Review of Literature
CHAPTER II

REVIEW OF LITERATURE

Sugarcane is an agro industrial crop forms an integral component of agriculture. In India, productivity of cane varies from place to place (50 to 105 tonnes per ha) but the average productivity of cane in our country is 72 tonnes ha\(^{-1}\) (Shahi, 2002). Though climatic factors play a greater role on sugarcane productivity, management techniques of the crop is also equally important in deciding the yield.

Nitrogen is an important nutrient for the growth and development of sugar cane, which leads to higher yield with quality. Soil applied mineral fertilizer N encounters with various losses in the soil resulting in lesser nitrogen use efficiency. The combination of organic and biological sources with mineral N in an integrated manner could improve the use efficiency of N. This strategy of N management could pave the way for higher cane yields in addition to better nutrient use efficiency. The relevant literatures pertaining to the enhancement of cane productivity through practices like organic manuring, N management and bio-fertilizers application are briefly reviewed in this chapter.

2.1. Effect of weather on productivity of the sugarcane

Sugarcane is a tropical crop, needs warm humid climate for its growth and development. The ideal temperature for optimum cane growth is 20° to 35° C. Temperature, light and moisture either through rainfall or irrigation are the main seasonal factors that control cane growth. Summer with warm weather and adequate rainfall during active growth phase and fairly dry sunny weather with moderate relative
humidity during maturity and ripening phases are the optimum situation for high cane and sugar yields (Humbert, 1968). According to Clements and Kubota (1942), sunlight is the important factor in deciding the yield than temperature. Moisture is the yet another important climatic factor influencing cane growth and yield.

2.2. Effect of organic sources of nutrients on cane productivity'

Increased dependency, non-availability of biological sources in required quantity are some of the factors which deter the use of chemical fertilizer in agriculture. Irrational use of chemical fertilizers deteriorates the agro ecosystems that necessitate the reintroduction of organic fertilizers in agriculture. The inclusion of organic manures has been found to enhance the efficiency and reduce the requirement of chemical fertilizers. Organic farming is gaining importance towards achieving sustainability in crop production. Use of vermicompost, FYM, pressmud, pressmud based compost, trash and green manuring grown in situ are tried with enormous effect in various crops including sugarcane. Some workers (Bhawalkar and Bhawalkar, 1993) advocated total organic farming, while others expressed the necessity of organics and inorganic fertilizers to achieve sustainability and targetted production. Since, the nutrient turn over in soil - plant system is considerably high under intensive farming neither the fertilizers not organic sources alone can achieve sustainability.

Organics also provide balanced nutrition apart from improving physical, chemical and biological properties of soil. In addition, they also facilitate the growth of micro organisms. Therefore, the present investigation was formulated to find out the effects of organic and mineral fertilizers on the productivity of sugarcane and their effect on soil properties.
2.2.1. Farm Yard Manure (FYM)

FYM is being used as the main source of nutrient until recently. Due to modernization of agriculture and change in social structure, the availability and usage rate of FYM become very rare. The farmers also started using chemical fertilizers as an alternate of FYM without knowing the consequence of it. The total replacement of FYM had led to so many problems both in agricultural production and in the soil environment. According to Shinde et al. (1992), FYM application increased the population of most soil microorganisms, organic carbon and soil nutrient availability. The Soviet Soil Scientist Zonn (1986) informed that the organic matter supplied through FYM act as a glue to join the soil particles together for its best structure, to catch hold of ions on the soil complex and supply the food for soil dwelling living organisms. The negative effect of Na ions in soil was also alleviated by FYM and improved the nutrient availability (Rao el al., 1990).

Vijay Kumar et al. (1999) opined that yield obtained by application of FYM in combination with half dose of N were statistically higher than the yield obtained by the application N alone in sugarcane. Tamilsevan and Jayabal (1993) informed that cane and sugar yield generally increased with higher rate of N and FYM. Dhillon et al. (1993) reported that the application of FYM combined with 150 kg of N and 60 kg of P$_2$O$_5$ ha$^{-1}$ the recorded the highest cane and sugar yield.

