BIO ORGANIC NUTRIENT MANAGEMENT IN SUGARCANE PRODUCTION - A REVIEW

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ABSTRACT

Organic manures and biofertilizers application in the nutrient management programme is inevitable for achieving sustainable sugarcane production. Application of farmyard manure, cane trash, pressmud, vermicompost and biocompost in combination with recommended inorganic fertilizers have recorded increased cane yield over inorganic fertilizer alone, besides improving the soil fertility and economizing the cane production. Intercropping and incorporation of green manures such as dalinch, sunhemp and cowpea and pulses like greengram, blackgram, lentil and frenchbean have established beneficial effects of improving nitrogen use efficiency, cane yield and improving the physio-chemical properties of soil. Nitrogen fixing biofertilizers are useful to economise the nitrogenous fertilizers and to increase the cane yield. Phosphorus solubilising biofertilizers solubilize the unavailable phosphorus to available P form and increase the P use efficiency. Inclusion of biofertilizers in the nutrient management programme has found to increase the yield of sugarcane by 5-10%, besides increasing the nutrient use efficiency.

Sugarcane (Saccharum officinarum L.) is one of the most important cash crops in India and plays pivotal role in both agricultural and industrial economy of our country. India is one of the largest producers of sugar and has neck-to-neck race with Brazil for the first position. Our country shares about 13.25% of the world and 41.1% of Asian sugar production. Sugar industry, being the second largest agro based industry; employs over 40 million cane growers and about 3.5 lakh skilled and unskilled workers (Shahi, 2000). In India, sugarcane is cultivated over an area of 4 million hectares and the production is estimated to be about 300 million tonnes with a productivity of 70 tonnes per hectare.

By 2010, India has to produce more than 320 million tonnes of sugarcane to cater the crushing requirement of sugar factories operated in our country. But due to continuous monocropping and judicious use of inorganic fertilizers alone, the cultivable lands are fastly depleted and becoming unfertile. The modern techniques of crop production have considerably raised output but have created problems of soil degradation, atmospheric and water pollution. In order to reduce the cost of cultivation and also to keep the soil health and fertility in better condition to sustain the productivity, there is an urgent need to find out some alternate sources of nutrients. Application of green manures, farm wastes, and factory wastes along with biofertilizers are found to be useful in supplementing the inorganic fertilizers and also maintain the cane productivity as well as soil fertility.

Importance of nutrient management in sugarcane

Sugarcane crop produces a heavy tonnage and tends to remove substantial quantum of plant nutrients from the soil. A cane crop producing the cane yield of 100t/ha removes about 208kg N, 53 kg of P, 280 kg K, 3.4 kg Fe, 1.2 kg Mn, 0.6 kg Zn and 0.2 kg Cu from soil (Yaduvanshi and Yadav, 1990). For achieving the higher cane yield, most balanced use of fertilizer nutrients, is the important management factor of cultivation. Fertilizer management plays an important role in the growth and development, yield and yield attributes and finally quality characters of sugarcane compared to other management factors. Use of inorganic fertilizer alone cannot maintain the soil fertility and use of organic...
manures is inevitable for sustained agricultural production. Slow release of nutrients from organics, could help a long duration sugarcane crop to take their complete benefit in one crop season.

Significance of bio-organic nutrients in sugarcane

Sugarcane is one of the chief consumers of fertilizers. Continuous and excess use of chemical fertilizers and intensive cropping system have created imbalance of nutrients in the soil and adverse effect on soil physico-chemical properties, health and ecology. Excessive usage of inorganic fertilizers alone results in environmental pollution and increases the salinity and alkalinity of soil. A detailed economic analysis showed that chemicals and fertilizers alone would account for 22 to 25 per cent of the cost of sugarcane production (Shankaraiah et al., 1999). Mathukia et al. (1999) reported that use of organic manures is inevitable for sustained agricultural production. Due to slow release of nutrients from organics, sugarcane a long duration crop can take its complete benefit.

