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The practice of INM could be very much helpful to the tea plantation to bring the ideal combination of inorganic fertilizers, organic and biofertilizers to meet nutrient requirements of tea plants at different growth stages. The advantages of inoculation with beneficial microorganisms under nursery conditions and quantification of the possible reduction of nitrogenous and phosphatic fertilizers by bioinoculants will provide benefits to tea plantation for sustainable yield and soil health. The world annual tea production reaches 2.5 million tonnes and it used to be achieved by following conventional inorganic sources of fertilizers most probably. In this scenario, a novel method of nourishment without losing yield and quality of tea, the integrated schedule of possible reduction in use of inorganic fertilizers with proven and native consortium of bioinoculants will be immensely benefited to tea industry in order to provide sustainable yield and quality without deterioration of productivity. Compatible properties of biofertilizers with various inorganic, organic fertilizers and agrochemicals used in tea plantations concurrently minimize the application rounds and manpower consumption. The present study includes the response of tea crop at different stage of growth (nursery, young tea and mature tea) against various doses and/or combinations of inorganic fertilizers and organic manures incorporated with bioinoculants so as to achieve higher yield, better quality and retain soil environment healthy.

In vitro studies on bioinoculants

The specific growth media of *Azospirillum lipoferum* is Doberenier & Okon’s medium and for Phosphobacteria is KNB & Pikosvskayas medium which grew lesser in specific media as not like that of LB medium. Actually, the specific media are used to detect and enumerate the colonies of respective organisms and may be reason because the LB could provide preferable nutrients to both the organisms and resulted better growth. The present findings showed that besides nitrogenase enzyme production and P-solubilization, *A. lipoferum* and PSB were
also found to produce both IAA and GA₃ giving them additional beneficial traits of plant growth promotion. Growth hormone produced by bioinoculants is very much useful in improving the crop yield and productivity which might be one of the basal mechanisms under biological nutrition management. Govindan and Purushothaman (1984) described the increase in growth characters due to Azospirillum to its ‘N’ fixing role and also the production of phyto-hormones. With this view, attention was being focused on the use of organic manures and biofertilizers (Azospirillum lipoferum + phosphate solubilizing bacteria (Satter and Guar, 1987) are capable of producing growth promoting substances. Many plant growth promoting bacteria, which stimulate the growth of roots, can produce small amounts of auxin (Pattern and Glick, 1996). These results indicated microbial inoculation can change the levels of IAA in the rice root environment (Raja et al., 2006). Similar observations on N₂ fixation, P-solubilization and production of IAA and GA₃ by Azospirillum and Beijernickia have been made earlier (Naikar, 2003 and Kulanthaivel et al., 2006). GA₃ produced by Azospirillum plays an important role in the early stages of plant growth in graminiae (Lucangeli and Bottini, 1997) by enhancing shoot growth through in vivo production of phytohormones (Lucangeli and Bottini, 1996) and root growth especially by increasing root hair density in physiologically active areas for nutrient uptake and water absorption (Fulchieri et al., 1993).

The ability of Pseudomonas sp. to produce auxin can very much affect plant growth, as it has some very important functioning in plant such as hormonal adjustment, plant cell division and development, and nodule formation (Khakipour et al., 2008). So the production of these plant growth hormones by bioinoculants tested in the present study may perform to achieve higher yield and productivity of tea in the field level. The nitrogen fixation mostly could be done by the presence of nitrogenase enzyme in either symbiotic or asymbiotic system. A.lipoferum has capacity to produce nitrogenase enzyme for fixing the nitrogen in tea soils and make available to the tea crop. In this present study, the A.lipoferum proved that the
production of nitrogenase enzyme when PSB had produced phosphatease higher. This was supported by earlier report of Karthikeyini (2002); Suneesh (2004) and Neelam & Meenu (2003) and they noted that three *Azospirillum* isolates showed P solubilizing zones which may be due to phosphatase enzyme production on Sperber’s agar indicating their ability to solubilize insoluble phosphate. Because of phosphatase enzyme production by PSB, they are able to solubilize the rock phosphate and unavailable forms of other phosphorus in to available form in order to uptaken by plants.

PSBs are known to release several organic acids, which are known to solubilize bound phosphates (Kim *et al*., 1998). In the present study, phosphobacteria reported that the organic acid production high than *A.lipoferum*. Similarily, organic acids released by PSB resulted the bring down the pH and increased the P content reported by Sperber (1957). The drop in soil pH with PSB inoculation and in certain treatments involving *Glomus intraradices* also reported (Filion *et al*., 1999). The acid production of bioinoculants is the responsible for the solubilization of complex nutrients and provides easily available minerals to the plant system. In addition, *A. brasilense* and PSB might affect plant growth as a result of their ability to synthesize plant hormones (Rodríguez and Fraga, 1999).

In the present study, PSB possessed higher antagonistic potential against common tea pathogens than *A.lipoferum* which may be due to production of certain antifungal compounds such as siderophore and hydrogen cyanide, etc. Whereas, *A.lipoferum* were unable to produce such compounds and which could synthesise other leading plant growth promotion. This might be the production of an array of lytic enzymes by the phosphobacteria in order to disintegrate the fungal cell wall components. When dual inoculation of AMF along with *Azospirillum* could also reduce damping off by 72.7 % over control. This may be due to the effect of
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Azospirillum and AM fungi interaction which makes the plant healthier by way of enhanced uptake of nutrients and trigger the host defence mechanism (Kavitha et al., 2003). Apart from phosphate solubilization and production of plant growth promoting substances, fluorescent Pseudomonads have been widely studied with respect to biocontrol potential (Suneesh, 2004). The effectiveness of fluorescent pseudomonads against multiple pathogens have been reported earlier (Tripathi and Johri, 2002; Muralidharan et al., 2004; Megha, 2005; Shivakumar, 2007). Findings of Rashmi (2004) reported that biocontrol potential of P-solubilizing Serratia and Pseudomonas sp. besides producing plant growth promoting substances like IAA and GA₃ which very much supported the results of present studies. Cell wall lytic enzymes such as chitinase, β-1,3 glucanase, protease and etc., produced by the biocontrol microorganisms are responsible for degrading the cell wall components of fungus. This indicated that these bacteria are capable of utilizing various substrate sources by producing lytic enzymes. Production of lytic enzymes is the main mechanism operated in bacterial biocontrol agents (Saxena et al., 2000). With these supporting evidences, the bioinoculants consortium of nitrogen fixer, PSB and AMF used in the present study are imparting informations on plant growth promotion and preventing the entry of fungal invaders simultaneously in the rhizosphere zone of tea.

As a result, the bioinoculants are multibeneficial to agricultural and plantation crops like tea. They used to improve the growth and development of crop plants by influencing the physiological status such as phytohormone production (Chabot et al., 1996), nitrogen fixation (Bashan and Holguin, 1997), nutrient uptake and efficient use of nutrients, antibiosis against phytopathogens (Raja et al., 2006). Population of bioinoculants were noticed high in jaggery amended coirpith formulation over coirpith without jaggery which may be due to sufficient supply of energy to the maximum growth of the organisms in it observed in the present study and it also assumed that moisture holding capacity of coirpith
and nutrients availability possessed in the formulation tend to help the bioinoculants so as to establish well to the certain period till nutrients declined and accordingly the population load also reduced.