The number of millable canes, weight of individual cane, cane and sugar yield were the highest when FYM was combined with 100 per cent recommended dose of N (Mathukia et al., 1999).
Swamy et al. (1995) reported that the integrated use of FYM and 100 per cent recommended N fertilizer application not only increased the yield of crops grown in the rotation but also improved the soil fertility status and also higher available nitrogen and phosphorus. It also reduced the depletion of soil available potassium. The same view was also expressed by Mathukia et al. (1999).

Patel et al. (1991) informed that cane and sucrose per cent were significantly increased by FYM application. Khandagave (2001) noticed that addition of FYM @ 25 t ha\(^{-1}\) recorded significantly higher cane and sugar yield of 84.39 and 11.39 t ha\(^{-1}\) respectively over no organic fertilizers.

2.2.2. Vermicompost

Vermicompost is the product obtained by composting organic residues using earthworms. Earthworms can consume all kinds of organic matter and they can eat as much as their own body weight. It is also estimated that 1000 tonnes of moist organic matter can be converted by earthworms into 300 tonnes of compost. The excreta or “castings” of earthworms are rich in nutrients and also increase the bacterial and actinomycetes population (Preethi Joshi, 2002).

Earthworms can act as bio-concentrators of heavy metals and toxic materials. The toxic materials are stored in the tissues of earthworms. Use of vermicompost and vermicast are suitable manures in crop production for maintenance of balanced soil health.
In India, about 7000 million tonnes of wastes are generated annually and agricultural wastes alone contribute to 320 million tonnes. Majority of it remains unutilized. The manurial value of this total biomass in terms of N is estimated to meet 90 per cent of nitrogenous fertilizers requirement of India (Thimmiyah and Bhatnagar, 1999).

During recent years, earth worms (like *Edudrilus eugeniae*, *Eisenia fetida* and *Perionyx excauatus*) have been identified as one of the major beneficial organisms to process the biodegradable organic material (Julka and Senapathi, 1987; Graig Smith *et al.*, 1992). The utilization of waste material through earth worms has given the concept of vermicomposting, Earth worms assimilate organic waste and discharge beneficial products known as vermin cast/vermin compost (Indrajeet *et al*, 1999)

Vermicompost is a granular aggregate, the stability of which is due to coating of mucopolysaccharides of microbes and earthworms. It is a mixture of worm and casts which are rich in macro and micro nutrients (Radha *et al*1995; Purakayastha and Bhatnagar, 1997). The carbon nitrogen ratio of vermin compost prepared from different sources varied between 1.3: 1 and 16: 1 as reported by Indrajeet *et al*. (1999).

It acts as an excellent base for the establishment of beneficial free living and symbiotic N fixers. Its application increased the microbial population and their activity in soil (Kale *et al.*, 1992; Srivastava, 1994; Manna and Ganguli, 1998) thereby improving the availability N and P to crops (Singh and Sudharshan, 1999). Vermicompost act as a source of vitamins, growth hormones like gibberellins (Srivastava, 1994: Purakayastha and Bhatnagar 1997; Thomas Mathew, 1999) and several enzymes which splits complex for polymers in wastes to simple molecules and further utilized by soil micro organisms
A large number of earthworm eggs present in vermicompost helped its continuous production in soil (one million per ha. per month) (Srivasta, 1994; Senthil Kumar et al., 2000). The earthworms produced thus dwell in soil even up to 3 meters, consume plant liters, and convert them into, compost and by virtue of their activity cause continuous process of soil fertility improvement and plant growth.

Vermicompost could acts as a better earner material for microbial inoculants including *Azospirillum*, *Rhizobium*, and PSMs. Its other principal benefits included soil aggregation, improvement in soil structure and soil fertility, encouraging favourable soil reaction, prevention ot soil erosion, higher efficiency of applied chemical fertilizers improvement in water holding capacity of light soils and soil permeability.

A few workers also observed that application of vermicompost led to higher earthworm population which reduced nematode population and controlled sucking pests of chillies (Ramagobala Varma and Supare, 1997) and groundnut (Ramesh, 2000).