Increased prices coupled with short supply of fertilizers have posed a question whether the nutritional scarcity and imbalanced nutrient supply, effectively be met through use and recycling of organic farm wastes, FYM, compost and green manures. Hot climate and intensive cultivation have exhausted the nitrogen and organic matter contents of Indian soils. Therefore, organic matter content of soil has to be built up by recycling the organic wastes for sustaining the production (Yadav et al., 2000).

ORGANIC MANURES

Organic manures provide balanced nutrition in addition to enhancing the water holding capacity, nutrient use efficiency and improving the physical properties of soils. Organic manures further facilitate growth of microorganisms, assist in better uptake of nutrients and counteract adverse effect of agro chemicals. Use of organic manures has been reported to improve the physical, chemical and biological properties of soil (Acharya, 1954). Inclusion of green manures, farm wastes, factory wastes and biofertilizers along with inorganic fertilizers are found to be useful in supplementing the inorganic fertilizers and also maintain the cane productivity as well as soil fertility.

Farmyard manure: Farmyard manure contains the entire essential nutrient elements required for the crop growth. Many experiments proved that farm yard manure improve the soil structure and enhance the water holding capacity. It is used to improve the soil organic carbon and soil aggregation. Yadav and Prasad (1992) reported that continuous use of FYM increased the organic carbon content of the soil by 0.01% compared to urea alone which decreased the organic carbon by 0.01%. The reduction in cane yield from the original plant crop to fourth ratoon was the largest in urea applied fields (38.3 t ha⁻¹) and the least yield reduction in FYM applied fields (30 t ha⁻¹). The combination of FYM and urea resulted in a total yield reduction of 31.3 t ha⁻¹. Many of the studies all over India confirmed the positive influence of FYM on cane yield (Shinde et al., 1992; Srinivas, 1996; Mathukia et al., 1999).

Green manure intercropping: Sugarcane is often cultivated in a two year cropping system of cane rotation, cane-rice cropping sequence and thus the farmers find no time to go in for the application organic manures. More over organic manures such as FYM, compost, pressmud are also not available in sufficient quantity. Hence, the cheap and simple method of supplying the soil with organic manure is possible by the way of green manuring (Mahendran et al., 1997). Growing of green manure in the inter row spacing and incorporation at appropriate time not only
supplement the fertilizer but also maintain the soil fertility and sustain cane yield (Linge Gowda, 1965). Green manures are also known to conserve the soil moisture and slowly release fertilizer nitrogen due to wide C: N ratio, which benefits the corps (Jenkinson and Ladd, 1981). Green manure inclusion in cropping system is an alternate way and it increases the physico-chemical properties of the soil. Green manures contribute nearly 41-85 kg N ha⁻¹ depending upon the type of green manure and time of incorporation and roots of green manures alone contribute 40% of total N incorporation (Yadav et al., 2000). Sowing of daincha in single continuous line and insitu incorporation with recommended level of N application produced lengthier cane, higher individual cane weight and cane yield, (Kathiresan and Ayyamperumal, 1996 and Kathiresan et al., 1996). Srinivas (1996) observed that insitu incorporation of daincha at 14 t ha⁻¹ along with 50 per cent N application recorded higher cane girth and cane yield, but the number of internodes were not influenced by daincha intercropping. Similarly, daincha intercropping in sugarcane resulted in higher numbers of millable cane with both plant and ratoon crops even with comparatively lower tiller production. Maximum cane yield was obtained in daincha intercropping and it was comparable with sunhemp intercropping over sole crop of cane (Mahendran et al., 1997). Jayapaul and Yadav (2000) reported that sugarcane intercropped with two rows of daincha and insitu incorporation at 45 DAP registered higher number of millable canes and significantly higher cane yield (Table 1). Incorporation of daincha green manure crop along with the recommended NPK application recorded higher number of millable cane and 4.6 per cent higher cane yield (Ramesh, 2001).