Generally the plant root exudates are known to affect survival, reproduction and development of various microorganisms in soil through extremely complex phenomenon. Plants and bacteria can form nonspecific associations in which normal plant processes stimulate the microbial community, which in the course of its normal metabolic activity degrades contaminants in the soil. Raja et al., (2006) explained that the chemicals secreted into the soil by roots are broadly referred to as root exudates. Through the exudation of a wide variety of compounds, roots regulate the soil microbial community in their immediate vicinity, encourage beneficial symbiosis and change the chemical and physical properties of the soil (Nardi et al., 2000). The present findings demonstrated that the beneficial bioinoculants level get improved in rhizosphere over non rhizosphere soil of BSS – 1 seedlings and Clone UPASI 9 (Balamurugan et al 2010). So the present study suggested that this association may be helpful for healthy soil environment of tea and promoting higher productivity of seedlings over non inoculated plants observed. Then, the root exudates induce chemotactic responses which are essential in the early establishment, colonization and maintenance of rhizospheric populations.

Under in vitro conditions, rice root exudates were found to exert a strong influence on motility of these bacteria towards plant roots (Bacilio-Jimenez, 2003). Retention and establishment of bioinoculants in the rhizosphere may be varied and depends upon the root secretion by the crop plants. Characterization of biochemical compounds in the root exudates responsible for stimulation of the beneficial organisms and they tend to minimize the pathogenic microbes present in the rhizosphere. Tea roots secrete root exudates that contained antimicrobial
metabolites which also influenced the quantity and quality of rhizosphere microflora (Tensingh, 2007). Root exudates contain several metabolites and minerals which may be nourishable to soil microbes in the soil environment. Plant roots can provide root exudates releasing in the rhizosphere zone as well as increase in ion solubility. These biochemical mechanisms increase the remediation activity of bacteria associated with plant roots (Jing et al., 2007; Daniela Labra Cardón et al., 2010).

The present study indicated that consortium of *Azospirillum* and PSB recorded higher population than their individual application. This was highly proved with the findings of Raja et al., (2006) and they reported that *Bacillus megaterium* alone applied treatment recorded lowest population and in microbial consortium treatment the same inoculant recorded the maximum population at all days of observation. The understanding of the biology of root exudation processes may contribute to devising novel strategies for improving plant fitness, it is increasingly clear that chemical composition of exudates can have dramatic influences on plant to microbe, microbe to microbe, by altering uptake of water, nutrients and determination of community structure in the rhizosphere. Interactions between consortium of microbial inoculants and plant systems will pave way to explore more benefits from microbial inoculants for improving plant growth and yield.

When considering weather conditions, such as rainfall and sunshine were very much influenced the status of soil microbes of tea plantations soil. In the present study, the artificially inoculated soil retained maximum population of both bioinoculants and *Azospirillum* was higher than PSB in general during monsoon period which may be due to high moisture retention in the soil consequently making easily available and mobilized state of nutrients and minerals which will be favoured by such beneficial microbes. The population of bioinoculants was
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influenced by age of the tea bushes, nature of the soil and cultural practices and prevailed weather conditions (Tensingh, 2007). During pre and post monsoon periods, the microbial load was less due to higher soil temperature and maximum sunshine hours prolonged. End of premonsoon, starting of post monsoon and monsoon months could be favoured and brought higher population of microbes. Similar findings were reported by several researchers and supported the present study viz., Yadav and Singh (1991) opined that the large variation in the population of Azospirillum and PSB in different soils was due to the difference in soil type, climatic conditions and cropping history (Gupta et al., 1986) and organic carbon and types of crops (Tensingh 2007).

In tea plantation, irrigation used to be carried out during summer in order to quench the soil temperature and make nutrients mobility to the crop. When the soil is under dry condition, all minerals and nutrients are in unavailable form and soil microflora also less and inactive form. Most of the microbes produce either spore or lead to decline its population. Once the soil gets irrigated, microbiota will be triggered and they make the soil minerals easily available to the plant through solubilization and mobilization in to root system. Interestingly, present observation revealed that the bioinoculants in the INM treated plots were very well improved their population due to irrigation practice over non irrigation period.

Sensitivity of bioinoculants to agrochemicals used in tea

Compatible properties of beneficial organisms with synthetic and/or organic fertilizers could be very much useful to agriculture crops for higher yield and soil environment healthy. The present study indicated that NK mixture at lower dose supported the bioinoculants when higher dose suppressed. Whereas the rock phosphate highly influenced the growth of them. Similarly, population of Azotobacter and Azospirillum in soil after harvest was markedly increased with
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integrated use of biofertilizer, organic manure and chemical fertilizer system and was reduced with the exclusive application of chemical fertilizers (Jayathilake et al., 2006). The nitrogen fixers present in the soil, it might have helped in increasing various growth parameters by exerting its synergistic effect with inorganic and biofertilizers (Ramanandan et al., 2008). Jayathilake et al., (2006) indicated that integrated nutrient management with biofertilizer (Azotobacter and Azospirillum) in combination with 50% inorganic N through organic manure (VC or FYM) and rest of the N, P and K through chemical fertilizer was considered most useful for obtaining maximum yield with higher fertility status in soil for onion cultivation. Chemical fertilizers as nutrient source may have a beneficial influence on microorganisms in short run (Eno and Blue, 1954). However in due course, they may have adverse effects, especially on soil microflora by way of changes in soil properties. The lowest population of these bacteria in the soil applied with chemical fertilizers (control) may be due to the absence of organic media in the soil and no simulative effect to increase the bacterial population. Hence several attempts were made to substitute the synthetic fertilizers with biofertilizer, atleast in part in an attempt to maintain the soil health by various workers with different crops. But the literature pertaining to the use of organics and biofertilizers in crop particularly in tea is very much limited. The microbial activity showed satisfactory population in soil under different level of chemical fertilizer regimes in combination with biofertilizers (Karthikeyini, 2002).

The present observation indicated that the bioinoculants used were compatible to neem at 25% level of concentration and they got inhibited by higher dosage of neem. It reflected that bioinoculants can be able to tolerate at particular concentration level and when it exceeds it will be lethal to them. With the increase in concentrations of the neem extracts, a declining trend was noticed in the population level of bacteria. Also it explained that the integration of neem with
bioinoculants at optimum concentration will help nutrient requirements of plants for sustainable agriculture under field and/or nursery conditions of tea crop. Moreover, reports of Rajagopal and Ramarethinam (1997) and Behera et al., (2007) explained that inoculation of biofertilizers strains with organic manure eg.,neem cake powder would give better population of target organisms and provided health soil environment than individual application.

