CHAPTER I

INTRODUCTION

In 2007, sugarcane production area of the world was 21 million hectares (ha), produced 1,557 million Mg of millable cane with average yield of 70.9 Mg ha^{-1} (Food and Agriculture Organization of the United Nations, 2009). In the same year, sugarcane planting area in Thailand was 1.01 million ha with millable cane production of 64.4 million Mg and average yield of 63.7 Mg ha^{-1}. Sugar production in Thailand was 6.9 million Mg of which 4.5 million Mg was exported (ranked 2^{nd} of the world) (Food and Agriculture Organization of the United Nations, 2009). The majority of sugarcane planting area of Thailand is in the northeastern region with the planting area of 0.33 million ha and the millable cane production of 15.7 million Mg in 2006. The regional average yield in 2006 was 47.13 Mg ha^{-1} which was slightly lower than the average of the whole country (49.4 Mg ha^{-1}) (Office of Agricultural Economics, 2007a). Approximately, 80% of sugarcane planting area in Northeast Thailand is in sandy soils which inherit low fertility. Most sugarcane in this region is planted in late rainy season (October-November).

Yield decline of sugarcane due to soil degradation caused by monocropping has been reported in many countries (Prammanee et al., 1995; Van Antwerpen and Meyer, 1996; Garside et al., 1997). There are many factors that cause soil degradation under continuous sugarcane cultivation. Large amounts of biomass production cause high nutrients removal yearly. A millable cane yield of 100 Mg resulted in removal of 120 kg of N, 33 kg of P and 125 kg of K (De Geus; 1973). While Hunsigi (1993) estimated yearly nutrients removed in 1 Mg millable cane were 0.56-1.20, 0.38-0.82, 1.0-2.5, 0.25-0.60, 0.20-0.35 kg of N, P_2O_5 , K, Ca and Mg, respectively. Soil P, K and organic matter were reported to decline in many countries, for instance, the Philippines (Alaban et al., 1990), Fiji (Masilaca et al., 1985), India (Sundara and Subramanian, 1990) Swaziland (Henry and Ellis, 1995). A decline in plant nutrients does not only occur as a result of high nutrient removal by the cane, but also by the lack of a nutrient replenishment. High cost of chemical fertilizer and unreliable rainfall cause many farmers reluctant to apply fertilizers at recommended rate. Soil nutrient replenishment is worsened when sugarcane fields were burnt prior to harvesting to ease manual cutting. Approximately 70-95% of the dry matter and nitrogen (N) are lost from the system by such practice. Sugarcane residues (trash) contained considerable quantities of dry matter and nutrients, particularly N (Wood, 1991; Ball-Coelho et al., 1993; Mitchell et al., 2000). When sugarcane is burnt other nutrients were also lost but in lesser quantities than N (Mitchell et al., 2000). Sugarcane trash was estimated to return 30-60 kg N ha^{-1} if the field was not burnt (Robertson and Thorburn, 2000). There are some evidences that pre-harvest burning of sugarcane contribute to a decrease in soil quality, by causing a decline in soil microbial activity and the physical and chemical properties of the soil.

Continuous sugarcane cultivation has been reported to affect biological, chemical and physical properties of the soil. Soil microbial biomass has been reported to be lower in old sugarcane fields than the new ones (Henry and Ellis, 1995; Garside et al., 1997). Besides, there was a build-up of soil pathogens with sugarcane monoculture (Garside et al., 1997). Soil pH has also been reported to be reduced by continuous sugarcane cultivation in many countries. The reduction in soil pH might be attributed to continuous use of ammonium-N fertilizer, high rainfall, leaching of cations and removal of bases by harvested sugarcane (Moody and Aitken, 1995). Soil bulk density has been reported to increase under continuous sugarcane planting in many countries (Maclean, 1975; Srivastava, 1984; Swinford and Boevey, 1984; Wood, 1985; Hartemink and Kuniata, 1996). Increases in soil bulk density or a decrease in porosity might be due to the use of heavy machinery for land preparation, cultivation, loading and transportation.