Intercropping and incorporation of sunhemp at 45 DAP might have adequately supplied the plant nutrients to the sugarcane crop resulting in enhanced number of millable canes and cane yield as compared to sole crop of sugarcane (Nasir Ahmed, 1999). Similarly, Buragohain and Medhi (1999) stated that application of recommended dose of N (135 kg ha⁻¹) in combination with green manure crop recorded more millable canes and higher cane yield. Intercropping cowpea or sunhemp or daincha in double rows along the ridges increased the yield of sugarcane as compared to without intercropping (Durai and Ravichandran, 1999). Mathukia et al. (1999) concluded that the combined application of organic sources like green manure and fertilizers increased the cane yield as compared to sole application of fertilizer alone.

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Table 1. Effect of different organic manures on the productivity of sugarcane

<table>
<thead>
<tr>
<th>Organic manures</th>
<th>Without organic manure</th>
<th>With organic manure</th>
<th>Increase/decrease (t/ha)</th>
<th>References</th>
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<tbody>
<tr>
<td></td>
<td>Cane yield (t/ha)</td>
<td></td>
<td></td>
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<tr>
<td>Farmyard manure</td>
<td>140.67</td>
<td>149.83</td>
<td>9.16</td>
<td>Shinde et al., 1992</td>
</tr>
<tr>
<td></td>
<td>85.50</td>
<td>103.20</td>
<td>17.70</td>
<td>Srinivas, 1996</td>
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<tr>
<td>Green manure intercropping</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daincha</td>
<td>111.39</td>
<td>128.26</td>
<td>16.87</td>
<td>Mahendran et al., 1997</td>
</tr>
<tr>
<td></td>
<td>128.12</td>
<td>143.11</td>
<td>14.99</td>
<td>Jayapaul et al., 2000</td>
</tr>
<tr>
<td></td>
<td>115.20</td>
<td>120.74</td>
<td>5.54</td>
<td>Ramesh, 2001</td>
</tr>
<tr>
<td>Sunhemp</td>
<td>92.60</td>
<td>96.30</td>
<td>3.70</td>
<td>Durai and Ravi Chandran, 1999</td>
</tr>
<tr>
<td></td>
<td>135.30</td>
<td>148.40</td>
<td>13.10</td>
<td>Nasir Ahmed, 1999</td>
</tr>
<tr>
<td></td>
<td>155.00</td>
<td>181.00</td>
<td>26.00</td>
<td>Shankaraiah, et al., 1999</td>
</tr>
<tr>
<td>Cowpea (GM)</td>
<td>92.60</td>
<td>106.30</td>
<td>13.70</td>
<td>Durai and Ravi Chandran, 1999</td>
</tr>
<tr>
<td>Pulses intercropping</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green gram</td>
<td>80.50</td>
<td>92.40</td>
<td>11.90</td>
<td>Verma, et al., 1999</td>
</tr>
<tr>
<td></td>
<td>73.52</td>
<td>68.49</td>
<td>-5.03</td>
<td>Singh, et al., 2000</td>
</tr>
<tr>
<td>Lentil</td>
<td>76.25</td>
<td>78.80</td>
<td>2.55</td>
<td>Menhilal, et al., 2000</td>
</tr>
<tr>
<td>Frenchbean</td>
<td>155.00</td>
<td>182.00</td>
<td>27.00</td>
<td>Shankaraiah, et al., 1999</td>
</tr>
<tr>
<td>Pressmud cake</td>
<td>61.86</td>
<td>68.68</td>
<td>6.80</td>
<td>Ramalingaswamy et al., 1999</td>
</tr>
<tr>
<td></td>
<td>158.78</td>
<td>165.30</td>
<td>6.50</td>
<td>Nagaraju et al., 2000</td>
</tr>
<tr>
<td>Cane trash mulch</td>
<td>140.67</td>
<td>153.47</td>
<td>12.80</td>
<td>Shinde et al., 1992</td>
</tr>
<tr>
<td></td>
<td>57.00</td>
<td>71.50</td>
<td>14.50</td>
<td>Rana et al., 2000</td>
</tr>
<tr>
<td>Vermicompost</td>
<td>78.94</td>
<td>92.94</td>
<td>14.00</td>
<td>Thirugnanam et al., 1999</td>
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Pulse intercropping: Adoption of wide row spacing and slow growth rate of sugarcane at the initial stage offer ample scope for accommodating short durational intercrops. Pulses like black gram, soybean, green gram and French bean provide extra monetary returns. Intercropping and incorporation of legumes such as French bean, soybean and sunhemp etc. have established the beneficial effect of increasing the N use efficiency. Legumes as intercrops in sugarcane not only offer a new high yielding environment for pulse production but also provide sustainability to the plant-ratoon system through incorporation of their residues in the soil. Jayapal et al. (1989) recorded significant increase in cane yield by incorporation of green gram harvested on 45th day and by allowing beyond that stage of intercrop reduced the cane yield considerably. Sunhemp was buried at six weeks, green pods in French bean and dry pods in cowpea were harvested and plants incorporated in situ were able to produce a significant improvement in the yield of sugarcane (Shankaraiah et al., 1999). According to Dixit and Misra (1991) growing of intercrops in spring planted sugarcane was generally remunerative by recording higher cane productivity for pulse production but also provide sustainability to the plant-ratoon system through incorporation of their residues in the soil. Jayapal et al. (1989) recorded significant increase in cane yield by incorporation of green gram harvested on 45th day and by allowing beyond that stage of intercrop reduced the cane yield considerably. Sunhemp was buried at six weeks, green pods in French bean and dry pods in cowpea were harvested and plants incorporated in situ were able to produce a significant improvement in the yield of sugarcane (Shankaraiah et al., 1999). According to Dixit and Misra (1991) growing of intercrops in spring planted sugarcane was generally remunerative by recording higher cane productivity. They
further added that sugarcane + cluster bean intercropping was the most profitable, as it gave 18 per cent higher cane yield. Nasir Ahmed et al. (1991) reported that the millable cane production was not very much affected due to soybean or black gram intercropping in cane. Sathyavelu et al. (1991) also registered higher number of millable canes when sugarcane was intercropped with legumes.

