The relevant literature available on various aspect of betelvine cultivation including important cultivars and their management through using organic, inorganic and biological sources of nutrients included in the present study have been briefly reviewed hereunder.

2.1. Evaluation of betelvine cultivars

In India more than 100 types of betelvine are reported to be in cultivation and most of them are synonyms and confusing one. To assess the varietal wealth of betelvine, different ecotypes are need to be collected from various parts of India for evaluation of higher yield and quality (Arulmozhiyan et al., 2005). The cultivators and consumers recognize more than 100 cultivars (landraces) based on regional and organoleptic considerations, while in terms of phytochemical constituents only five groups have been identified for all the landraces (Verma et al. 2004). Reddy (1996) reported that in south India, mostly non-pungent types were grown, while pungent types were under cultivation in north India.

Rawat and Balasubramanyam (1988) identified six cultivars based on their chemical characteristics of leaves, namely Kapoori, Bangla, Deshawari, Sanchi, Meetha and Khasi types. They also reported that the reliable characteristics for the identification and classification of betelvine varieties are GLC of essential oils and peroxidase isoenzyme patterns beside the leaf morphology, though the morphological characteristics of some cultivars are only marginally distinguishable. The GLC of the essential oils of some varieties have shown marked differences with respect to the number and size of peaks, while types belonging to the same group have corresponding chromatographs (Anonymous, 1988).

Betelvine germplasm grown in India exhibit a wide diversity in exomorphic characters like 100 leaf weight, number of leaves, number of laterals and number of main vines (Reddy, 1994).
A study on genetic variability, coefficient of variation and character association of 12 characters of 16 genotypes of betelvine revealed significant variation was observed for all the characters. The heritability estimate was high for all the characters indicating the scope of effective selection in respect of all the characters. The number of leaves per vine had a positive correlation with leaf area, leaf length, leaf breadth, number of laterals per vine, vine length, diameter of internodes, chlorophyll a and b content and 100 leaves weight. Hence, during formulation of selection criteria these characters should be given preference (Das et al., 1999).

The importance of genotypes x environmental interaction (G x E) has been recognised from very beginning especially the crops like betelvine where environmental fluctuation play a pivotal role in its seasonal production and productivity. Number of workers studied on the important characters of the available genotypes and evaluated for yield and different yield attributing characters under different locations of the country.

Performance of 27 genotypes of betelvine was evaluated at Kalyani, W.B. by Rahaman et al. (1997) in winter, summer and rainy season for leaf length, breadth and leaf area. They observed that most of the genotypes under study reacted violently with the environmental changes for total leaf area/vine (i.e., leaf yield) and the G x E interaction was highly significant for all the characters under study excepting leaf length, stomatal length and stomatal breadth though the cultivars recorded significant variation in stomatal frequency. Depending upon their morphological, anatomical features and chemical composition of leaves ten different cluster were formed.

Yousufzai et al. (2009) studied the stomatal frequency in the flag leaf of wheat and its interrelationships with yield and yield components. Different cultivars showed significant differences with respect to stomatal frequency, yield and yield components. Higher stomatal frequency in flag leaf was positively associated with yield and yield components. The cultivar Sarsabz having significant superiority in yield and yield components also showed significantly (p<0.05) higher stomatal frequency at adaxial and abaxial surface of flag leaf as compared to other cultivars.

Inamdar et al. (1991) reported that two important plant processes viz., photosynthesis and transpiration are influenced by stomatal frequency in many crop plants. Yoshida (1976) also found that stomatal frequency can be used as an indicator of photosynthetic capacity leading to high yield.

Das et al. (1995) evaluated eight Bangla cultivars of betelvine and revealed that the Ghanaghate was the best performing cultivar producing minimum shoot growth with
thickest and shortest inter-nodal length and maximum leaf area with longest petiole. The cultvar was also produced the highest number of leaves (88) per vine annually having highest fresh weight (380.75 g) and dry weight (44.60 g) of 100 leaves.

Arulmozhiyan et al., (2005) collected, maintained and evaluated forty three betelvine entries at Sugarcane Research Station, Sirugamani and four clones SGM-1, Karpuri, Vallaikodi and SPb-12 were found to be promising and subjected for further testing. Among the four entries tested at twenty seven multi-locations of Tamil Nadu, the Acc. No. SPb-12 excelled over all other entries with an annual average leaf yield 38.35 lakh/ha. Five improved varieties of betelvine were evaluated by Padmanabhan et al. (1995) in Tamil Nadu. The selection SB 35 was found superior in leaf yield (106 lakhs/ha) than the other varieties in both at Research Station and Farmers’ field and the variety also showed profuse branching with yellowish green leaves in close resemblance to cultivars like Vellaikodi and Kapoori.

