CHAPTER 7

DISCUSSION

7.1. Climate and agroclimatic conditions of the surveyed area for sugarcane crop

Pyay township is situated on the border of the delta wet zone and dry zone of Myanmar and therefore it shows transitional characteristics. According to KÖppen classification system, Pyay falls into the type of tropical Savanna climate: temperature of the coldest month exceeds 18°C and the precipitation of the driest month is less than 60 mm.

The climate parameters are paramount influence on crop growth and development. Generally, the climatic condition is favorable for sugarcane crop in term of temperature (Sundra, 1998; Blackburn, 1984; Gascho and Shih, 1983). Since maximum photosynthesis rate occur at about 34°C (Alexander, 1973) for sugarcane crop. Moreover, the average maximum temperature of studied area exceeds 38°C in the driest months (March-May) so that intensity can reduce photosynthetic rate (Kootchar, 1972). The daily maximum temperatures always close to reach at 35°C during the driest months (March-May). To do so, cane plants suffered from wilting by irrespective of water supply (Blackburn, 1984) while irrigation facilities are lacking for sugarcane crop in the area. In addition, in the area, the average temperature in cold season (November-Mid February) exceeds 20°C and the night temperature (minimum temperature) lower than 20°C during December and January, and just above during February. Therefore, the ripening or maturity may slightly delay due to the effect of slightly high temperature at maturity stage of cane crop (Gascho and Shih, 1983; Sundra, 1998). It may be more effect when the late rainfall occurs in some years (Sundra, 1998).

According to the secondary data of climatic condition, the annual rainfall of the area is above 1000 mm. The rainfall distribution is normally concentrated during June – October. In late May, Monsoon usually enter into the area. The amount of annual rainfall is seem to be enough for sugarcane can grow range of annual precipitation between 500-2500 mm. However, in terms of agroclimatic point of view, according to the fifty years study (1950-1995), potential evapotranspiration of sugarcane crop in Pyay region had greater than the precipitation in dry months of November to May. It was the highest in April. When the water-balance for sugarcane is calculated, total crop water requirement is 1580.54 mm per annum and water deficit occurs from December to May (Maw, 1998). Moreover, the low intensity of solar radiation and less duration of sunshine received during July and August coincided with the active vegetative growth stage of sugarcane plant. Consequently, slow rate of dry matter accumulation can be expected during these months despite great amount of precipitation available for the plants.

When the climatic factors such as temperature, rain fall and it's distribution pattern, solar radiation, were matched with the timing of crop development stage, it was clearly that sugarcane growth and development was severely suppressed by water deficit during dry season. Therefore, irrigation during dry period is prime factor for the growth and development of sugarcane. It enhances for the buildings up of main yield components, i.e., tillering and leaf area at early growth stages (Yadav and Prasad, 1988). Adequate supplement water and nutrient via well-developed root and shoot system could encourage more manipulate high solar radiation while it is peak in the area during April-May. However, most of the sugarcane growing area in the township is still lack of irrigation facilities. Although, two dams, two wires and their net-work irrigation systems have already developed, they are mainly imposed for rice production. The policy for irrigation supply and schedule should be reviewed at policy level. Recently, the irrigation project; Ayeyarwadi river water pumped irrigation project, have been implementing, it was mainly aimed for sugarcane crop and the expected irrigation area is more than 1000 hectare.

7.2. Soils' properties of sugarcane growing area

According to the secondary data from soil survey report (LUD, 1959) and the results of soil tests during the survey, indicated that soils where sugarcane has been growing are need to sufficient additional nitrogen-sources either organic or inorganic, or both. Generally, the soil pH of cane growing fields were range 5.5 to 6.3 that can be categorized as optimum range for cane growing (Blackburn, 1984).

Among major nutrient elements, total nitrogen content contain as the lowest level, varies from 0.11% to 0.18%. Samples from ZYC site also low content in available P_2O_5, vary from 11.52 to 26.20 (troug P, ppm). But, almost of others had medium level. Few samples were found low content of available K_2O. Meanwhile, due to current farmers' nutrient practices might be not enough to replenish for soil nutrient availability. Since the nutrient removal by sugarcane crop is high; one tonne of sugarcane removed 0.56-1.2 Nitrogen, 0.2 to 0.82 P_2O_5, 1.0-2.5 K_2O kgm respectively (Zende, 1990).

