (M) and vermicomposts (V) recorded significant ($p<0.05$) increase on comparison with the controls (C) and microbial composts (M) respectively. The 3:1 ratio microbial vermicompost (M+V) recorded significantly ($P<0.05$) the highest magnesium content and in all treatments, the percent increase was high in the same ratio.

All the ratios of vermicomposts (V) revealed significantly ($p<0.05$) low sulphur contents when compared to their controls (C) and microbial composts (M). The sulphur contents in the 1:1 to 4:1 ratios of microbial vermicomposts (M+V) were significantly ($p<0.05$) lower than those of the controls (C), microbial composts (M) and vermicomposts (V). The percent decrease in both vermicompost (V) and microbial vermicompost (M+V) was high in the 3:1 ratio.

The 1:1 to 4:1 ratios of microbial composts (M) resulted in significantly ($p<0.05$) higher iron contents than the controls (C). All the ratios of vermicomposts (V) showed significantly ($p<0.05$) higher iron contents than the controls (C) and microbial composts (M). The 1:1 to 3:1 ratios of microbial vermicomposts (M+V) marked significantly high iron content when compared to the controls (C), microbial composts (M) and vermicomposts (V). The percent increase in all the treatments were high in 3;1 ratio sample.

The 1:1 to 3:1 ratio vermicomposts (V) and microbial vermicompost (M+V) exhibited significant ($p<0.05$) increases in the zinc content as compared to their levels in the controls (C) and microbial composts (M). In the three treatments a high percent increase in the zinc content was exhibited by the 3:1 ratio.

The copper contents in the 1:1 to 3:1 ratios vermicomposts (V) and microbial vermicompost (M+V) recorded significantly lower ($p<0.05$) values than their controls (C) and microbial composts (M). The 3:1 ratio of microbial vermicompost expressed significantly ($p<0.05$) the lowest copper content and the percent decrease was high in the same ratio of both vermicompost (V) and microbial vermicompost (M+V).

As regards molybdenum, significant ($p<0.05$) changes towards control (C) was found only in the 2:1 and 3:1 ratios of microbial composts (M) with high percent decrease when compared to other ratios. In the vermicomposts (V), the values upto 5:1 ratios were significantly ($p<0.05$) higher than in the controls (C) and microbial composts (M). The microbial vermicomposts also expressed significant ($p<0.05$) increase upto 5:1 ratio. In vermicomposts (V) and microbial vermicomposts (M+V) the percent increase in 3:1 ratio sample was higher than in other ratios.

The boron content in 3:1 ratio of microbial vermicompost (V) was significantly ($p<0.05$) higher than control (C). In the vermicomposts (V), the values upto 4:1 ratios were significantly higher than controls (C) and microbial composts (M). The 1:1 to 4:1 ratios of microbial vermicomposts (M+V) expressed significantly ($p<0.05$) higher levels of boron content as compared to controls (C) microbial composts (M) and vermicomposts (V). In all the treatments the 3:1 ratio sample revealed the highest percent increase when compared to other ratios.

The above results showed that the pH was around neutrality in the 3:1 ratio microbial vermicompost (M+V). The highest percent increase in the electrical conductivity, total nitrogen, phosphorus, potassium, available nitrogen, available phosphorus, available potassium, magnesium, iron, zinc, molybdenum and boron levels of 3:1 ratio tapioca solid waste – cow dung mixture revealed that microbes, earthworms and microbes with earthworms promote the tapioca solid waste degradation only upto 3:1 ratio with cow dung.

The activity of microbes, earthworms and microbes with earthworms in the 3:1 ratio tapioca solid waste - cow dung mixture also expressed maximum percent decrease in the organic matter, sodium and copper values. This confirms that earthworm activity was maximum in the 3:1 ratio tapioca solid waste - cow dung mixture. But among the three treatments, the 3:1 ratio tapioca solid waste - cow dung mixture microbial vermicompost (M+V) showed better results in most of the parameters.

The results of Phase I showed that **3:1 ratio tapioca solid waste – cow dung mixture** showed better results for most of the parameters when compared to other ratios. Hence the study was continued in Phase II by taking 3:1 sample alone.