Reddy (1996) compared various characters of the different collections using metroglyph analysis for identifying the variations and redundancy in betelvine collections for further screening. The varietal differences for number of leaves and 100 leaf weights together enabled classification of entries in to two distinct groups consisting of pungent and non-pungent types. The non-pungent types were characterized by lower 100 leaf weight with light green colour of the leaves than the pungent types.

A field experiment was conducted at Gangetic plains of East Bengal with seven cultivars of betelvine to evaluate their growth and yield attributing characters. The cultivar Chandrakona proved superiority with respect to vine length, leaf area, leaf yield and fresh weight of 100 leaves as compared to other to others (Sheet, 2002).

The analysis of the karyotype and the chemical constituents of 14 genotypes of *P. betel* L. indicated that the varieties with 2n = 78 chromosomes had high content of oleoresin and essential oils and there was a genotypic control of the chemical content at the inter-varietal level (Jose and Sharma, 1983).

Balasubramaniam et al. (1990) reported significant variation of the chlorophyll content in the leaves of different cultivars of betelvine. The fresh leaves of c.v. Sanchi was recorded the highest chlorophyll content (2.49 mg/g) followed by Mitha, Bangla, Deshwari and the cultivar Kapoori recorded the lowest content in chlorophyll (0.93 mg/g). In an another experiment, Mandal et al. (1993) observed that the chlorophyll content of the leaves were increased in cultivar Sanchi and Bangla with the application of neem cakes.
Balasubramanyam and Rawat (1990) studied the chemical constituents of the different cultivars of betelvine and reported that there was no significance difference in amino acid composition among the cultivars. Euginol (phenols) was found in all the cultivars and dominant in Bangla. Sanchi was marked the presence of Stear-aldehyde which was absent in other cultivars and anethole (phenolic ether) was present in Mitha variety only.

Guha (2006) reported the following composition of fresh betel leaves: water : 85-90%, fat : 0.4-1.0%, protein : 3-3.5%, mineral : 2.3-3.3%, fibre : 2.3%, chlorophyll :0.01-0.25%, carbohydrate : 0.5-6.10%, vitamin C : 005-0.01%, vitamin A :1.9-2.9 mg/100g, tanin : 0.1-1.3%, nitrogen : 2-7%, phosphorus : 0.05-0.6%, potassium : 1.1-4.6%, calcium : 0.2-0.5%, iron : 0.005-0.007%, essential oil : 0.08-0.2% and energy : 44 K.Cal/100g.

2.2 Integrated nutrient management of Betelvine

Integrated plant nutrition system (IPNS), as conceptualized by FAO, is the maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired productivity through optimization of the benefits from all the possible sources of plant nutrients in an integrated manner (Roy, 1995).

Integrated nutrient management (INM), developed on the principles of eco-friendly and efficient balanced fertilization and based on optimization of nutrient supplies from all available sources, inorganic and organic, for pre-defined yield targets of the cropping sequences through an efficient combination of soil, water, organic matter and nutrient management constitutes the IPNS and such an IPNS is a prescription for sustainable agricultural development (Finck, 1998).

Integrated nutrient management (INM) refers to the practice of using optimum combination of different components (chemical, organic manure, crop residue, green manures, non-conventional sources and bio-fertilizers) of INM as sources of nutrient supply for efficient crop production and INM is always advantageous from a long-term perspective both in terms of cost of production of betelvine and soil health (Debnath et al., 1985).

During the second half of the 20th century, significant progress in crop production and productivity was achieved world over through increased use of chemical fertilizers. Unfortunately, this improvement was not accompanied with any major effort to maintain
soil health in terms of its microbiological and nutrient components, which are so important for crop productivity.

Ever since Hiltner (1904) coined the term ‘Rhizosphere’ to designate the zone of intense microbial activity that immediately surrounds the roots, the soil-root interface has come to be recognized as an important functional component of plants contributing significantly to their performance and production in any ecosystem. The distinctness of rhizosphere relates to the dynamic gradients around the roots in nutrient concentration, pH, redox potential, exudates and microbial activity which together determine to a large extent the plant’s competitive ability to grow and produce under a given set of ecological conditions. These gradients are determined by soil chemical and physical factors and plant factors, such as species and nutritional status, and also by microbial activity in the rhizosphere (Marschner, 1995).