According to Khandagave (2001), vermicompost @ 5 t ha⁻¹ significantly increased the cane and sugar yield by 5.63 and 1.0 t ha⁻¹ respectively over control. However, the low response of it draws attention to assess the additional merits of it over FYM/ control as observed by Kale et al. (1992) who expressed that it should be used in bulk quantities like other manures for achieving fruitful results. Thirugnanam et al. (1999) opined that 500 kg of vermicompost with 100 per cent recommended nitrogen and 1000 kg of vermicompost with 4 kg of Azotobacter and 2 kg of phosphobacteria was yield wise superior over other treatments.
2.2.3. Green manures

Incorporation of green plant tissues into soil for enhancing soil fertility commonly referred as green manuring. It is an age old indigenous effective technology for sustaining production by economizing the agricultural production system which improves productive capacity of soil without causing any environmental problem. Non availability of quality green manure seeds, intensive agriculture, non availability of irrigation water and labour intensive operations are major constraints in adoption of green manuring crops, Green manure, particularly the legumes are comparatively high in nitrogen, low in C: N and also supply appreciable quantity of other nutrients including trace elements (Mundal et al., 1992). The saving of fertilizer nitrogen through green manure incorporation was also reported by Jyothimoorthy et al., 1971. Further, growing green manure in the inter row spacing, not only supplement to fertilizer but also maintain the soil fertility and sustain cane yield (Linga Gowda, 1965, Bose and Thakur, 1980 and Rao, 1990).

2.2.3.1. Effect on growth characters of sugarcane

Intercropping of soybean and daincha did not have any marked influence on cane bud germination (Bawsakar et al., 1997). Similar findings of non-significant influence of intercrop pulses on sugarcane germination were earlier reported by Ethirajan et al. (1981) Yadav et al. (1987), Jayabal (1988) and Mahendran (1994). Nasir Ahmed and Singaravelu (1986) reported that the tiller production in sugarcane was reduced when intercropped with groundnut, greengram sunflower. But in contrast, Chauhan and Yadav (1988) reported that greengram intercropping did not influence on the number of tillers significantly.
Intercropping of green manure crops resulted in reduced tiller production and sole crop of cane recorded maximum tiller production and was significantly superior over green manure intercropped canes (Mahendran et al., 1997). Nasir Ahmed (1999) stated that raising sunnhemp as intercrop in sugarcane reduced tiller production. Similar results were reported by Jayapaul et al. (2000) who observed that sole cropping of sugarcane registered higher number of tillers than the daincha intercropping cane.

2.2.3.2. Effect on cane yield

Inclusion of green manures in the cropping system improved the crop yield and sustains the soil fertility (Siddeswaran and Palaniappan, 1995). Sowing of daincha in single, continuous line and in situ 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., 1993). Srinivas (1996) observed that in situ 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 under both plant and ratoon crops even with comparatively lower tiller production maximum cane yield was obtained in daincha intercropping and it was comparable with sunnhemp intercropping, over sole crop of cane (Mahendran et al., 1997). Jayapaul et al. (2000) and Yadav et al. (2000) reported that sugarcane intercropped with two rows of daincha and in situ incorporation on 45 DAP registered higher number of millable canes which inturn reflected in higher cane yield.
Intercropping and incorporation of sunnhemp 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). Buragohain and Medhi (1999) informed that application of recommended dose of N (135 kg ha per cent) in combination with green manure crop recorded more millable and higher cane yield. Intercropping cowpea or sunnhemp 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 source like green manure and fertilizers increased the NMC and cane yield as compared to sole application of fertilizer alone. Jayabal et al. (1989) recorded significant increase in cane yield by incorporation of greengram harvested on 45th day and by allowing beyond that stage of intercrop reduced the cane yield considerably.