In contrast, Dhoble and Khuspe (1983) stated that the individual cane weight did not differ between pulses intercropped and sole sugarcane crops. Yadav et al. (1987) reported that though legumes improved the soil fertility, failed to show impact on cane yield enhancement. They attributed that legumes might have caused initial shading during early stage of cane establishment, thus adversely affecting tiller production. Similar findings were reported by Yadav (1987) and Chauhan and Yadav (1988), indicating the unfavourable effect of broad-leaved legume intercropping on cane productivity. Menhi Lal et al. (2000) also observed that the intercropping of one or two rows of lentil did not significantly affect the number of millable canes and cane yield.

Pressmud cake: Pressmud cake is an important byproduct in sugar industry, which is having good manurial value apart from its use as amendments for amelioration of the salt affected soils. On an average about 3-7% pressmud cake produced during cane crushing and its annual production in India is estimated to be about 5-6 m.t. Pressmud cake besides being an excellent source of nutrients, add organic matter lead to better nutrition and promotes CEC, the microbial activity in soil improve substantially due to application of Pressmud and as such Pressmud has been considered as the effective source of carrier material for microbial inoculants. This can be used to manufacture phosphatic fertilizers and ameliorate the saline soils. It consists of 1 to 3.1 % N, 0.6 to 3.6% P and 0.3 to 1.8% K and other nutrients (Kambar et al., 2000). Yaduvanshi and Yadav (1991) reported that application of sulphitation pressmud at 10 t ha⁻¹ with 75 kg N ha⁻¹ produced cane yield equal to that of 150 kg N ha⁻¹. Thus an economy of 75 kg N ha⁻¹ was obtained. Application of six tonnes pressmud /ha along with 2/3 dose of recommended phosphorus appeared optimum for cane productivity (117.62 t ha⁻¹). It gave an economy of 1/3 dose of recommended phosphorus. Productivity of sugarcane crop got augmented with increasing doses of pressmud cake and inorganic phosphorus fertilizers. This indicated that pressmud was effective for maintaining soil fertility at higher levels (Bhanavase et al., 1996). Similarly, application of phosphorus solubilising microorganisms like Agrobacterium radiobacter and Bacillus megaterium and supplementing phosphorus through single super phosphate and pressmud at 50:50 as the better and cheaper source of P fertilization to sugarcane (Shankaraiah and Nagaraju, 1997).