Regarding to nutrient content level in samples, resulting that the adequate dose of nitrogen fertilizer should be applied into soils in some places while they are not necessary in others. Especially, Phosphorous supply is moderately needed in ZYC fields since the available phosphorous is less than 25 ppm (Blackburn, 1984). The deficiency of P manifested by poor tillering and rooting, delay closed-in and shorter internodes which taper rapidly at the growing points (Hunsigi, 1993). As for the potassium, it is more than 10 mg per 100 gm soil in nearly almost of soil samples so that it is seem to be moderately sufficient for normal growth (Blackburn, 1984). However, it may be needed to apply with certain level when the others were increased. According to the finding results, chemical fertilizers should be applied to the soil and at the same time some erosion controls may be required where side sloping area of hills.

The soil humus content was approximately 1% in average. The organic-carbon content in all soil samples less than 1%. It reflects to the low content of organic matter in the soil. The desirable amount of organic matter is difficult to quantify. Generally, values of between 2 and 4 % are considered as adequate for one year sugarcane crop (Blackburn, 1984). Therefore, the organic manure is required to increase the soils while it is important for both in the soil nutrient retention and supply the plant nutrient in the development and maintenance of favorable structure for plant growth. As sugarcane produces big amount of biomass, therefore, the application of cane crop residue could be utilized as nutrient source for farming. Moreover, one of the by-products of sugarcane; baggase enriches in varieties of nutrient contents (Yadava, 1991; MSE, 2000b) so that it is another source of supplementary nutrient for sugarcane. One point should consider IPNs (Integarated Nutrient Management Systems) approach including synthetic fertilizers, is needed for long term stability and sustainability of soils through several ways, that is not only for economic point but also for environment.

7.3. Cropping systems and patterns

In the area, most of the farmers posses both upland and low land, and they grow different crops on their farmlands. Therefore, cropping systems and patterns are diversifying. Although their decision-making systems could reduce the certain level of risk in farm production systems as an advantage. Nevertheless, it may lead to conflict to have optimum time for their farming activities. Especially, for poor farmers who are not able to hire for sufficient energy since harvesting and sowing time of sugarcane are overlapping with the harvesting time of rainy season paddy.

In the study area, most of the cane growers have been adapting the sugarcane based rotational system. This practice is generally good and sound for the crop production for the sustainability in term of ecological point of view and it enhances efficient nitrogen use (Kurtz *et.al.,* 1984). Moreover, when farmers could not able to access to high inputs for the crop production, it can be helped to keep the certain level of crop productivity while referring to the report by Bell *et.al.,* (2001): breaking out from continuous sugarcane cultivation practices enhance sugarcane yield from 4 to 84% due to varying soil, climate and management. Most of the farmers adapt two or three year sugarcane-base rotational system. Peanut, pulses and sesame crops were usually grown during the rotated crop season. Therefore, their rotated and sequence of crop is also good and sound for the crop production system while the leguminous crops were grown as succeeding crop. Legumes enhance or maintain the soil fertility through their symbiotic nitrogen fixation system and nutrient-replenishment into soil system through crop residues, have been well documented in numerous studies (Kanwar, 1976; Hoang, 2000). However, the optimal crop pattern should be searched for cane growers in the region to keep sustainable sugarcane cultivated area and sugarcane productivity with better economic return and ecological sounded manner as well.

7.4. Cultural practices in sugarcane cultivation

Cultural practices of sugarcane mainly develop through native wisdom and the ingenuity of the farmers who are familiar with the local problems. As for land preparation, there are mainly two points had to discuss; although farmers take care for land preparation for sugarcane growing, since farmers are mostly depending on their family labor and animal power for their farm activities, therefore, they may be lost to get optimum time in farm management while relying on their own animal power is not sufficient for their activities and it takes more time. As the second point, although they reported in formal survey "they do the best for land preparation to get their satisfaction level, their tillage depth range from 20 cm to 25 cm". The fact that is quite adequate for conventional tillage practice (Morbley, 1972). However, mechanized power required for land preparation, to get deep and well tillage since it enhance for initial root and crop growth by creating better physical conditions of soil (Sundara, 1998). Moreover, it allows capturing the optimum condition while the climatic are favorable for land preparation because it can reduce time requirement. Therefore, minimum mechanized plough should corporate with traditional tillage system.