In Northeast Thailand, 80% of sugarcane planting areas are sandy soil and most sugarcane is grown in the late rainy season (October-November). Such practice allows longer growth duration of sugarcane than that grown in other regions which sugarcane is usually planted in the beginning of the rainy season (May-June). In Northeast Thailand, the upland fields are left fallow after the last ratoon cane crop harvest (November-April), until a new sugarcane crop is re-established in late rainy season (October-November). This fallow period covers the period of one rainy season. Therefore, there is a good opportunity to restore soil fertility during the fallow period by planting green manure.

Restoration of soil fertility to continuously cropped soils can be achieved through various methods. The main strategy is continuously maintaining organic residues and minimizing soil disturbances. The value of maintaining organic matter and practicing crop rotation to sustain soil health for continuous sugarcane production has long been known (Bell, 1938). The practical methods of maintaining and/or increasing organic matter are: 1) adding inorganic nutrients in adequate amounts for cane crop uptake and removals from the soil; 2) adding organic materials as organic amendments: animal manures, composts, municipal and industrial biosolids, municipal solid waste, food-processing wastes, mills byproduct, etc and 3) adding organic matter as green manure and/or cover crops.

Positive residual effects of N_2 fixing legumes on subsequent cereals in rotation system have been reported in the past and modern agriculture (Giller and Wilson, 1991; Peoples et al., 1995). Green manure can be used as alternatives to mineral fertilizers particularly for subsistence farmers whose resource base is small (Clements, 1980). Slow release of N from decomposing green manure residues may be matched with crops demand based on crop growth pattern (Abdul-Baki et al., 1996; Agustin et al., 1999; Cline and Silvernail, 2002). Green manuring has been shown to improve soil properties and reduce the incidence of disease, with accompanying increases in sugarcane yields in Thailand, South Africa and Swaziland (Schumann et al., 2000).

Green manure, as a source of N, was a common practice in many sugarcane production regions. Benefits of an improved fallow by adding green manure on soil fertility and crop yield seemed to depend on the species (Jama et al., 1998). Legume plant species that have high biomass production, i.e. grain legume, peanut, common green manure legumes (pigeonpea, jackbean and sunnhemp) and some weed legumes (*C. striata* and hairy indigo) are potential legumes that might be able to use as green manure for sugarcane production in the Northeast of Thailand.

Peanut is one of economic grain legumes adapted well to growing conditions in Northeast Thailand. It has been grown after rice in summer under irrigation and planted after sugarcane in early rainy season under rainfed area of this region. Besides cash income from pods, peanut plants are used for animal feeding or leaving to decompose in soils. It was reported to fix high N_2 at 101-146 kg N ha^{-1} (McDonagh et al., 1993; Hemwong et al., 2008). Moreover, peanut residues also showed fast decomposition and N release (McDonagh et al., 1995b; Vityakon et al., 2000). Cherr et al. (2006a) reported that *Crotalaria* (sunnhemp), *Indigofera* (indigo), and *Cajanus* (pigeonpea) are the most widely used tropical green manure legumes.

Pigeonpea is the most popular legume crop for intercropping with maize in Malawi (Sakala, 1994). It grows well in all free draining soils and is an important crop grown mostly by resource-poor farmers throughout the region. Pigeonpea can nodulate well and has been estimated to fix N_2 up to 90% of its total N (Kumar Rao and Dart, 1987). During pigeonpea growth, substantial amount of senescent pigeonpea leaves fall to the ground with the estimation of 28-40 kg N ha^{-1}. Immediately, rapid net N mineralization was found with green pigeonpea leaves.

Sunnhemp (*Crotalaria juncea* L.) was among the legumes that produced high biomass after 3 months in Kenya (Mureithi et al., 2003). Balckom and Reeves (2005) showed the N replacement value of less than 60 kg ha^{-1} for sunnhemp in corn production on loamy sand in Alabama. Cherr et al. (2006b) found greater N benefit provided to sweet corn (*Zea mays* L.) immediately after sunnhemp termination.

Jackbean (*Canavalia gladiata*) and swordbean (*Canavalia ensiformis*) are probably the second most widely used introduced green manure and cover crops. They are resistant to drought, poor soils, insects and diseases and are capable of surviving and growing well in the worst conditions. Jackbean can be used during the dry season and in very marginal environments where most crops will not grow. It has an ability to absorb large amount of nutrients from soils and is also capable of helping wastelands to regenerate.