Sunnhemp was buried at six weeks the green pods in French bean and dry pods in cowpea were harvested and plants incorporated in situ were produced 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 recording higher cane productivity. They added that sugarcane + cluster bean intercropping was 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 intercropped and sole sugarcane. Yadav (1986) 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 et al (1987) and Chauhan and Yadav (1988) indicating the unfavourable effect of broadleaved legume intercropping on cane productivity. Menhilal et al, 2000 also observed that the intercropping of one or two rows of lentil did not significantly affect the number of mill able cane and cane yield.

2.2.3.3. Effect on cane quality and sugar yield

Daincha incorporation through continuous line sowing registered significantly higher sugar yield (Kathiresan and Ayyamperumal, 1996). Mahendran et al (1997) indicated that intercropping of daincha recorded the maximum commercial cane sugar, followed by sunnhemp intercropping over sole crop in both plant and ratoon canes. Mathukia et al. (1999) stated that the sucrose and CCS per cent of sugarcane were not influenced in individual years, however in polled results they were significantly increased with application of either bulky organic manures or organic manures along with fertilizer nutrients. Nasir Ahmed (1999) observed that sugar yield was significantly influenced with sunnhemp intercropping in sugarcane but the commercial cane sugar did not show significant difference.

In contrast, Lakshmikantham (1983) reported that intersowing of Sesbania speciosa along with cane rows and incorporated after sixth week and addition of 47 kg N ha⁻¹ did not show any significant effect on cane yield and juice quality parameters, like
purity per cent, brix value and recovery per cent. The same observations were made by Srinivas (1996) and Durai and Ravichandran (1999) by growing of intercrops like cowpea, sunnhemp and daincha and incorporation in sugarcane and informed that no change has been taken place in the CCS per cent of cane as compared to sole sugarcane. Goto and Eguchi (1998) reported that the N uptake was significantly higher in green manure incorporated fields because of the organic carbon and available N and K.

2.2.4. Bio fertilizer

Bio inoculants, popularly called bio fertilizers are biologically active strains of bacteria, algae and fungi. Bio fertilizers are carrier based preparations containing mainly effective strains of microbes in sufficient numbers which are useful N fixers in plants and synthesis growth promoting substances. Certain micro-organisms like bacteria and blue green algae have the ability to use atmospheric nitrogen and carry this nutrient to the crop plants. Some of these N fixers like rhizobia are obligate symbionts in leguminous plants; while others colonize the root zones and fix N to loose association with plants. A very important bacterium of the later category is *Azospirillum*, which was discovered by a Brazilian scientist and which attracted the world community in mid 1970s. *Azospirillum* application increases the productivity crops from 5-30 per cent.

Hunshal et al. (1996) observed that application of *Azospirillum* associated symbiotic N fixing bacteria improved the cane and sugar yield. Basal incorporation of *Azotobacior* @ 8 kg ha⁻¹ along with N increased the millable cane population and cane yield. Irrespective of levels of N, the bio fertilizer application has increased the cane yield (Durai, 1996). Increase in cane growth due to the application bio fertilizer was reported
by Snehal Joshi and Zende (1998). Kumarasamy and Rajasekaran (1994) observed that application of bio fertilizer *Azospirillum* not only increased the yield of plant crop but also increased the ratoon crop.

Application of *Azospirillum* @ 2 kg ha\(^{-1}\) on 35 DAP and 3 kg ha\(^{-1}\) on 65 DAP increased the cane yield under different levels of N and however, the CCS per cent was not found to be increased by the *Azospirillum* application (Manoharan *et al.*, 1991). Buragohain (2000) reported that application of bio fertilizers such as *Azotobactor* and *Azospirillum* significantly increased the millable cane population and cane yield. In contrast, Sathyavel *et al.* (1999) informed that application 75 per cent recommended dose of nitrogen (200 kg ha\(^{-1}\)) along with *Azospirillum* (10 kg) did not resulted in higher yield of cane compared to normal dose of N. Integration of biofertilizers crop residues and organic manures etc., with mineral fertilizers shows potential for 20 to 50 percent economy in fertilizer nutrients to sugarcane besides soil sustainability (Shankaraiah and Nagaraju, 1997). Muthukumarasamy *et al.* (1994) informed that a yield increase of 12.5-17.5 t ha\(^{-1}\) and a 50 per cent nitrogen saving through integration of biofertilizers with mineral fertilizers. According to Arangarasan *et al.* (1997), application of recommended chemical fertilizers along with FYM (1Ot ha\(^{-1}\)) and bio fertilizers resulted in 23 and 6 per cent increased cane yield and Brix value respectively. Similarly, cane yield percentage of sugarcane and net income were the highest at 25 t pressmud ha\(^{-1}\) along with recommended NPK (N applied as neem blended urea) and 10 kg *Azospirillum*.