Agrochemicals especially pesticides, fungicides and herbicides could be used for minimizing pest, diseases and weeds respectively in tea plantation. They proved their adverse effect on growth of beneficial bioinoculants when mixed in the in vitro medium. The recommended dose of deltamethrin, quinolphos, COC and combination of glyphosate with kaolin used in tea plantation supported the growth of beneficial organisms. This may be because of biodegradation and bioremediation properties of those beneficial biological organisms to break up the hazardous chemicals whichever reside in soil and consume energy from the agrochemicals. Like, when they meet in the soil environment and they got seriously affected with agrochemicals whichever used for pest and disease control and it was evidenced with the report of Gadkari (1987), due to the incorporation of insecticides in the growth media causing either cell disruption or formation of cyst-like bacteria. The pesticides generally reduced the microbial population counts and inhibitory effect varied with different pesticides in tea soils (Bezbaruah, 1999). The present study revealed that half recommended of NK, neem and recommended dose of RP supported the growth of bioinoculants. As like that, application of herbicides in very low concentration significantly augmented the proliferation of aerobic nonsymbiotic nitrogen fixing bacteria in the rhizosphere but in higher concentration the effect was negative (Debnath et al., 2002). It has also been reported that the microorganisms utilized the herbicides and degraded products for their growth and development (Tensingh, 2007). Studies done by Pandey and Palni (1996) clearly
provided the multiple benefits of combined use of *Azospirillum / Rhizobium* with PSB plus RP or SSP, MOP and compost in sustaining higher yields, better N, P and Zn assimilation by crops and improved soil quality in acidic soil. These bacterial bioinoculants based INM formulations with incorporation of crop residues in rainfed cropping system promoted more biological nitrogen fixation, better soil aggregation and earthworm activities and thereby regulated a better C and N dynamics in soils.

Natural soil containing more bacterial population over the RDF revealed that sole application of chemical fertilizer affected the population of bacteria in natural soil. This could be due to rapid multiplication of bacteria applied through seedling root dip and soil application in preferable medium of organic manure, particularly vermicompost. In addition, vermicompost is inherently rich in microflora such as *Azotobacter, Azospirillum* and actinomycetes (Jambelkhar, 1994). Bhavalker (1991) demonstrated that occurrence of natural nitrogen fixing bacteria i.e., *Azotobacter* and *Azospirillum* in uninoculated organic treatments also showed the significantly higher value over the inorganic treatments. Kalyani *et al.* (1996) studied the interaction of *Azospirillum* and fertilizer nitrogen on cauliflower Cv. Jawahar moti and reported that soil inoculation of *Azospirillum* coupled with less nitrogen (80 kg/ha) had beneficial effect in improving the growth and yield, besides saving of recommended nitrogen upto 50%.

The current investigation reported that inoculation of AM fungus, PSB with rock phosphate was positively supported to improve the colonies and the recommended doses of NK mixture pesticides, fungicides and weedicides were found to megarly support or toxic to the bioinoculants when amended in soil under pot culture. In connection with compatibility of bioinoculants indirectly it referred that biodegrataion of agrochemicals input were discussed here. The present study
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indicated that target bioinoculants were quite capable of degrading recalcitrant compounds like propargite to a certain limit due to its repeated applications and consequently when reflected in the field condition, the soil microfloras could react alike in tea plantation and this present findings were substantiated by Soumik Sarkar (2010). Earlier reports suggested that while different pesticides may be toxic to some important bacterial groups like nitrogen-fixing bacteria, other microorganisms are able to use some pesticides as energy and nutrient sources (Johnsen et al. 2001: Monkiedje et al. 2002). Bacteria capable of degrading organochlorine pesticides have been reported by Silva et al., 2007 and Nagpal et al., 2008. It might be that these organisms can utilize agrochemical (pesticides) as their carbon or energy source. Hence this microflora can tolerate or degrade these agrochemicals. Kar et al. (1996) showed the effect of glucose on phenol biodegradation while, Magbanua et al. (1994) used glucose as a cosubstrate for degradation of phenol and 4-chloro phenol by P.putida. Pfaender and Alexander (1973) reported the accelerated degradation of DDT in sewage as a result of glucose addition. This may be due to co-metabolism, whrer addition of easily metabolized organic matter such as glucose increases biodegradation of recalcitrant compounds that are usually not favoured as a carbon and energy sources by microorganism (Prescott et al., 2002). Enzymes generated by an organisms growing at the expense of one substrate also can transform a different substrate that is not associated with that organim’s energy production, carbon assimilation, or any other growth processes.

Biofertilizers can be incorporated with any of organic carrier materials so as to minimize the cost of preparation. PGPRs strains may withstand themselves in organic materials either coirpith or vermicompost by observing the nutrients from the carrier materials and made available the inbuilt nutrients of such organic materials to the plants well. In order to field application of PGPRs through proper bridge material and to deliver the organisms and nutrients to soil and plant, organic
carrier material are needed. Organic manures (FYM or VC) increasing the mineral nutrients, growth hormones, vitamins and improving other physical characters in soil (Ismail, 1995) might have significant influence on microbial population.

Coir pith as an industrial waste from coir industries served as a good source of organic nutrients to many horticultural crops (Selvi and Augustine, 1997) which would be the best supporting matrix for establishment of beneficial microorganisms. Similarly, biofertilizers such as Azospirillum brasilense, Phosphate solubilising bacteria (Pseudomonas putida) and AMF (Arbuscular Mycorhizal fungi) were extensively used to make available more quantity of nutrients to the plants so as to increase the productivity with reduction in the use of inorganic fertilizers (Morita and Konishi, 1989; Merina, 1991). The present observation revealed that AMF, PSB and A. lipoferum among themselves, by using the organic source of carrier materials such as coirpith, vermicompost showed synergistic activity satisfactorily and higher population of incorporated organisms. Moreover the moisture retaining capacity of vermicompost was poorer than in coirpith which may be reason for retaining higher colony forming units of A. lipoferum. It was confirmed with the findings of Fallik et al., (1988) and Muthukumar et al., (2001). Similar findings was reported by Shinde et al., 1992 and Jayathilake et al. 2006 and they denoted that VC is a better source of N and a good carrier material for Azospirillum and Azotobacter than the FYM.

The effects of microbial activities on the biogeochemical cycling of plant nutrients are essential for sustainable ecosystems (Sabannavar and Lakshman, 2009). Nitrogen fixer, PSB and AMF were noticed as higher in the soil treated with 50% IOF + BF in the present study and it was proved with the report of Jayathilake et al., (2006) which narrated that the overall trend of the population of Azotobacter and Azospirillum in the soil after harvest of the onion crop clearly indicated that
incorporating of organic manure alone or in combination with biofertilizers and chemical fertilizer significantly increased the population than the control.