The growing period is from November to mid February in the area. Farmers adjust themselves to sowing time. The growing time is one of agronomic tactics to achieve better yield under given climate and soil circumstances (Yadava, 1991). However, the optimum sowing time may differ due to variety and soil type under same climatic conditions in the area. Therefore, the optimum sowing time for each variety and homogenous groups of soil should be searched through field trials within the area.

The row spacing is differed from 0.6 m to 1.4 m among the surveyed sites, even in the same site. The sett rate was also differed approximately from 7 to 15 tonnes ha^{-1} in normal girth since most of farmers prefer to high sett rate to ensure the germination. Although, the fresh cane yield is mainly depended on the population of cane stalk (Bull, 1975; Hunsigi and Srivastava, 1975). The serious objections to narrow spacing are the high cost of seed cane, cultural practices, and harvesting. Most of the farmers used the top portion of cane stalks for cane setts, except LB and TPC site. However, recently, the percentage of farmer who utilize the top portion of cane stalks had declined due to the scarcity of cane sett/ seed during their variety changing period that reported in informal survey. There is no cane grower who manages to have separate nursery for sett/ seed purpose. The optimum plant density and population should be found for the each homogenous group of soil and input level in the area for recommend varieties, in order to get targeted yield. One of the recommended practice; soaking the chopped cane setts in the 1% lime solution for 15-30 minutes before planting have not been adapted in all sites. Since, it ensures to well moisture of sett for better germination (IISR, 1966), and can be helped to protect from soil pest like termites and mole crickets as well.

Weed prevalence and occurrence is not seemed to be as a serious problem to low productivity of cane among survey sites. Since the tillage practice of cane growers is well to control the weed as pre-emergence weed control through cultural practices, and lack of moisture unfavorable for weed prevalence. Nevertheless, there is necessary to control the weed at second inter-culturing where weed occurred as considerable prevalence when the practice with fertilization together, in order to get more efficient fertilization for cane crop. Because, cane yield increase 17.5 % when weed controlled was well done at initial stage (Srinivasan *et. al.,* 1981). As the context for the second inter-culturing practice or full earthing-up practice recommended by MSE, most of cane growers have practiced except LB and TPC site. Since this practice enhance for the tillering, to prevent nutrient loss, and to get good drainage system and to save from the lodging (Sundara, 1998).

As for de-trashing practice, one of recommended practices for good aeration and sugar recovery, pest -control strategy, however, only the LPD site farmers have practiced. One point should consider; trashed leaves can replenish to soil through decomposition and can save soil moisture for next ratoon crop. Average nutrient content in sugarcane trash has been estimated to be around 0.35% N, 3.13 % P_2O_5 and 0.65% K_2O (Sundara, 1998). Leaving the dead leaves on the soil surface increased in soil biomass production, improved soil fertility and increased in the amount of soil carbon sequestered in soils (Phan Gia Tan, 1995). This practice in long-term enhances potentiality of soil N mineralization, increase in available soil P and K and certain amount of N application can reduce for succeeding crop. However, it had adverse effect on decreasing pH that regular liming is needed as correction, reported by Graham *et.al.,* (2000). In addition, the removed trash leaves can be used as roof materials so that it creates an income-source as well. Therefore, this practice should be encouraged to cane growers through extension workers, farmer training programs, to adapt widely in the whole region.

At harvesting, some cane growers lost their optimum harvesting time; of course, they could not able to harvest large amount or large area of their farms due to the poor transportation facilities for cane. It is serious impact on the ratoon crop leading to poor germination from cane stubble mainly due to high temperature and low soil moisture (Sundara, 1998). Consequently, the recommended practices for ratoon management i.e., refilling, irrigation and fertilization at initial stage are not able to practice in the farmer fields. Because, high cost and high labor requirement and lack of sufficient moisture and irrigation. In this case, cane procuring, transportation and crushing program of mill play as vital role.