Indigenous weed legumes produced vigorous biomass may manage to be an efficient green manure, for example hairy indigo and *C. striata*. Hairy indigo (*Indigofera hirsuta* L.) is a leguminous weed, grows vigorously in sugarcane and cassava fields with high seed production (Promchoom and Moongunya, 1994). There are a few reports on using hairy indigo as a green manure crop. It was reported to produce dry biomass of 5 Mg ha^{-1} and its nodules were found on roots at the depth of 10 cm. Similar plant characteristics of hairy indigo is indigo (*Indigofera tintoria*) used in dye production. Indigo was reported to use as green manure in tomato in Taiwan (Thönnissen et al., 2000) and rice in the Philippines (Agustin et al., 1999).

The effective management of green manure crops in cropping systems needs a better understanding of their chemical and biochemical properties, decomposition and nutrient release patterns. Chemical characteristics of crop residues were reported to regulate the decomposition and N mineralization. The initial residue N content (Frankenberger and Abdelmagid, 1985), lignin (Müller et al., 1988), polyphenols (Constantinides and Fownes, 1994b) and soluble C concentrations (Reinerstsen et al., 1984; Oglesby and Fownes, 1992; Kachaka et al., 1993) are useful indicators of residue quality. Indeed, the criterion of quality used to predict mass loss or N mineralization during crop residue decomposition is the C:N ratio of the plant material (Taylor et al., 1989; Vanlauwe et al., 1996). Among these factors in many legumes, the residue N content has been shown to be the main factor predicting the kinetics of decomposition (Tian et al., 1992 and 1995).

Understanding decomposition and nutrient release patterns of plant materials is an important first step to better manage green manure residues. Rates of N mineralization differ among species having different chemical characteristics (Palm et al., 2001) and vary among different plant parts (e.g. leaves, stems, roots) within a species (Frankenberger and Abdelmagid, 1985). *In situ* grown plant residues are usually applied as heterogeneous mixtures, containing green leaves, leaf litter and stems that are different in both physical and chemical characteristics (Frankenberger and Abdelmagid, 1985; Oglesby and Fownes, 1992). Variation in quality and quantity among plant components depends partly on plant varieties, age and management that can produce dramatic changes in rates and patterns of decomposition and N release (Oglesby and Fownes, 1992).

In actual field condition, plant residues incorporation is combination of stems, leaves and leaf liters within the same plant species or in forest is mixed among plant species. Handayanto et al. (1997b) suggested that mixed residues of different quality were likely to show strong interactions only when large amounts of reactive, soluble C or polyphenols were present in one of the residues. Chapman et al. (1988) suggested that the rapid decomposition of high quality leaf litter produced high ambient N availability which stimulated the decomposition of lower quality litter by allowing the transfer of nutrients between litters, leading to a more rapid utilization of carbon substrates. Residue quality also directly affects the abundance, composition and activity of the decomposer community, which may thus alter decomposition patterns.

Management of legume green manure in sugarcane production under Northeast Thailand conditions need understandings of decomposition, N release patterns of many legumes and their effects on growth and yield of sugarcane. Therefore, this thesis had the following objectives:

1) to evaluate the potential legumes on their biomass production, N content and N_2 fixation, and soil moisture affected by planting legumes on sugarcane emergence.
   (presented in chapter III – field experiment)
2) to evaluate effect of residues of 6 legume green manure as N substitute for mineral N fertilizer application at planting sugarcane on sugarcane growth and production.
   (presented in chapter III – field experiment and chapter V – pot experiment)
3) to understand decomposition and fate of N from legume residues.
   (presented in chapter III – litterbag technique, chapter IV – pot incubation)
4) to trace N from legume residues contributed in sugarcane cropping system
   (presented in chapter III – high enriched ^{15}N residues)
5) to understand contribution of N from legume residues, either as individual plant parts and the combination of the plant parts.
   (presented in chapter IV – pot incubation)

This thesis research was conducted at Khon Kaen Field Crops Research Center from March 2000 to January 2002. It consisted of 6 chapters and was written in manuscript forms.