Most of population of diazotrophs starts to establish the symbiotic relationship between the plant and bioinoculants start to develop in a dual fashion (i) due to synergistic activity among bioinoculants the production of phytohormones and biological nitrogen fixation increase (ii) due to the availability of fixed nitrogen the plants start a normal metabolism and the production of root exudates increases and thereby increasing the population of all the bioinoculants. The same study indicated the beneficial relationship among the diazotrophic and non-diazotrophic inoculants also creating a symbiotic relationship with the plants. Synergistic effects of combined inoculation of PGPRs have also been reported in various crops, for examples potatoes (Kundu and Gaur, 1980a), rice (Tiwari et al., 1989) and sugar beet and barley (Cakmakci et al., 1999). So the tested bioinoculants in the present study interacted synergistically to each other and this information was harvested from mixed application of those organisms in a single pot and treated with various INM practices. So it was correlated with the findings of Raja et al., (2006).

The present work revealed that co-inoculation of Nitrogen fixer, PSB and AMF strains synergistically react with themselves. Moreover they solubilized rock P and other minreals which were added into the soil and made them much more available for uptake by plant roots. The yield and uptake of nitrogen and phosphorus was substantially increased due to use of bioinoculants. Similar findings reported by Muthukumar et al., (2001) mentioned that combined inoculation of *G. intraradices*, *G. geosporum*, PSB and A. brasilense increased plant growth of carrot. The increase in phosphorus uptake by plants has been made possible by combining the abilities of the phosphorus solubilizing microorganisms.
and the efficient P uptake mechanisms of the VAM fungi (Dwivedi et al., 2003). VAM fungi produce obligate symbiotic association with plant roots and increase P availability by mobilizing the P with the help of their extrametrical hyphae, particularly in soil with less available P (Mosse, 1973).

**Effect of Integrated Nutrient Management (INM) on productivity of BSS - 1 seedlings under nursery**

Bioinoculants (BF) and/or inorganic fertilizers (IOF) were registered higher rate in the development of nursery grown BSS (biclonal seed stocks) seedling plants. In the present study of both seedlings and clonal - INM nursery trials, half recommended dosage of inorganic fertilizers with bioinoculants provided significantly higher values of biometric characteristics either on par with or comparable to standard practice (100% IOF). Application of *Pseudomonas aeruginosa* LES4 with half dose of fertilizers resulted in equivalent growth and yield of sesame to full dose treatment (Sandeep Kumar et al., 2009) which substantiated the present findings of INM in tea. The present study results were very much supported with findings of Sabannavar and Lakshman (2009) and they reported that for maximizing the better growth and vigour of *Eugenia bacteria, Eugenia jambolana, Terminalia bellerica* and *Terminalia tomentosa* seedlings at nursery level (combined application of PSB, VAM and rock phosphate has been recommended to obtain healthy timber seedlings (Lakshman, 2003) and Plants inoculated with VAM (*Glomus mossae*) and treated with different levels of super phosphate and rock phosphate grown in green house conditions showed enhanced nutrients in shoot, when compared to non inoculated plants (Kerur and Lakshman, 2004). The inoculated seedlings had greater plant height, stem girth, leaf number and area compared to uninoculated controls both at 60 and 120 DAT (Muthukumar et al., 2001). So it revealed that 50% IOF + BF provided significantly higher productivity in the biometric parameters of seedlings which were comparable to
100% IOF followed by 33% IOF + 33% OM + BF. Terry et al., (1996) supported the present study and revealed that application of both Azospirillum brasilense and Azotobacter chroococcum along with 30 kg N increased the plant height, root length and fresh and dry weight of aerial parts in tomato. Similarly, Chen (2006) found that a combination of the arbuscular mycorrhizal fungi Glomus aggregatum, the PGPR Bacillus polymyxa and Azospirillum brasilense maximized biomass and P content of the aromatic grass palmarosa (Cymbopogon martinii) when grown with an insoluble inorganic phosphate. Moreover, Ramanandan et al., (2008) substantiated the present findings and reported that application of recommended NPK fertilizers along with and Azospirillum resulted in maximum dry matter production in stem, leaf and tuber at harvest during both the years of investigation as a result of the synergistic interaction between biofertilizers and inorganic fertilizers.

For interpretation, application of organic manures in conjunction with both biofertilizers and inorganic fertilizers at different levels had resulted in a significant influence on plant height, stem girth and number of leaves per plant. This may be attributed to the fact that vermicompost with its richness in both macro and micro nutrients besides having humus forming microbes, sustained availability of nutrients throughout the crop growth period (Ramanandan et al., 2008). Application of Pseudomonas aeruginosa LES4 with half dose of fertilizers resulted in growth equivalent to full dose treatment without compromising with the growth and yield of Sesame. (Sandeep kumar et al., 2009). In accordance with shoot and root growth, dry matter content of tea plants was also increased in BSS – 1 seedlings and clonal nursery of INM trials in the present study. These observations are similar to earlier findings of Baby et al., (2002) who reported Azospirillum inoculation to significantly increase growth of tea seedlings and was attributed to increased root development and absorption of mineral nutrients brought about by
**Discussion**

*Azospirillum* inoculation. Similar reports on improved growth and nutrient uptake due to *Azospirillum* inoculation in different crop plants have been made earlier (Rao and Charyulu, 2006). The mycorrhizal inoculation (*Glomus fasciculatum* and *Acaulospora laevis*) with rock phosphate and *Pseudomonas striata* increased significantly the height, shoot and root biomass of TSES 1 and TSES 4 varieties. Non mycorrhizal control plants produced very little dry biomass (Sabannavar and Lakshman, 2009).

The present study showed that biometric observations of BSS – 1 seedling were very much influenced by integrated application of native bioinoculants with 50% IOF. Since the biometric and biomass of tea plant height, number of leaves, leaf area and root growth are the major contributors for dry matter production, increase in all these parameters in inoculated treatments might have led to the increased dry matter production of tea plants. These results are in line with the findings of several workers (Vikram, 2001 and Afzal et al., 2005), who have reported increase in plant growth, dry matter content and nutrient content/ uptake of different crop plants due to inoculation of beneficial promising bioinoculants. It may be inferred that, when organics are applied along with inorganic fertilizers to soil, complex nitrogenous compounds slowly break down and make steady N supply throughout the growth period of crop, which might have attributed to more availability and its subsequent uptake by the crop (Kondapa naidu et al., 2009).

Chlorophyll is the green pigment found in leaves and is undoubtedly the most important plant pigment determining the photosynthetic efficiency and productivity of plants. Chlorophyll was estimated higher in BSS-1 seedlings when they were treated with 50 % of inorganic fertilizers and biofertilizers which was observed in this research study. A greater content of chlorophyll in leaf tissues could greatly influence increased photosynthesis thereby improving yields
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(Krishnapillai and Ediriweera, 1986). The present findings showed that the nitrogen fixers and phosphobacteria with phosphate mobilizer (AMF) present together which might have helped in increasing various growth parameters by exerting its synergistic effect with inorganic and organic fertilizers and this was supported by Bano et al., (1987) and there was no alike reports on about in tea crop so far. Nitrogen and magnesium are important as they play a vital role in the formation of the structure of the chlorophyll molecule itself and therefore their importance need not be stressed. Other major elements, notably potassium also play an important role in the synthesis of chlorophyll by taking part in various enzyme activities necessary for such building up process (Evans and Sorger, 1966). Interestingly, the present study expressed the similar results submitted by Panwar and Singh (2002) and they intended that the role of biofertilizers in wheat and revealed that N₂ fixing bacteria (Azospirillum brasiliense) and phosphorus solubilizing bacteria (Bacillus subtilis) significantly increased chlorophyll content and nitrate reductase activity over other treatments. This reason could be attributed to the higher initial nitrogen application which would enhance the soybean growth and translocation of nitrogen to the leaves sufficiently and favorably induced chlorophyll formation (Vu van Thu et al., 2001). These findings substantiated and indirectly explained the reason for higher productivity of tea seedlings while bioinoculants integrated with inorganic fertilizers in the present study.