Manickam *et al.* (2000) reported that the cane yield, sugar yield and net income were the highest at 25 t pressmud (filer cake) ha \(^{-1}\) + recommended NPK (N applied as neem blended urea) t- 10 kg each of *Azospirillum* and phosphobacteria. Sundara and Hari
(1998) reported that the stalk population was the highest (89599 ha\(^{-1}\)) in the single super phosphatelOO per cent with phosphate solubilizing bacteria applied plot, followed by the plots in which single super phosphate was substituted to the extent of 50 per cent with rock phosphate and supplemented with phosphate solubilizing bacteria. Ramalingasamy et al. (1999) reported that integrated use of 168 kg N ha\(^{-1}\) + 4 t ha\(^{-1}\) pressmud cake + 5 kg Azotobacter gave nitrogen economy of 56 kg ha\(^{-1}\) besides maintaining the cane yield. Integrated use of pressmud cake at 4t ha\(^{-1}\), Azotobacter at 5 kg ha\(^{-1}\) with recommended N fertilizer recorded 11 per cent increased cane yield over recommended N alone. 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 pressmud cake and Azotobacter (Nagaraju et al., 2000),

2.3. Effect of organic manures on soil fertility

Application of FYM increased the population of most soil micro organisms, organic carbon and soil nutrient availability (Shinde et al., 1992). FYM alleviated the negative effects of Na ions, and also improving the nutrient availability (Rao, 1990). Addition of organic improves the humus content of soil 3 to 4 times and has the capacity of clay to hold onto not only cations, but anions too (Bill Butterworth, 2002). He further says that humus will hold onto nitrates.

Green manure incorporation to sugarcane crop could reduce the rate of fertilizer N (Marialculandai and Morachan, 1964). Lingegowda (1965) also reported that growing of green manures in the inter row spacing and incorporation at appropriate time not only supplement to fertilizer but also maintain soil fertility. Since, sugarcane is the highest
consumer of N, growing of such green manures along with different levels of N was beneficial. Venkatakrishnan (1980) indicated that available soil nitrogen status was improved when *Sesbania aculeata* was grown *in situ* and incorporated.

Palaniappan *et al* (1990) concluded that *Sesbania aculeata* was capable of producing 26.3 t ha\(^{-1}\) of biomass and accumulating 185 kg N ha\(^{-1}\) which worked out to 30.8 kg N ha\(^{-1}\) day while Swarup (1991) reported that the incorporation of 50 days old *Sesbania aculeata* (3.85 t ha\(^{-1}\) of biomass) contributed 110 kg N ha\(^{-1}\). Singh *et al.* (1994) pointed out that the green manuring of legumes in sugarcane farming contributed about 41 to 85 kg N ha\(^{-1}\) for sugarcane.

Intercropping and incorporation of legume have established the beneficial effect of increasing the N use efficiency in cane (Shankaraiah *et al.*, 1999). Similarly, Jayapaul *et al.* (2000) stated that the available plant nutrients like NPK and organic carbon content of the soil were in the increasing trend after the harvest of sugarcane when sunnhemp was grown as intercrop and ploughed *in situ* on 45\(^{th}\) DAS.