Ball-Coelho *et.al.,* (1993a and 1993b), demonstrated that harvested first ratoon cane yield in mulch was greater than burn treatment, attributed in increased water retention and reduced weed growth and increases in phosphorous availability under green trash blanket. All of cane growers practice for trash burning after harvesting. Since, sandy soils which are low moisture holding capacity, are most occupied in sugarcane growing area, the burning practice should be adjusted due to the time of harvesting and residual moisture for the next crop, ratoon. In fact, burning should not be practiced when the harvesting time was late on where the cane crop was grown on sandy soils which are dominant in TPC, ZYC sites.

7.5. Nutrient and Fertilizer management system in sugarcane cultivation

The results of field survey indicated that farmers managed nutrient on the farm is quite simple and traditional. Most of the cane growers adapt sugarcane based rotational system. This practice can help to maintain the soil fertility and nutrient status evenly within the soil layers while the different root systems uptake the nutrient from different soil layers. In addition, it can contribute to nutrient recycling by different crop residue (Sundara, 1998; Yadava and Vermaa, 1994).

All of the farmers apply cow dung manure in crop production as tradition; the application rate is approximately 1800kg ha^{-1} $year^{-1}$ in average. They usually apply cow dung manure to pre-monsoon upland crops rather than cane plantation. However, their handling on cow dung manure is unsystematic ways so that nutrient content may be low and the rate of application is relatively low. Nevertheless, this practice enhances the soil physical properties and can improve soil chemical properties, more or less. Since, synthetic fertilizers are cost and take more risk associated with erratic rainfall so that the other nutrient practices such as green manuring, cover cropping with legumes, can be introduced into their farm systems. However, there is no farmers have ever practiced in their farm. These agronomic practices are low cost, low risk and more sustain to keep soil fertility for long term (Sundara, 1998; Reijntjes *et.al.,* 1992). Moreover, since these practices contribute to increase in organic matter, their synergetic effect with synthesized fertilizers enhances for the crop growth and quality (Htun Than and Tin Nyaunt, 1984).

The levels and rates of fertilization in all sites are still very low. Cane growers usually apply urea 46% fertilizer rather than other types of fertilizers. Since, the soils growing sugarcane contain low level for N nutrient, the rate of application for fertilizer N should be applied in adequate amount to get better yield and greater economic return while cost of cultivation had already relatively high. Moreover, one point should be considered, that the economic return and efficiency for applied fertilizer is usually higher at first application, later decreases until optimum. As a context of this point, if application of N has become higher, the other nutrients are also needed to apply in balance, especially, P and K, through several sources (Htun Than and Tin Nyaunt, 1984; Jassen, 1998). Therefore, the optimum application levels of fertilization should be found for the recommendation for cane growers throughout the whole region for each homogenous group of soil and its nutrient status. It should be based on their cropping patterns.

The rationale behind the timing of fertilization is based on two factors, namely, the small foraging capacity of roots at initial stage and the major need at tillering. Survey results indicate that the application of fertilizer at basal is seldom in all survey sites, however, cane growers used to apply fertilizer at before full canopy stage when crop age was approximately 150-180 DAS. Since adequate fertilizer should be applied within 60-90 days (Hunsigi, 1991), but a little late in farmer practice because of lack of sufficient moisture within that duration. As for timing of fertilization should match with the crop demand or crop uptake in order to get better efficiency. Generally, the rate of nutrient uptake is highest during the grand growth period. In this case, it is supposed to be necessary to take care for basal application. It enhances for initial growth and development of sugarcane without damaging to root system with right dose and right method before main application at grand growth stage that had already demonstrated in the field experiment.

7.6. Consideration on constraints of cane growers

In the township, cultivated area of sugarcane has decreased in recent years. However, according to the analysis of gross-margin and perception of cane growers, it is can be stated that farmers still want to grow sugarcane. The remarkable cost of production for new plant sugarcane was higher 2-8 times than other crops, but it was reduced doubly in ratoon cane crop production. Therefore, cane growers responded to the facts; low price of cane and low investment, as first and second rank for their constraints. The responsible government organizations should consider supporting credit, and other subsidies to cane growers at right times with sufficient amount. San Thein and Ba Shein (2001) reported that transportation cost in Pyinmana sugar mill area where well established than the study area, is relatively high in their core problem analysis. The transportation cost constituted 7-12.5% of total production cost of sugar per unit, mainly due to current transportation system and procurement system while sugarcane growing area are spatially distributed and infrastructure is still poor. It effects on the price of sugarcane. They reported that the production strategy should emphasize on vertical approach where near around mill area. Therefore, transportation facilities and infrastructure should be also developed in the area.