In case of carbohydrates content estimation, the storage energy reserve compounds as carbohydrate were noticed higher which may be influenced by incorporation of bioinoculants integrated with possible reduction (50%) in use of inorganic fertilizers. The increased uptake of nutrients due to the application of chemical nutrients at 50% and the biofertilizers might have produced enough carbohydrate in leaves for translocation to the sink for better tuber number and length. The combined effect of chemical fertilizer and the biofertilizer resulted in saving of chemical fertilizer input to the crop in addition to increasing the yield.
This study was supported with the findings of Saikia and Borah, (2007) and they proved that combined application of biofertilizer through vine dipping and soil application along with inorganic fertilizers is efficient than application of inorganic fertilizers alone with respect to growth, yield and net return for sweet potato cultivation.

The present research reports revealed that nutrient status of shoot and root collected from nursery grown BSS - 1 seedlings treated with bioinoculants integrated with 50% inorganic fertilizers. The increase in shoot and root growth is attributed to the increased cell elongation and multiplication due to enhanced N and P uptake by plants and/or due to the production of plant growth promoting substances (Han et al., 2006). Similarly, the increase in nutrient uptake in sorghum leaves may also be due to altered root surface characters involved in nutrient uptake which helps the plant to absorb nutrients from solution at faster rates than uninoculated plants resulting in accumulation of more nutrient content in the stem, roots and leaves leading to enhanced plant growth (Pacovsky et al., 1985). In the present study, it was clearly evident that the plants showed significantly improved growth and nutrient content over non-inoculated control.

However, RDF and half RDF + biofertilizers were on par and significantly superior to half RDF and control in respect of K uptake in fodder sorghum (Ramanjaneyulu et al., 2010). Like wise, Casuarina seedlings inoculated with AM fungi, Frankia, a symbiotic N – fixing actinomycete, associative symbionts of Azospirillum, PSB or their mixture showed substantial increase in seedling biomass, nutrient content and use efficiency under nursery conditions. (Rajeshkannan and Muthukumar., 2009). In the present study, higher rate of nitrogen was noticed in both shoot and root biomass in the tea seedlings treated with 50% IOF + BF. This was clearly correlated with the findings of Sabannavar and Lakshman (2009) and they noted that shoot phosphorus content showed higher percentage at the 15.0 mg/kg rock phosphate amendment with Acaulospora laevis.
and *Pseudomonas striata* than control and other treatments. Percent content of nitrogen, phosphorus and potassium and their uptake was higher in soybean plants inoculated with VA mycorrhizal fungi compared to uninoculated plants (Mali *et al*., 2009). Ghulam *et al*., (2007) indicated highest nutrient uptake by crop recorded as N under half N and P + biofertilizer. The investigation was found to be in conformity with that of Sundara *et al*., (2002) who found that the application of PSB increased the P availability thus P uptake by the plant and when used in combination with P fertilizer, it reduced required P dosage by 25%. The highest P content was observed under application of 50% IOF+BF over NPK alone in the present study dealt on INM trial with BSS – 1 seedlings of tea. This is in accordance with the finding by Sharma and Mittra (1991); Vu van Thu *et al*., (2001). Then Tisdale and Nelson (1968) opined that P increases root growth and proliferation thereby creating more desorptive area for uptake of nutrients. The enhanced uptake of P in AM-fungi-inoculated seedlings may be due to an increase in the number of uptake sites per unit area of roots and a greater ability of these roots to exploit the soil nutrients (Bolan, 1991).

The yield and uptake of nitrogen and phosphorus was substantially increased due to use of beneficial bioinoculants. The phosphorus solubilizing bacteria have the capacity to dissolve the insoluble phosphatic compounds present in soil. The increases in phosphorus uptake by plants have been made possible by combining the abilities of the phosphorus solubilizing microorganisms and the efficient P uptake mechanisms of the VAM fungi (Dwivedi *et al*., 2003). An integrated application of rock P and K materials with co-inoculation of bacteria that solubilize them might provide faster and continuous supply of P and K for optimal plant growth. Soil inoculation with PSB (Phosphate solubilizers) or KSB (Potassium solubilizers) significantly increased N, P and K uptake in pepper and cucumber plants (Han *et al*., 2006).
**Discussion**

Increase in N, P and K uptake generally occurred in the combined treatment *i.e.*, soil coinoculated of N,P and K uptake in shoot and in the root. It is interesting to note that combined bacterial inoculation and rock material fertilizer application also increased the N uptake by the plants (Han and Lee, 2005). The amount of biological nitrogen fixed in consortium is the cumulative amount of nitrogen fixed by *Azospirillum lipoferum* and *Pseudomonas putida* but the amount of nitrogen incorporated *i.e.*, the nitrogen use efficiency seems to be higher in consortium than single/non inoculants treated plants (Raja *et al.*, 2006).

The rhizosphere is a region of dynamic process initiated by root exudations, release of organic nutrients and is influenced by host factors, soil factors, environmental conditions, cultural practices and soil microbial interactions (Jayanthi *et al.*, 2001). Also the plant root exudates enriched rhizosphere region of the soil attracts a variety of microorganisms. A strong interaction prevails between the group of microorganisms colonizing the rhizosphere region and plant roots (Raja *et al.*, 2006). Similarly, population dynamics of the microbes in the rhizosphere soils of BSS - 1 seedlings was enumerated as higher population in the treatment of 50% IOF + BF than non-rhizosphere and other treatments which may be due to application of reduced level of inorganic fertilizers with bioinoculants treated in BSS -1 Seedlings nursery trial under INM and substantiated with the findings of Balamurugan *et al.*, (2010). Similar results were reported by Tensing (2007) and he proved that the population level of *Azospirillum*, PSB and other microbes were higher in the rhizosphere soil compared to the non rhizosphere tea soil and also there was a clonal preference. Jayathilake *et al.*, (2006) supported the present findings and reported that highest population of *Azospirillum* (5.0 x 10^4 cfu/g soil) was recorded in the treatment with *Azospirillum* in combination with VC and FYM followed by inoculation of *Azospirillum* with VC and chemical fertilizers. In this study, the soil planted with BSS – 1 seedlings treated with 100%
Discussion

IOF, recorded significantly lesser population to all the remaining treatments which may be due to influence of bioinoculants establishment in the rhizosphere. This situation brought pH reduction in soil by production of organic acids and required minerals may be supplied via chemical fertilizers to bioinoculants. It ensured the improvement of soil fertility with higher plant nutrients content and higher population of *Azospirillum* and phosphobacteria as compared to application of recommended dose of chemical fertilizers in tea. Incorporation of bioinoculants along with chemical fertilizers enhanced the colony forming units of soil microflora provided an acidic soil pH, permissible limit of EC favoured to tea crop, high organic matter content along with significant improvement in major nutrients (NPK) status in tea soil which were observed in the present study and similar trend of results were harvested by Pandey and Palni (1999). Plantation crops like arecanut, cashew, cocoa, rubber, cardamom and sapota grown in acidic soils colonized *Azospirillum* in their root system (Hu *et al.*, 2006).