One hundred years of research, since Hiltner (1904), on these aspects, especially the rhizosphere microbiology, has provided enough insights and materials to manipulate the rhizosphere, biologically, to improve plant’s survival fitness, performance potential and production capacity. Rhizosphere micro-organisms are now distinctive tools to improve plant production in agriculture, forestry and horticulture.

Aseri et al. (2008) reported that in soil, plant’s root system is always in close association with multitude of micro-organism and other nutrients. The microbes in root zone are maintained due to variety of secretion from the roots and constitute which is often described as rhizosphere. These microbes in their turn supply nutrients to the soil system through their heterotrophic activity and thus supplement nitrogen and phosphorus supplied with the use of chemical and organic fertilizers.

The use of sub-optimal doses of nutrients by the farmers has led to severe depletion of nutrients reserves of the soil resulting in multiple nutrient deficiencies. These factors together suggest a need for reduced consumption of chemical fertilizers and increase use of organic manure, crop residues and bio-fertilizers to pave the way to integrated nutrient management.

Kumar (1999) reported that betelvine has two very short periods of active growth, from February to mid-April and from July to mid-November in the sub-tropical regions and in summer and winter, the growth of the vine is reduced greatly due to extreme temperature. The time of the nutrient application matches with the growth season and major part of the fertilizer treatment is carried out from July to October at about 10 days interval. Most of the betelvine growers are of the opinion that the quality of the
leaves and resistance of the vines to the diseases and pests are lowered if chemical fertilizers are used and apply heavy quantity of organic manures in the form of mustard cake near the root zone in a number of splits. However, Maity et al. (1995) reported that application of 200 kg N/ha through 1:1 ratio of organic and inorganic sources was the best way for obtaining for higher yield of betelvine. Usha et al. (2010) opined the similar opinion and suggested that the integration of organic sources of nutrients with urea gave highest yield and strengthens the concept of integrated plant nutrient management system.

Pal (1987) reported that the betelvine responded to N up to 460 kg/ha but not to P fertilization and the leaf yield was nearly four times higher compared to zero N. Betelvine responded to amide form of nitrogen rather than ammonical forms in terms of yield and quality, however, incidence of wilt [Phytophthora nicotianae var. parasitica], Sclerotium sp. And leaf spot [Colletotrichum sp.] was increased beyond 100 kg N (Pradhan and Das, 1984). Application of urea, alone or with mustard oilseed cake, predisposed Piper betle to attack by anthracnose [Colletotrichum capsici], bacterial leaf spot [Xanthomonas campestris pv. betlicola] and vine rot. The addition of mustard and neem cakes alone resulted in significant reduction in the disease complex. However, incidence increased proportionately with increase in level of N irrespective of the source (Das et al., 1989).

The doses of N recommended for yield and quality improvement without increasing the disease incidence for different states are 200 kg/ha/year through mustard cake and urea (1:1) for Assam, through linseed cake and urea (1:1) for Madhya Pradesh, through neem cake alone for Maharstra; 100kg/ha/year through neem cake for Uttar Pradesh; 150 kg/ha/year through mustard cake and urea (1:1)for Orissa and through neem cake and urea (1:1) for Tamil Nadu (Anonymous, 1992). However, Maity (1989) reported that the nitrogen 200 kg/ha/year is essential for better growth and leaf production and N through inorganic source are most cost effective.

Debnath et al. (1985) found that the best yield was obtained when 25-50% of the nitrogen was applied in the form of urea and rest in the form of organic (oilcake) along with P and K as the latter two nutrients also played an important role in the production of leaves and affecting resistance to Phytophthora parasitica var. piperina. Sengupta and Gupta (1988) studied the effect of potassium application on growth and productivity of betelvine and observed that the highest benefit:cost ratio was obtained with K at 100 kg/ha. The incidence of Colletotrichum capsici decreased with increasing K doses from
8.37% in zero K (control) to 2.65% at 150 kg/ha. Maity (1989) reported that the application of 200 kg N, 100 kg P$_2$O$_5$ and K$_2$O per ha per year for better growth and yield of vine under West Bengal condition.

A technical Sub-committee on development of West Bengal recommended that basal manuring should be done with Groundnut + sesame cake (1:1) @ 400 kg/ acre i.e., 20 kg N/acre for betelvine (Anonymous, 1987a).