Ramalingaswamy et al. (1999) reported that integrated use of 168 kg N ha⁻¹ + 4t ha⁻¹ PMC +5 kg Azotobacter ha⁻¹ gave economy of 56 kg N ha⁻¹ besides maintaining the cane yield. Integrated use of pressmud cake at 4t ha⁻¹, Azotobacter at 5 kg ha⁻¹ along with recommended nitrogenous fertilizer recorded 11 per cent increased cane yield over recommended N alone. Application of 180 kg N through urea and pressmud cake at the rate of 1:1 ratio increased the number of millable canes and yield (Sharma et al., 1999). Manickam et al. (2000) reported that the cane yield, percentage sugar and net income were highest at 25 t press mud (filter cake) ha⁻¹ along with recommended NPK (N applied as neem blended urea) and 10 kg each of Azospirillum and phosphobacteria. Thus, possibility of saving fertilizer N to a tune of 25 per cent without loss in yield could be possible upon
integration of N with PMC and Azotobacter (Nagaraju et al., 2000).

**Composted cane trash**: Crop wastes are natural resources and therefore their management and effective utilization is a must. After harvest of sugarcane, the removal of cane trash from the field is a laborious process. So many a times, farmers burn the trash nearly 8 to 10 tonnes of trash per hectare of cane field. About 24 to 30 lakh tonnes of trash is burnt every year in Maharashtra state alone. Composting is one of the best ways of making the trash as organic manure by using microbial culture. But its decomposition is at very slower rates. It contains about 0.35% N, 0.50% P, 0.60% K, 4.5% moisture and C: N ratio of 125:1. According to Shinde et al. (1992), incorporation of chopped or unchopped sugarcane trash at the rate of 7.5 t ha$^{-1}$ supplemented with 8 kg urea, 10 kg of SSP and one kg cellulose decomposing fungal culture per tonne of trash increased the cane yield by 12.8 t ha$^{-1}$ over control i.e., recommended fertilizer nutrient alone. The soil pH was reduced in the cane trash-applied fields and also the organic carbon content of soil was increased considerably. The positive effect of trash mulch on cane yield was reported by Durai and Ravichandran (1999). Similarly, ratoon cane with one hoeing and chopped trash mulching at the rate of 6t ha$^{-1}$ along with additional 25 kg N ha$^{-1}$ gave the highest cane yield and number of millable canes at Pantnagar (Rana et al., 2000).

**Compost and vermicompost**: Composting is the process of biochemical break down of organic materials to humus like substance. This product has lower bulk volume, greater stability and lower C/N ratio than the fresh residues. Converting the wastes in to usable compost material through earthworms is called vermicompost. Sugar industry byproducts like pressmud, bagasse and sugarcane trash are used for composting. Earthworms can act as bio-concentrators of heavy metals and toxic materials. Vermicompost and vermicast are suitable manures in crop production for maintenance of balanced soil health. It contains 0.5% N, 0.30% P and 0.2% K (Kambar et al., 2000). The investigation of vermicompost effect on cane yield clearly indicated that 500 kg of vermicompost with 100% recommended nitrogen as well as one tonne of vermicompost alone with 4 kg of Azotobacter and 2 kg of Phosphobacterium resulted in higher cane yield (Thirugnanam et al., 1999). According to Venkateswara Rao (1999), application of 80 kg N with bio-compost at 5 t ha$^{-1}$ records higher cane yield (122.8 t ha$^{-1}$) over the recommended dose of NPK. The author also found out that application of bio-compost alone or in combination with chemical fertilizers was economical and a minimum of 20 per cent inorganic nitrogenous fertilizer could be saved. Similarly, combined application of chemical fertilizers and compost increased the cane yield (Zende, 1984 and Jadhav et al., 1993).