**INM with Clone - UPASI 9 under nursery**

As that of INM trial with BSS – 1 seedlings under nursery condition, all observations were made with another trial with different jat (Clone – UPASI 9). Biometric, biochemical, nutrient uptake, soil nutrient status, microflora in soil of the clonal nursery trial coincided with the results of BSS – 1 seedlings. Interpretations and supporting findings of seedlings trial could be substantiated these results. Plants treated with 50% IOF + BF recorded second next to recommended dose of inorganics with BF in the case of biometric characteristics of UPASI 9. It may be the reason the compatibility of bioinoculants with reduced level of inorganic fertilizers which made them easily available to the plants. Also, the N$_2$ fixers showed significant increase in shoot and root growth, dry matter accumulation and nutrient content in tea plants over uninoculated control. This may
be attributed to efficient N$_2$ fixation (Berkum and Bahlool, 1980) which promoted better growth and dry matter content of plants. Biometric observations of the trial indicated that consortium of bioinoculants can promote the growth in rice, most like through mechanisms that involve changes in growth physiology of crops by transferring fixed N$_2$ and by improving nutrient uptake through modulation of hormone-linked phenomena, root morphology and mainly through biological nitrogen fixation in microbial consortium (Raja et al., 2006). The lower dose of inorganic fertilizer conjunction with composted paddy straw or bioinoculants have achieved same grain yield of soybean under rice-based cropping system and which was in line with the finding by Son and Ramaswami (1997). In the present study, application of bioinoculants when incorporated with half recommended dose of inorganic fertilizers enhanced all the growth parameters, nutrient uptake and dry matter content of tea plants of different growth stages significantly (nursery, young tea and mature tea) over rest of the treatments. The higher dry matter production is attributed to the cumulative effect of progressive increase in the growth attributes, viz., plant height, stem girth and number of leaves per plant. Similar results have been reported earlier in cassava (Amanullahkhan, 1997) and sweet potato (Nedunchezhian and Srinivasulureddy, 2004). Suja et al., (2005) also reported similar results in cassava due to integrated use of biofertilizers, FYM and 50% of N and P and recommended K.

Bioinoculants possessed the ability to solubilize insoluble inorganic phosphate by PSB and mobilized through AMF then nitrogen accumulation by N$_2$ fixer at higher state due to better establishment of them when applied with partial dose of inorganic fertilizers in rhizosphere which might have contributed to improved growth and nutrient uptake in inoculated tea plants. The influence of *Azospirillum* on plant growth and plant biomass through N$_2$ fixation are well known (Berkum and Bohlool, 1980). Nitrogen promotes vegetative growth and
encourages the formation of foliage thus promoting the production of more dry matter (Vanderwerf et al., 1993). *Azospirillum* and PSB inoculation is also known to benefit plant growth by improving root development, mineral uptake and plant water relationships (Prasad and Govindarajan, 2001). Plant growth promoting substances produced by these bacteria are known to change the root morphology and increase their biomass enabling the plants to contact more soil volume for nutrient uptake (Malik et al., 1997). Thus, such bacteria can complement the beneficial effects of nitrogen fixation and phosphate solubilization and geocycles that release nutrients into the rhizosphere. Ragland et al., (1989) indicated that application of 75% recommended dose of N and P along with *Azospirillum* and VAM increased the bulb yield in onion as compared to the uninoculated control, which was on par with 100 per cent recommended dose of NPK and biofertilizers.

Combined effect of organic manure, inorganic fertilizers with bioinoculants treated plants too proved yield and quality which was comparable to standard practice and half recommended dose of IOF with bioinoculants treated in the present study. Similar findings were reported by Sendur et al., (1998) which showed that use of organic manures like *Azospirillum*, FYM and vermicompost combined with recommended dose of inorganic fertilizers showed better performance in terms of growth and fruit yield of tomato. Prabhu et al., (2002) reported that application of biofertilizer and FYM with reduced dose of inorganic fertilizers increased yield and yield attributes in okra. The treatment combination of FYM (10 t/ha) + 2/3 RDF + *Azospirillum* + VAM resulted in higher yield. Rafi et al., (2002) reported that application of FYM (12.5 t/ha) with reduced level of recommended dose of fertilizer (50% RDF) helps in higher vegetative growth and yield in tomato.
INM in Young tea

In the present study, the reduction in inorganic fertilizers could be compatible in nature which reflected the better biomass yield due to easily available the nutrients to plants made them by artificially implemented bioinoculants organisms. This could also have accelerated cell division and elongation as well as greater chlorophyll synthesis and higher metabolic activity as suggested by Nazeerahmed and Tanki (1998). Performance of 50 % IOF integrated with bioinoculants treated graftings (CR 6017 x UPASI 9) registered more number of branches and leaves next to 100% IOF + BF in young tea trial of this present study. Graftings treated with 50 % IOF + BF stood first in terms of chlorophyll content followed by conventional practice. On the whole, biofertilizers integrated with 50 % of IOF increased biometric parameters which lead towards luxurious growth and better establishment of graftings in the field. Graftings treated with combined application of each 33% of IOF and OM integrated with biofertilizers also performed marginally similar to 50% IOF + BF and standard practice of manuring in tea.

Ramanandan et al., (2008) revealed that application of recommended NPK fertilizers along with vermicompost and Azospirillum resulted in maximum dry matter production in stem, leaf and tuber at harvest during both the years of investigation as a result of the synergistic interaction between vermicompost, biofertilizer and inorganic fertilizers among the different INM treatments tested. Paul et al., (2005) reported that apart from P-solubilization by fluorescent pseudomonads, improvement in the uptake of other nutrients and phytohormone production like IAA and GA₃ were some mechanisms that directly enhance plant growth and dry matter content. Improved plant growth, dry matter accumulation and nutrient content due to bioinoculants with inorganic fertilizers have been reported by Mishra et al., (2005) in tea and Zargar et al., (2005) in other crop plants.
Discussion

and lend support to the findings of the present investigation. Free-living diazotrophs have been reported to improve nutrient uptake and efficiently and to fix nitrogen through associative and endophytic associations with graminaceous plants (Raja et al., 2006). Rizwan et al., (2008) in both pot and plot studies indicated that biofertilizer, supplemented either with 88 or 132 kg N ha⁻¹ significantly increased the growth and yield of maize over full dose of N fertilizer. The current investigation has clearly brought out the importance of PGPRs of tea plants in enhancing growth and nutrient uptake of tea plants through multiple beneficial functions.