Daincha was more efficient in mining P from subsurface soil layers and making it available to the succeeding crop (Subbiah and Mannikar (1964). Talashittas and Patil (1979) indicated that phenolic and aliphatic acids produced during decomposition of organic matter were responsible for the solubilization of appreciable amount of phosphates resulting in increased P availability in soil. Ghosh *et al.* (1981) have also reported the same information. Khind and Maskina (19S6) found that *Sesbania aculeata* increased the microbial population of soil and thus enhanced mineralization of soil and other essential nutrients.
A comparative study conducted by Alam et al. (1997) informed that among prickly sesban or local daincha (*Sesbania aculeata* L.), African daincha (*Sesbania rostrata* L.), indigo (*Indigofera tintoria* L.) and sunnhemp (*Croialaria juncea* L.), sunnhemp was found to be the best suitable green manure for fast growth at all the stages. The total N and availability of P and S of soil also increased slightly after use of green manures. Kormilitsyn (1995) reported that green manuring had the greatest effect on crop productivity, however the increase in yield depends upon the quantity of organic matter and N ploughed in.

Vermicompost could acts as a better carrier material for microbial inoculants including *Azospirillum*, *Rhizohium*, and phosphate solubilizing bacteria. Its other principal benefits included soil aggregation, improvement in soil structure and soil fertility, encouraging favorable soil reaction, prevention of soil erosion, higher efficiency of applied chemical fertilizers improvement in water holding capacity of light soils and soil permeability (Indrajeet et al, 1999).

2.4. Role of inorganic N on cane productivity

About 5 - 10 per cent of the dry weight of plant is composed of the inorganic nutrient elements like nitrogen, phosphorus, potassium and other micro elements (Samuel et al, 1984). Soil is the prime source of these essential elements, as well as other elements which are all beneficial for growth and development of plant. According to Zonn (1986), the phosphorus in the soil combines with the available iron or calcium carbonate and forms water insoluble iron phosphate or calcium phosphate. The poor
humus content lead to low nitrogen in our soil. Therefore, our soil is normally shortages of these nutrients. This problems are managed by inorganic fertilizers all over the world very intensively since 1960s.

Nitrogen is the important element for the growth and development of sugarcane. Although N constitutes only a fraction of 1 per cent of the total dry weight of mature cane, it plays a role as important as C, H and 0 which altogether constitute more than 90 per cent of dry matter (Yadav, 1980). The most important role of N in the plant is its presence as integrated structural constituent of the protein molecule. In addition, it is also found as constituent of purines, pyrimidines, porphyrins and coenzymes. Purines and pyrimidines are important constituents of the nucleic acids, RNA and DNA, essential for protein synthesis and control of life. The porphyrin structure is found in metabolically important compounds as the chlorophylls and cytochrom enzymes, essential in photosynthetic and respiratory electron transfer system related to energy transformation. Coenzymes are essential for the functioning of many enzymes. Some other metabolically important plant constituents like vitamins also contains N in their structure.

Nitrogenous constituents of plants and particularly the aminoacids, undergo constant breakdown and resynthesis. With an abundance of carbohydrates and nitrogenous compounds, growth is usually rapid. Studies on nitrogen nutrition have generally concluded that the number and character of the stalk population is affected by the nitrogen supply. Higher dose than usually recommended produce a denser stalk population but simultaneously cause a higher mortality of primaries and greater incidence of suckers (Yadav, 1993). Direct increases in yields of total green weight, total dry weight and millable canes result from each additional amount of nitrogen applied. A
progressive depression in juice sucrose is associated with increased nitrogen fertilization which is caused by immature suckers, continued growth and bonding of sugars with nitrogenous compounds usually known as ‘undesirable nitrogen’ in cane. Excess nitrogen also accounts for succulence and invites pest and disease attacks. Management of nitrogen in sugarcane production is most critical (Singh et al, 1981).

2.5. Effect of levels of nitrogen

Ojha et al (1977) reported that the different sources of nitrogen did not exhibit any significant effect on germination of sugarcane. Trmbhekar and Cristian (1978) found that germination was not affected by different levels of Nitrogen. The same view was opined by Salunkhe et al (1981) that germination was not affected by different levels and time of application of nitrogen.