In Phase II, the 3:1 ratio of tapioca solid waste - cow dung mixture was precomposted, and then composted in four different ways as explained in Phase I. In order to know the metabolic activity and growth of earthworms, the activity of cellulase, β- glucosidase, protease, urease, dehydrogeanase, acid and alkaline phosphatase activity were determined on the 25th, 50th and 75th days of the composting period. The maturity of composts were also observed by determining the humic acid level, carbondioxide evolution, earthworm biomass and number of cocoons on the 25th, 50th and 75th days of the composting period. The number of earthworms and yield of the composts were calculated on the 75th day.

The growth, multiplication and metabolic activity of earthworms are important factors during composting. These can be analyzed by way of studying the activity of enzymes at different stages of the composting process. The maturity of the composts can also determined by analyzing the compost maturity tests.

The cellulase activity in the microbial compost (M), was found to be significantly ($p<0.05$) increased upto the 75th day. On the other hand in the vermicomposts (V) and microbial vermicompost (M+V) of tapioca solid waste, the values significantly decreased ($p<0.05$) on the 75th day.

In the microbial composts (M) and vermicomposts (V) of tapioca solid waste, the β glucosidase activities registered significant ($p<0.05$) increases till the 75th day. On the contrary, a significantly ($p<0.05$) low activity was observed in the microbial vermicompost (M+V) on the 75th day.

The protease activity in the microbial composts (M), vermicomposts (V) and microbial vermicomposts (M+V) of tapioca solid waste exhibited significantly ($p<0.05$) low enzyme levels on the 75th day.

The urease activity in the microbial composts (M) of tapioca solid waste were significantly ($p<0.05$) increased upto the 75th day. Vermicomposts (V) and microbial vermicomposts (M+V) on the contrary, expressed low enzyme levels on the 75th day.

The microbial composts (M) and vermicomposts (V) recorded significantly ($p<0.05$) increased dehydrogenase activity upto the 75th day. However, the enzyme activity in the microbial vermicompost (M+V) was significantly ($p<0.05$) low; when compared to the 50th day sample.

In all the types of composting processes, the acid and alkaline phosphatase activities were significantly ($p<0.05$) increased upto the final day. On comparision of all treatments, the microbial vermicomposts (M+V) expressed significantly ($p<0.05$) the highest level on all the sampling days.

The microbial compost (M), vermicompost (V) and microbial vermicompost (M+V) of expressed significantly ($p<0.05$) high the humic acid levels upto the 75th day. On the other hand, the microbial vermicompost (M+V) revealed maximum level of humic acid, when compared to other treatments.

In the microbial composts (M) and vermicomposts (V) of tapioca solid waste, the carbondioxide evolution was significantly ($p<0.05$) increased upto the 75th day, whereas, the microbial vermicompost (M+V) showed significantly ($p<0.05$) low carbondioxide evolution on the 75th day.

Vermicomposting (V) significantly ($p<0.05$) increased the biomass of the earthworms upto the 75th day. On the contrary, microbial vermicomposting (M+V) slightly decreased the earthworms weight on the 75th day.

The number of cocoons in the vermicomposts (V) of tapioca solid waste significantly ($p<0.05$) increased throughout the experimental period. On the other hand, there was a decrease in the number of cocoons in the microbial vermicompost (M+V) on the 75th day.

The number of earthworms in the microbial vermicompost (M+V) was significantly ($p<0.05$) higher than in the vermicomposts (V) and the maximum compost yield was shown by the 3:1 ratio microbial vermicompost (M+V).

In Phase II, the decreased activities of cellulase, β glucosidase, protease, urease and dehydrogenase reflect the depletion of the substrates by the combined action of earthworms and microbes. On the other hand, high acid and alkaline phosphatase activities being intracellular enzymes represent the survival of the microbes and its metabolic action upto the end.

The highest humic content and compost yield in the microbial vermicompost (M+V) clearly showed that inoculation of microbes alongwith earthworms promotes organic matter degradation and enriches the nutrient content of the final compost. This confirms that inoculation of selected microorganisms hastens the degradation of organic matter and promotes the reproduction of earthworms, protozoa and fungi which are assumed to form a substantial part of the earthworm diet.