The increase in tuber yield was noticed and attributed to the synergistic interactions between vermicompost, biofertilizer and inorganic fertilizers (Subbiah, 1994), improvement of soil physical conditions (Maurya and Goswami, 1985), the increased availability of nutrients resulting from the decomposition of vermicompost (Devlin, 1973) and increased translocation of photosynthates from leaves to the tubers leading to increase in the number of tubers per plant in addition to tuber length and girth (Singh et al., 1997). Similarly, the present findings implied that reduction in IOF could be compatible with introduced bioinoculants in nature and reflected on better biomass (green leaf harvest during tipping process of young tea cultivation) production which is due to easy availability of nutrients for plant metabolism. Inoculations of G. intraradices, G. geosporum, PSB and Azospirillum increased seedling growth and quality. Significantly higher mycorrhizal colonization and PSB and Azospirillum populations might have accompanied growth stimulation. The growth response produced by G. intraradices, G. geosporum, A. brasilense and PSB when inoculated simultaneously suggested that this combination was the best over other combinations. Along with this, inoculation with AM fungi (Phavaphutanon et al., 1996) or Azospirillum (Okon and Labandera-Gonzalez, 1994) can reduce fertilizer
requirement in plant production. Thus, the results of the present investigation clearly indicated that microbial inoculations can substantially reduce fertilizer requirement in tea gardens. It has been observed in the present study that combined application bioinoculants with half recommended dose of IOF / OM proved to be increasing in soil nutrient content, higher microbial population and favourable organic matter over individual application of 100% inorganic fertilizers or organic manures. The supplementary and complementary use of organic manures and inorganic chemical fertilizers augment the efficiency of nutrient mineral sources to maintain a high level of soil productivity (Kondapa naidu et al., 2009).

In tea soil and plantation fields, the elements are continuously removed at each plucking round and thus in a year, considerable amount is removed from the soil which requires to be replenished to maintain the sustainable productivity of tea. Chemical fertilizers with instant ability to renovate deleted nutrients in necessary quantities and forms have come to be recognized as a key component of the soil fertility management and sustainable productivity (Karthikeyini, 2002). Productivity indicated by yield and harvest index and soil fertility indicated by available NPK in soil after harvest were significantly increased with the application of biofertilizer in combination with 50% N through organic manure (FYM or VC) and rest of 50% N and 100% PK through chemical fertilizer (Jayathilake et al., 2006). An integrated application of rock P and K materials with co-inoculation of bacteria that solubilize them might provide faster and continuous supply of P and K for optimal plant growth (Han et al., 2006).

In the present study, higher N, P and K uptake in the graftings were noticed by the treatment of 50% IOF + BF followed by combination of OM + IOF with biofertilizers and which may subsequently promote the plant growth. Efficiency of biofertilizers strains integrated with organic manures and/or inorganic fertilizers
might be due to the fact that the organic manures would have provided the micronutrients such as iron, magnesium, manganese etc., at an optimum level. Moreover, the biofertilizer organisms will surely make use of fertilizer usage efficiency higher and which brought sustainable yield and nutrient uptake even in least availability of nutrients condition. *Azospirillum* has its role in atmospheric nitrogen fixation. Mycorrhizal plants are better able to obtain their nourishment in soil and resist biotic and abiotic stresses (Mali et al., 2009). The nitrogen availability and nitrogen content of plants is enhanced due to the application of FYM and *Azospirillum* and thus improves growth characters. Nitrogen is also the chief constituent of protein which is essential for the formation of protoplasm, which leads to cell division, cell enlargement and ultimately resulting in increased plant growth (Barkly, 1974).

Mycorrhizal colonization may alter the host root physiology which may in turn influence the microbial populations. The flow of carbon from shoot to root may be increased by AM colonization (Muthukumar and Udaian, 2000) which may alter the carbon availability for bacteria in the rhizosphere. Furthermore, it is well known that root exudates strongly modify microbial composition and activity in the rhizosphere and AM fungi can modify the quantity and quality of root exudates (Andrade et al., 1997). Significantly highest colony forming units (CFU) of *Azotobacter* was observed in *Azotobacter* inoculated with 20 t/ ha of FYM and 2.5 t/ ha of VC (134.67 x 10^4 cfu per g soil) followed by *Azotobacter* in combination with VC and chemical fertilizers. The highest population of *Azospirillum* (5.0 x 10^4 cfu/g soil) was recorded in the treatment with *Azospirillum* in combination with VC and FYM followed by inoculation of *Azospirillum* with VC and chemical fertilizers (Jayathilake et al., 2006).
INM in Mature tea

The quantity and quality of made tea is a reflection of the quantity of flush (2 – 4 leaves + bud) harvested, which is greatly affected by the amount of nutrients supplied through various sources of fertilizers and taken up by the tea plants (Wayoko and Mawakha, 1991). In the present study, introduction of BF resulted in 50% reduction in chemical fertilizers and BF treated plants performed better than un-inoculated control in terms of yield. Concurrent increase in the population of BF in rhizosphere of tea soils can improve the fertilizer use efficiency which ultimately leads to further reduction in application of chemical fertilizers. Results were comparable with recommended dose of inorganic fertilizers and combination of *Rhizobium* and PSB + 75% recommended dose of fertilizers + organics in soybean (More *et al.*, 2009). In the present study, when INM trial with mature tea was conducted in Anamallais, 50 % IOF + BF treated plots recorded significantly higher yield and nutrient reserve in soil over other treatments which may be due to proper exploitation of the introduced bioinoculants which may be compatible with the inorganics, thus resulted in improved performance of the treatment.

Nanthakumar and Veeraghavathatham (1999) noticed that combined nutrition of organic manure through FYM (2.5 t/ha) *Azospirillum* (2 kg/ha) and phosphobacteria (2 kg/ha) and 75% of recommended dose of inorganic nitrogen and phosphorus increased the yield and yield components in brinjal. Thus, the present study confirmed the beneficial effect of integrated application of 50 % IOF with bioinoculants on yield and productivity of tea. The beneficial effect of bioinoculants may not be evident immediately in over exploited soils. However, its repeated application will help to regain soil health and manifesting the beneficial effects. Generally, the plants will be healthy and the pest and disease incidence will be low in biofertilizer treated fields (Tensingh, 2007).
Discussion

The present study results of mature tea yield and nutrient uptake were very much supported the following reports. Premkumar et al. (2012) observed that INM experiment conducted in Nilgiris and Central Travancore regions, 75% IOF + BF, 100% IOF+BF and conventional practice registered higher crop and they are significantly different at five per cent probability over untreated control and their report supported the result of the present study. Moreover, Balasubramani (1988) reported that the seed and soil treatment of Azospirillum with 75% recommended dose of nitrogen per ha. recorded higher yield (17.5 t/ha) compared to control (9.6 t/ha) in bhendi. Thamizh and Nanjan (1998) stated that the combined application of Azospirillum, phosphobacteria and VAM with 75% of recommended NPK (90:90:90 kg/ha) recorded higher yield (14.96 t/ha) which was 21 per cent higher than uninoculated control (11.93 t/ha) in potato. The higher yield of made tea with those receiving bioinoculants in combination with organic and chemical fertilizers against to their corresponding treatments without biofertilizer could be due to association with higher population of these N fixing bacteria, PSB and AMF in the soil which activated the more effective interaction with plant roots to ensure higher nutrient uptake (Balamurugan et al., 2011).