Malik et al. (1982) stated that the dose of 300 kg N ha\(^{-1}\) significantly influenced the tiller production as compared to 150 kg N and control. Sundara (1985) informed that increased level of N helped in the production and retention of greater number of shoots. Srivastava et al. (1987) reported the increase in tiller production up to 200 kg N ha\(^{-1}\). Pandian et al. (1988) opined the significant increase in tiller production by increasing N level from 200 to 300 kg ha\(^{-1}\). Stephen Arul (1992) found that application of 280 kg N ha\(^{-1}\) in more number of splits recorded significantly higher number of tillers and survival per cent. Narayanamurthy (1995) observed that the application of 400 kg N ha increased the tiller production to the tune of 15 per cent over 100 kg N ha.
Gill and Singh (1976) concluded that an increase in N level from 0 to 252 kg ha\(^{-1}\) not significantly influenced on cane height. Kannappan (1982) and Ramasamy (1982) informed that the increased levels of N significantly improved the plant height. Kambar et al. (2000) reported that increased plant height was recorded with the application of 125 per cent recommended dose of N. Sundara (1985) informed that in early growth stages higher N application significantly increased the dry matter production at early growth stages. Narayanamurthy (1995) reported the highest DMP of 60.8 t ha\(^{-1}\) was recorded by application of 300 kg N ha\(^{-1}\).

The cane population at harvest was an important yield contributing parameter for the increase of cane and sugar yield which was significantly influenced by the application of N (Tagamohan Rao et al., 1960; Pande and Tilak, 1970; Khairwal, 1974; Khairwal and Babu, 1975). Salunkhe et al. (1981) reported that there was appreciable increase in the formation of millable canes with increased level of N from 168 to 337 kg ha\(^{-1}\). Verma et al. (1987) and Banwari Lai and Ramsewak (1988) informed that the number of millable canes had significantly increased when N levels were increased from 200 to 250 kg ha\(^{-1}\). Tamilselvan et al. (1992) noted that cane population was increased by 8 and 11 per cent by application of 125 and 150 per cent of recommended dose of nitrogen respectively. Similar report was given by Kambar et al. (1996). Increased millable cane length with increasing N levels was informed by several workers (Mathur, 1972; Mane and Salunkhe, 1978; Venkataraman et al., 1978; Narwal and Behi, 1979 and Panwar et al., 1980). Asokan (1981) informed that length of millable cane increased due to N application beyond 187.5 kg ha\(^{-1}\) did not prove to be useful. Bhutada and Parasher (1981) and Kannappan (1982) reported that there was increase in cane girth and cane weight at
higher level of N. Lingareddy (1982) observed that the cane weight and cane girth increased up to application of 220 kg N ha\(^{-1}\). Ramasamy (1982) stated that increasing N level to 280 kg ha\(^{-1}\) decreased mean cane weight but reduction was marginal. Chavan et al (1985) observed a steady improvement in cane weight from 150 to 300 kg N ha\(^{-1}\). The same trend was informed by Panneerselvam et al (1992) and Kambar et al. (1996).

Chougule and Patil (1981) stated that application of higher dose of 400 kg ha\(^{-1}\) increased the yield significantly over lower levels of N. Kannappan et al. (1990) reported that application of N at 325 kg N ha\(^{-1}\) recorded the highest cane and sugar yields. In early maturing varieties, the response to added N at 125 per cent of recommended dose was more (Patil and Shingate, 1981). Duraisamy and Ramiah (1991) observed that application 375 kg ha\(^{-1}\) increased the cane yield without affecting quality. Jagtap et al. (1992) reported that application of N at 312.5 kg ha\(^{-1}\) recorded significantly higher cane yield over lower levels. Sundara (1993) reported an increase of 6 tonnes in cane yield ha\(^{-1}\) due to application of 125 per cent of recommended dose of N. The same trend was also reported by Kambar et al. (1996). An increase in the level of N reduced the sucrose content in juice (Yadav and Sharma, 1981). Rakkiyappan (1981) pointed out that the sucrose per cent dropped from 18.5 per cent at 0 kg to 15.94 per cent at 40 kg N ha\(^{-1}\). Salunkhe et al. (1981) found a decrease in quality with increase in N levels from 168 to 337 kg N ha\(^{-1}\) Prasad et al (1983) reported that there was no marked differences in juice quality under different levels of N. Malik et al. (1984) informed that reducing sugars percentage was more at
lower levels of N. Sundara (1985) reported that there was decrease in juice brix, sucrose per cent purity co-efficient and CCS per cent and increase in reducing sugars level due to increased N fertilization.