**BIOFERTILIZERS**

Bio-inoculants, popularly called biofertilizer are biologically active strains of bacteria, algae and fungi. Biofertilizers are carrier based preparations containing mainly effective strains of microorganisms in sufficient numbers which are useful for nitrogen fixation in plants, solubilization and uptake of phosphorus and synthesis of growth promoting substances like hormones, vitamins and auxins. Biofertilizers improve the soil properties and sustain the soil fertility.

**Nitrogen fixing biofertilizers**: Application of Azospirillum in two splits, once at 35th day with 2 kg and the second at 65th day with 3 kg in combination with 225 kg N ha$^{-1}$ recorded cane yield of 124.2 t ha$^{-1}$ which is 9.3 per cent more over the recommended dose of N (275 kg N) alone, which could economize 50 kg N with additional yield of
Table 2. Effect of different biofertilizers on the yield of sugarcane

<table>
<thead>
<tr>
<th>Biofertilizers</th>
<th>Cane yield (t/ha)</th>
<th>References</th>
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<tbody>
<tr>
<td></td>
<td>Without biofertilizers</td>
<td>With biofertilizers</td>
</tr>
<tr>
<td>Nitrogen fixing biofertilizers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azospirillum</td>
<td>113.60</td>
<td>118.50</td>
</tr>
<tr>
<td>Azotobacter</td>
<td>105.00</td>
<td>115.50</td>
</tr>
<tr>
<td></td>
<td>92.80</td>
<td>97.50</td>
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<tr>
<td>Phosphorus solubilising biofertilizers (PSB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSB</td>
<td>147.00</td>
<td>160.00</td>
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<tr>
<td></td>
<td>94.90</td>
<td>103.10</td>
</tr>
<tr>
<td></td>
<td>142.90</td>
<td>152.30</td>
</tr>
<tr>
<td>Azotobacter and PSB</td>
<td>131.70</td>
<td>141.50</td>
</tr>
</tbody>
</table>

In contrast, Sathyavelu et al. (1999) reported that application of 75 per cent recommended dose of nitrogen (200 kg ha⁻¹) along with Azospirillum (10 kg) did not result in higher cane yield compared to normal dose of N (Table 2). Application of 275 kg N ha⁻¹ recorded 118.0 t ha⁻¹ of cane yield and it was on par with 225 kg N ha⁻¹ along with 8 kg of Azotobacter (116.8 t ha⁻¹). The result clearly indicated that by the substitution of 8 kg Azotobacter, 50 kg of N ha⁻¹ could be saved (Durai, 1996). Similar view was also expressed by Buragohain (2000) with the application of Azotobacter in combination with 100 per cent N improving the yield components and cane yield as compared to recommended fertilizer alone. However, Azotobacter application has not significantly improved the commercial cane sugar percent of sugarcane as against the recommended N of 135-kg ha⁻¹. Thangaraju and Govindarajan (2001) reported that inoculation of Azotobacter diazotrophicus strain A.d 5 increased the cane yield up to 15.25 per cent than the uninoculated control. The increase was 11.69 per cent with reduced fertilizer N level (75 per cent of recommended dose of N) than full dose of nitrogen fertilizer indicating a saving of 25 per cent of fertilizer N.

Phosphorus solubilising biofertilizer: Phosphate occupy second position next to nitrogen in plant nutrition. Phosphorus is taken by plants in the inorganic ion as PO₄³⁻. The phosphatic fertilizer when applied to soil in the available form, get converted in to unavailable form as CaPO₄ and MgPO₄ under alkaline pH condition. In such situation, a set of micro-organisms viz., Bacillus megstherium, B.polymyxa, Pseudomonas striata, Aspergillus awamori etc can produce several organic acids butyric acid, citric acid, formic acid etc. and convert the unavailable P to available form of P which is called as P solubilization. Use of P solubilizer certainly enhances the P availability and crop yields (Sreenivasa, 1999).