Incorporation of beneficial PGPR consortium with reduced rate of IOF resulted in a progressive improvement in the yield. Rout et al., (2001) reported that biofertilizers along with inorganic N fertilizers can substitute up to 20% N fertilizers and can increase the maize yield. The present study justified that conjoint use of organic manures along with biofertilizers and inorganic fertilizers at half recommended dose which exerted a significant influence on growth and development in the tea crop meanwhile the soil health also can be retained well with high population of beneficial microbes. Similar result was observed in cassava by Ramanandan et al., (2008). A balanced application of both organic, inorganics and biofertilizers appear to be an ideal proposition to meet nutrient requirements of
dry land crops rather than single application and for the nutrient uptake and residual soil fertility (Kondapa naidu et al., 2009) and it evidenced the present study findings. Their results revealed that green and dry fodder yield of sorghum were highest when the crop received RDF, but produced comparable green and dry fodder yields when it received half RDF + biofertilizers (Ramanjaneyulu et al., 2010). The superior performance of sorghum with RDF was mainly due to ready availability of N and P nutrients. Comparable performance of forage sorghum with half RDF + biofertilizers might be due to utilization of N and P supplied through inorganic fertilizers in the initial stages, and N and P were fixed and mobilized by Azotobacter and PSB, respectively in the later phases by sorghum crop (Kumar and Sharma, 1999). Similar results were published by Subha and Giri (2003) in spring sunflower and fodder sorghum. It was concluded that application of half RDF + biofertilizers not only saves half the dose of N and P but also improves soil health by producing growth hormones, antifungal substances (Sheoran et al., 2000) and vitamins (Das et al., 2004) to sustain the crop productivity. RDF and half RDF + biofertilizers enhanced the dry fodder yield by 45.8 and 41.2%, respectively over control (Ramanjaneyulu et al., 2010). Integrated use of biofertilizers, organic manure and chemical fertilizers resulted in yield increase in comparison with the exclusive application of chemical fertilizer (Jayathilake et al., 2006). This could be due to the increase in nutrient availability and uptake of nutrients resulting in faster synthesis and translocation of photosynthate from source (leaves) to sink (bulb).

**Impact of INM on tea quality**

Health problems, quality consciousness of plant products and degradation of natural resources on the environment have thrown new challenges. Several attempts have been reported to increase the yield potential of crops, but they are concerned with the use of chemical fertilizers. Unfortunately, not only the productivity potential is low, but the quality is also deteriorating. Hence, it is time
to think not only of increasing the production potential but also to improve the quality by applying advancements in scientific production to meet the increasing demand and boost up the export earnings (Mog, 2007). Due to burning problems, organic farming is gaining importance towards achieving sustainability in crop production. However, after the advent of chemical fertilizers, the importance of organic manuring has received least attention among the farming community, leading to increased toxicity in soil and farm produce.

New strategy of fertilization in agriculture depends on using manure and farm residues to produce compost for enhancing biological cycles, improving soil fertility and avoiding all forms of pollution that may result from conventional agricultural techniques. When biological sources of fertilizers integrated with organic and/or reduced level of inorganic fertilizers could improve quality of made tea meanwhile maintain the soil organic and health very well. Organics provide balanced nutrition in addition to enhance water holding capacity and improving physical, chemical and biological properties (micro organisms) of soils which assist in better uptake of nutrients (Mog, 2007). The organic manures also provide room for the better microbial establishment along with accumulation of excess humus content (Hayworth et al., 1966) and they enhance the growth characters is well known and they have a positive relationship with growth of bioinoculants so as to provide higher yield and better quality. Organic manures are more efficient than inorganic fertilizers in case of bringing better quality of plant products, whereas the combined use of organic with inorganic fertilizers is considered to be superior than the use of organic fertilizer alone (Sharma, 1991).

The quality of made tea and green crop shoots composition related to attribute the quality parameters are used to be very much influenced by climatic conditions, manuring practices and nature of crops, etc., amino acid and protein
content of tea leaves affect the quality of green tea and both of these are influenced by soil fertility (Fan et al., 2005). Biochemical parameters of crop shoots related to quality of tea were noticed satisfactory level by the treatment of bioinoculants with reduced use of inorganic and organic manure. Moreover, the present study revealed that total amino acid contents, soluble substance contents and tea polyphenol contents were all higher than those that of the control, which indicated the quality of tea leaves was enhanced and which is substantiated by the findings of Wang et al., (2006). In particular, OM alone treated plants stands first and resulted satisfactory level of quality parameters production.

Actually, tea polyphenol has significant antioxidant activity due to its ability to scavenge reactive oxygen species and chelate metal ions (Morel et al., 1993), which is beneficial to human health. Half recommended dose of inorganic fertilizers integrated with biofertilizers treated tea plants showed better quality components which were comparable to that of OM alone treated which was observed in the present study. However, water extracts and tea polyphenol content to total amino acid content declined in comparison with those of the control. Comparable content of caffeine and water extract were noticed by the treatment, 50 % IOF+BF to standard practice and which may be responsible for enhancing the briskness and cuppage of black tea. The increase of caffeine contents was noticed in the plots treated with combined application of either organic with bioinoculants or half recommended dose of inorganic with bioinoculants which enhance the palatability of tea leaves and which were evidenced with the findings of Werkhoven, (1975) and Wang et al., (2006). Mog (2007) revealed that the impact of fertilizers / manures not only on the productivity potential of carrot but also on the quality aspects and it justified the present studies on INM with special reference to biofertilizers to influence the yield and quality of tea.
The made tea analysis revealed that the quality of tea was better and higher in the crops harvested during low crop season over high crop period. Because the weather parameters such as sunshine and rainfall may have influence with soil nutrients to nourish the crop according to bring the biochemical components derivatives attributed to quality of black tea. Except untreated control, all other treatment effect reflected on the theaflavins and thearubigins content better level which are mainly responsible for briskness of black tea. Based on overall performance on tea quality parameters production, the present finding revealed that the 50% inorganic fertilizers in combination with bioinoculants treatment performed better and which is on par with recommended dose of organic manures application. Similar result was noticed by Mansour and Shaaban (2007) and it showed that combined application of N through mineral sources at 50 % out of the recommended rate of N plus Compost El- Neel and Biogen each at 25% was effective in improving leaf area, N %, yield and fruit quality of orange while compared to using N completely via., mineral sources or using mineral N at 25 % with other organic and biofertilizers. Integrated use of inorganic nitrogen and phosphorus fertilizers and biofertilizers is the most efficient way of economically improving the yield and agronomic efficiency of the crop. These applications have the added benefit of improving the physical, chemical and biological properties of the soil and bringing better quality of made tea.