Balusamy et al. (1994) reported that the application of 150 per cent of recommended dose reduced more than 2 per cent in juice quality and lowered sugar yield. Narayanamurthy (1995) recorded the progressive increase in reducing sugars content due to application of 400 kg N both at 10th and 12th months.

2.6. INM for sustainable cane production

Continuous use of chemical fertilizers affects the sugarcane yield and quality. Arangarasan et al. (1997) reported that application chemical fertilizers along with FYM and bio fertilizers resulted in 23 per cent increase in cane yield on an average. Kathiresan et al. (1993) informed that higher cane yield and juice quality were obtained by applying bio compost *Azospirillum*. Similar results were also confirmed by Venkateswara Rao et al. (2000). Shankaraiah and Nagaraju (1997) informed that only the judicious combination of mineral and organic sources of nutrients could be a potential food for sustaining soil fertility and crop productivity in sugarcane. Vijay Kumar et al. (1999) concluded that the integral use of inorganic fertilizers and organic manures would give best cane yield and juice quality. Mathukia et al. (1999) and Yaduvanshi (2001) informed that the combined application of organic sources like FYM, green manure, vermicompost and *Azotohactor* and chemical fertilizers increased cane yield, NMC as compared to chemical fertilizer application alone.
2.7. Effect of INM on soil fertility

Under integrated use of fertilizers the bulk density of soil was decreased and infiltration rate and water holding capacity increased in 100 per cent recommended NPK (Swamy et al, 1995). Patel et al. (1991) and Gangwar and Sharma (1997) reported that combined application of organic manures and chemical fertilizers were acted as complementary and supplementary to each other and resulted in adequate and regular supply of nutrients.

Vijay Kumar et al. (1999) informed that application of organic manures (FYM, pressmud and green manure crops) increased the organic carbon in the soil. The increase in organic carbon with application of FYM, pressmud and green manuring have reported by Rabindra et al. (1985), Yaduvanshi and Yadav (1992) and Sing et al. (1994). Shankaraiah and Nagaraju (1997) informed that incorporation of crop left outs and bio fertilizers improved the soil physico-chemical and biological properties of soil. They further reported that the organic matter and available N were also improved by INM. Venkateswara Rao et al (2000) reported that the INM have improved the soil fertility.

2.8. INM and Economics

Bangar et al (1994) reported that economic gain was increased through integrated use of nitrogen and pressmud cake. The highest cost benefit ratio of 6.54 was obtained with a targeted yield of 80 t ha\(^{-1}\) with the combined use of FYM and NPK (Dhakshinamoorthy et al, 1993). The integrated use of NPK, pressmud cake, \textit{Azospirillum} and phosphobacteria reduce the nitrogen dose of 65 kg ha\(^{-1}\) which save the cost of fertilizer (Manickam et al, 1999).
Benefit cost ratio was higher when green manure was sown continuously on the sides of the ridges (Ahmed et al, 1998). Rao and Veeranna (1998) reported that substituting 25 per cent nitrogen by Glyricidia green manure gave the best economic returns. Trash mulching in combination with FYM and nitrogen gave the higher net income (Tamilselvan and Jayabal, 1993).

Integrated use of N, pressmud cake and *Azoiobactor* saved about 56 kg N ha⁻¹ besides maintaining the yields of cane and sugars (Swamy et al, 1996). Comparing the cost of organics and inorganic fertilizer and cost benefit ratio from sugarcane, the economic gains increased with increased addition of organic and inorganic fertilizers than inorganics alone. The application of organic fertilizers was equivalent to 25 per cent of the recommended inorganic nitrogen yields (Kumar et al, 1997).