Beneficial effect of biofertilizer like Azospirillum and phosphobacteria in enhancing the yield of sugarcane was indicated by Rangiah et al. (1988) and Kumaraswamy et al., (1992). Inoculation of P solubilizer with different doses of phosphatic fertilizers (MRP+TSP) resulted in increased yield of cane (Yadav and Tripurari Singh, 1990). Banger et al. (1993) reported that application of phosphorus fertilizer with phosphorus solubilishing bacteria (PSB) was helpful at lower level of P (60 kg P₂O₅ ha⁻¹) to get increased yield of cane by saving of 15 kg P₂O₅ ha⁻¹.
Kumaraswamy and Rajasekaran (1994) recorded higher cane yield with the application of *Azospirillum* and phosphobacteria biofertilizer besides NPK as against NPK alone in neutral non-saline sandy loam soils of Cuddalore district in Tamil Nadu. According to Hunshal et al. (1996) phosphorus solubilising bacteria and *Azospirillum* along with 75 per cent recommended fertilizer (rock phosphate as P source) application resulted in higher cane yield in medium black soils of Belgaum district of Karnataka. Kathiresan et al. (1995) reported that 50 per cent $P_2O_5$ along with 10 kg phosphobacteria yielded comparable yield to that of 100 per cent $P_2O_5$ application in sugarcane (Table 2).

Inoculation of phosphorus solubilising microorganisms along with recommended fertilizer P resulted in six per cent more cane yield (Shankaraiah and Nagaraju 1997). Integration of phosphobacteria with Mussoorie rock phosphate was able to prove its P solubilising effect by recording significantly higher growth parameters, yield attributes and yield over Mussoorie rock phosphate and single super phosphate alone (Karamathullah, 1998). According to Kathiresan and Manoharan (1999), the cane productivity with phosphorus solubilising bacteria was higher compared to without PSB. Similarly, (Sundara, 2000) also reported that application of phosphobacteria along with inorganic phosphorus fertilizer used to increase the yield of sugarcane by 16 per cent compared with no phosphobacteria.

**CONCLUSION**

To maintain the productivity of sugarcane at a high level on a long-term basis it is necessary to evolve a system whereby adequate supplies of organic manures and biofertilizers along with chemical fertilizers can be assured without damaging the soil structure. For maintaining the sugarcane production under intensive cultivation, as practiced in the hot climate of India, the organic carbon content of the soil must be maintained either by the recycling of organic farm wastes or by the use of FYM.

Growing of green manure in the interrow spacing and incorporation at appropriate time not only supplement the fertilizer but also maintain the soil fertility and sustain the cane yield.

Many findings confirmed that there is an indication of saving of N up to 25% when green manures were raised as intercrop in sugarcane. Intercropping and incorporation of legumes such as French bean, sunhemp etc have a positive influence on improving the nitrogen use efficiency and cane yield, besides improving the physico-chemical properties of soil (Shankaraiah et al., 1999). Inoculation of nitrogen fixing bio-agents like *Azospirillum*, *Azotobacter* and *Acetobacter* brings about 20-25% economics in the fertilizer nitrogen of sugarcane besides improving the residual nitrogen content of soil. Similarly, phosphorus solubilising microorganisms viz., *Bacillus megstherium*, *B.polymyxa*, *Pseudomonas striata*, *Aspergillus awamori* etc. bring about improvement in P use efficiency.

Integration of biofertilizers, crop residues management, organic manures etc. with mineral fertilizers have shown potential for 20-50% economy in fertilizer nutrients to sugarcane besides soil sustainability. A judicious combination of inorganic, organic and biofertilizers is a potential tool for sustaining the cane productivity as well as soil fertility in sugarcane and sugarcane based cropping systems.
REFERENCES

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