Bio-fertilizers are the products containing living cells of different types of micro-organism which are capable of mobilizing nutrient elements from insoluble to soluble form through biological processes. The effect of bio-fertilizer on crop growth and yield are not spectacular as that of chemical fertilizers but it acts as renewable energy sources and helps to maintain the soil fertility. On application in soil, they multiply quickly and build up population under favourable condition supplement the nutrient needs to the crop plants.

Azotobacter, a free living heterotrophic nitrogen fixing bacteria enhances crop productivity by fixing the atmospheric nitrogen (20-25 kg N/ha.) and providing growth promoting substances to the plants. Arulmozhiyan and Thamburaj (1998) reported that the fertilizer use efficiency of nitrogenous fertilizers like urea at present is only 30-40% can be improved in combination of organic sources augmenting with the bio-logical nitrogen fixing sources. The study revealed that an application of 150 kg N/ha (Urea + FYM at 1:1), Azospirillum as pre plant vine dip (1 kg/ha) + soil spread (2 kg/ha) and triacontanol 0.5 ml/l had resulted in higher growth and leaf yield in betelvine cultivar Vellaikodi.

Large amount of P applied as fertilizer enters in to the immobile pools through precipitation reaction with highly reactive Al$^{3+}$ and Fe$^{3+}$ in acidic, and Ca$^{2+}$ in calcareous or normal soils (Gyaneshwar et al., 2002; Hao et al., 2002). Efficiency of P fertilizer throughout the world is around 10 – 25 % (Isherword, 1998), and concentration of bioavailable P in soil is very low reaching the level of 1.0 mg kg$^{-1}$ soil (Goldstein, 1994). Soil micro-organisms play a key role in soil P dynamics and subsequent availability of phosphate to plants (Richardson, 2001).

Phosphate solubilizing bacteria (PSB) are the group of soil bacteria capable of solubilizing the insoluble phosphate (20-25 kg P$_2$O$_5$/ha.) from soil and make available to the plants and it is used as bio-fertilizer since 1950’s (Kudashev, 1956; Krasilinikov, 1957). These micro-organisms secrete different types of organic acids e.g., carboxylic acid (Deubel & Merbach, 2005) thus lowering the pH in the rhizosphere (He & Zhu,
1988) and consequently dissociate the bound forms of phosphate like \( \text{Ca}_3(\text{PO}_4)_2 \) in calcareous soils.

Use of these micro-organisms as environment friendly biofertilizer helps to reduce the much expensive phosphatic fertilizers. Phosphorus bio-fertilizers could help increase the availability of accumulated phosphate (by solubilization), efficiency of biological nitrogen fixation and increase the availability of Fe, Zn etc., through production of plant growth promoting substances (Kucey et al., 1989). Trials with PSB indicated yield increases in rice (Tiwari et al., 1989), maize (Pal, 1999), wheat (Afzal and Bano, 2008) and other cereals (Afzal et al., 2005; Ozturk et al., 2003).

Combined inoculation with \( \text{N}_2 \) fixing and phosphate solubilizing bacteria was more effective than single micro-organism for providing a more balanced nutrition for plants (Belimov et al., 1995). Dual inoculation increased yields in sorghum (Algawadi & Gaur, 1992), barley (Belimov et al., 1995), black gram (Tanwar et al., 2002), soybean (Abdalla & Omar, 2001) and wheat (Galal, 2003).

Aseri (2008) reported that the combined treatment of Azotobacter chroococcum and Glomus mosseae was found to be most effective. Besides enhancing the rhizosphere microbial activity and concentration of various metabolites and nutrients, these bio-inoculants helped in better establishment pomegranate plants under field condition.

The seed inoculation with phosphate solubilizing bacteria (PSB) and vesicular arbuscular mycorrhizae (VAM) followed by PSB alone recorded higher yield of chickpea. The application of rock phosphate and biofertilizer (PSB+VAM) to chickpea showed significant residual effect on the succeeding fodder sorghum (Thenua et al., 2010).

### 2.3. Betelvine diseases and their management:

The condition favourable for cultivation of the crop is also congenial for the development of micro-organisms which cause fatal diseases like Phytophthora foot and leaf rot, collar rot, anthracnose and bacterial leaf spot (Raychoudhury and Verma, 1987). The diseases of the betelvine are mainly soil borne, cutting borne and air borne.