In the microbial vermicompost (M+V), the decrease in carbondioxide evolution, earthworm biomass and cocoon number on the 75^{th} day indicate the decreased action of microbes and earthworms accompanied by depletion of the substrate.

In the current study, the changes in the activity of enzymes, humic acid levels, carbondioxide evolution, earthworm biomass, earthworm number and cocoon number clearly showed that compost maturity applicable for plant growth was found only in the 3:1 ratio microbial vermicompost (M+V). So **the 3:1 microbial vermicompost (M+V)** was selected to study its effects on plant growth.

In Phase III, the effect of the 3:1 ratio microbial vermicompost on the growth of selected plants was studied. Different proportions of 3:1 the ratio microbial vermicompost (C –control, T1- 20%, T2 -40%, T3 -60% and T4 -80%) was mixed with soil. These mixtures were then used to grow black gram (*Vigna mungo*) plants and fenugreek (*Trigonella foenum gracum*) for a period of 90 and 10 days respectively. After this period, biometric parameters like germination index, root and shoot lengths, fresh and dry weights of roots and shoots, number of nodules and seeds and biochemical parameters like soluble sugar, protein and amino acid contents in the plants were studied and compared with those grown in only soil.

Vermicompost is known to contain most of the nutrients that can be easily absorbed by plants. The effect of microbial vermicompost (M+V) from the 3:1 ratio tapioca solid waste - cow dung mixture on the growth of selected plants was analyzed.

The germination indices of black gram plant was significantly ($p<0.05$) high in T_1, T_2 and T_3 samples, when compared to the control (C) and T_4.

The root lengths of black gram plants grown in T_1 and T_2 samples expressed significantly ($p<0.05$) higher values than the control (C) T_3 and T_4.The shoot lengths of the black gram plants were significantly ($p<0.05$) higher in T_1, T_2 and T_3 samples when compared to the control (C) and T_4.

The root fresh weights of black gram plant in T_1 and T_2 samples were significantly ($p<0.05$) higher than in the control T_3 and T_4. Similarly, the dry weights of roots were significantly ($p<0.05$) high in the T_1 sample, when compared to all other samples and control (C).

The T_1 and T_2 samples recorded significantly ($p<0.05$) higher shoot fresh weights in black gram plants than the controls (C), T_3 and T_4 plants. With reference to the shoot dry weights of black gram plants, the T_1 sample revealed significantly ($p<0.05$) the highest value.

As regards number of nodules and seeds in the black gram plants, the T_1 plants expressed significantly ($p<0.05$) higher values than the control and all other treatments.

The shoot lengths, root lengths, root fresh weights and dry weights, shoot fresh and dry weights, germination indices, soluble sugar levels, protein contents, amino acid levels in both the shoots and roots of fenugreek plants, were significantly ($p<0.05$) high on application of T1 (20 % microbial vermicompost - soil mixture) when compared to other treatments and control.

It is clear from the results that application of 20%, 40%, and 60% 3:1 ratio tapioca solid waste : cow dung microbial vermicompost (M+V) influenced the growth of black gram plants and among the three; the 20% microbial vermicompost - supplemented soil showed better results. In the case of fenugreek plants also, the growth was best in the 20% microbial vermicompost - supplemented soil.

Thus, the results of the present study clearly revealed that soil and land pollution caused by the accumulation of tapioca solid waste could be managed effectively by microbial vermicomposting which is an effective technology in solid waste management. The compost obtained from the tapioca solid waste can be used as good organic manure for the growth of plants.

RECOMMENDATIONS FOR FURTHER STUDIES

- Raw tapioca solid waste before drying can be used for the vermicomposting process, since drying is time consuming and a weather orientated process. Moreover, wet composting minimizes fermentation and foul odour.

- Tapioca solid waste may be mixed with other types of wastes with high nitrogen source instead of cow dung as bulking agent. This would have a dual effect of composting two solid wastes to get compost.

- Bacterial and fungal strains which are capable of decomposing raw tapioca solid waste in short duration using nitrogen fixing genes, cellulase gene and phosphorus solubilizing genes by genetic engineering strategy could be developed.

- The effect of compost from the tapioca solid waste on the growth and yield of other plants could be studied.