Singh and Joshi (1971) reported that continuous rains in the active growth phase from July to September provided the most favourable conditions for disease development, and betel vine mortality due to \( C. \ capsici \) infection reached a maximum of
58.4% in August. Chourasia and Vyas (1997) reported that the total losses might run up to 40-100% every year due to Phytophthora, if attack is serious in nature. Nema and Nayak (1976) observed the mortality of _P. betle_ vines due to natural infection with _Macrophomina phaseolina_ attained a peak of about 15% in October, when the mean maximum soil temperature was about 29°C and the soil moisture content 65-71%.

Choudhury (1945) recorded about 51.6% mortality caused by _Sclerotium rolfsii_ in Jabalpur region. Singh _et al._ (2003) advocated biological control of collar rot diseases caused by _Sclerotium rolfsii_ using bacterial strains of different morphology. In an another experiment it was observed that _Trichoderma viride_ applied through oil cake at quarterly interval significantly reduce Phytophthora foot rot and increase leaf yield (Dasgupta _et al._, 2003) as well as it can avoids the slightest adverse effect of using toxic chemicals to control the fatal diseases.

Singh _et al._ (2003) reported that Collar rot disease of betelvine (_Piper betle_ L.) caused by _Sclerotium rolfsii_ is difficult to control by conventional means by use of chemicals; therefore, use of bio-control agents is desirable and two strains, _Pseudomonas fluorescens_ NBRI-N6 and _P. fluorescens_ NBRI-N, were selected for their ability to inhibit the mycelial growth of the pathogen significantly. They also reported that screening method should prove useful in identifying rhizosphere bacteria with the greatest potential for controlling diseases caused by phytopathogenic fungi.

The capacity of the _Pseudomonas fluorescens_ strains to produce siderophores has also been considered as an important factor in suppression of soil borne pathogens by depriving the pathogen of iron (Hofte _et al._, 1991). Production of toxins such as cyanide, however, is probably of more general importance in this respect (Schippers _et al._, 1990).

Rhizosphere organisms also provide an initial barrier against pathogens attacking the root (Weller 1988) and micro-organisms that can grow in the rhizosphere are ideal for use as bio-control agents. Phosphate-solubilizing micro-organisms have potential for the bio-control of plant pathogens (Ozgonen _et al._, 1999) as they change insoluble phosphatic compounds into soluble forms (Chin a-Woeng _et al._, 2000; Ramamoorthy _et al._, 2002) thus increasing the growth and yield of crop plants (Gupta and Namdeo 1997).

Siddiqui and Akhtar (2007) studied the effects on chickpea (_Cicer arietinum_) of the phosphate-solubilizing microorganisms _Aspergillus awamori_, _Pseudomonas aeruginosa_ (isolate Pa28) and _Glomus intraradices_ in terms of growth, and content of chlorophyll, nitrogen, phosphorus and potassium and on the root-rot disease complex of chickpea caused by _Meloidogyne incognita_ and _Macrophomina phaseolina_ in Aligarh.
Muslim University. Application of these phosphate-solubilizing microorganisms alone and in combination increased plant growth, pod number, and chlorophyll, nitrogen, phosphorus and potassium contents, and reduced galling, nematode multiplication and root-rot index of chickpea. *Pseudomonas aeruginosa* reduced galling and nematode multiplication.

Arbuscular mycorrhizal (AM) fungi also colonize the roots of many crop plants and are of great value in promoting the uptake of phosphorus, minor elements and water. They also influence the severity of several plant pathogens. Root infection with VA mycorrhiza is another factor which might suppress soil borne pathogens such as *Fusarium oxysporum* in tomato and suppression of soil borne root pathogens by VAM can be attributed to improved phosphorus nutritional status of the host plants (Perrin, 1990).

Among the air borne diseases bacterial leaf spot is one of the most devastating disease caused by *Xanthomonas campestris pv. betlicola*. Wide spread occurrence of bacterial leaf spot has been reported from all over the betelvine growing states (Bhale et al., 1987) and loses might gone up to 50%. In recent years, the disease has been classified as destructive from all important betelvine growing areas (AICRPB Annual Report, 1988-89).

Nema (1990) reported that Nitrogen (as urea, neem and linseed oilcakes) increased the susceptibility of *Piper betle* to *P. parasitica var. piperina* [*P. nicotianae var. parasitica*], while phosphorus (as superphosphate) and potassium (as muriate of potassium) reduced susceptibility. Potassium also increased the keeping quality of *P. betle* leaves. Das et al. (1989) reported that application of mustard cake and neem cake alone caused significant reduction in disease incidence. Further application of K₂O at 125 kg ha⁻¹ annually helps in disease management (Das et al., 1990; Wasnikar, et al., 1993).

---------- x ----------