Farmers reported in the formal survey and informal survey that some of the cane varieties (Co 775, Co-1001, POJ-419) were infected by red rot disease especially in LB and TPC sites. Moreover, they reported that the productivity and ease of handling (straight, weight) of the cane varieties in their hand is relatively lower than new released K varieties. Farmers are very enthusiastic for verities changes and interested in new released K varieties. Therefore, they reported that inferior variety was rank as a constraint in the cane production. Although, red rot disease have never occurred as epidemic in the area, it should be taken efforts to variety change for the above sites since the disease is dangerous to those of susceptible varieties when the weather is favorable.

Since sugarcane plant growth might be suppressed by water deficit during in early growth stage that already discussed before, irrigation facilities for sugarcane crop should be pay more attention and irrigation policy in regional should have to be reviewed. Irrigation is needed during not only early growth but also grand growth; in order to get better response to N fertilization contributing to cane yield and quality. Therefore, irrigation water should apply to cane field with crop water balance (ET) approach, pointed by Wiedenfeld (2000).

Since, both of bio-physical and socio-economical factors are interrelated each other, contributing to the reason of low productivity in sugarcane production. Each of those reflects to consider for the development program that need to make efforts with appropriate manner. Therefore, interdisciplinary approach or system approach is important while trying to keep a sound balance management. It allows exploring the core problem when considering for the package development program for such region or group because these factors may be differed from one to another. However, this study did not attempt to comprehend in detail all of those factors. In stead, it focused on cultural practices and fertilizer management in order to improve cane productivity with better efficiency of fertilization for early growth stage of sugarcane.

7.7. Sugarcane response to nitrogen and water management systems

The responses of sugarcane to nitrogen and water management systems were observed and examined in the field experiment at early growth stages. Since, most of the cane growers could not easily access to irrigation at present, but, could be in near the future so that sugarcane responses irrigation system was designed in the field experiment together with under rainfed system. As for irrigation system, nitrogen can be easily lost through several ways, but mainly by volatilization and leaching. Therefore, the estimated crop water requirement had applied with weekly interval to keep optimum moisture in soil-plant system and to avoid losses. According to the results of field experiment, generally, the observed variables—root density, root dry weight, above ground dry weight, number of tillers per hill and leaves area per hill—had similarly responded to applied nitrogen (Urea) under different water management system. Detail discussion on the response of each observed variable as follow:

7.7.1. Root dry weight

Root dry weight of sugarcane in soil volume, showed negative response to applied nitrogen rates at first observed stage (40 DAS), in both water management systems. This result indicates that the applied nitrogen beyond 100 kg N ha^{-1} affect on physiological and metabolic processes of the root system of sugarcane. It might be severe at 400 kg N ha^{-1}, because, root dry weight at that rate was still lack behind to none application until 70 DAS (Figure 3). It was more clearly that the mortality percentage of transplanted plants had relatively high, especially in rainfed system rather than irrigation system (Table 14).

The results effected by urea nitrogen application was agreed with Verma *et.al.,* (1985) and similar as the results from Yadava (1981). Since, urea releases ammonium compound, nitrate compound, during hydrolysis process and carbonic acid as end product of chemical reaction in the soil (Clements, 1980). The effect responded by following possible causes well documented in many literatures. First, exosmosis could be temporarily occurred in plant system while ion concentration in soil solution was higher than plant sac (Clements, 1980). Second, ammonium accumulation during urea hydrolysis, it stipulates free ammonia and ammonium harmful to root system. The effect might mainly due to free ammonia produced by hydrolysis of urea near roots. Third, temporal accumulated nitrite during mineralization process might be damaged to plant system. According to Pang *et.al.,* 1975 (*cited in* Haynes, 1986c), demonstrated that NO_2 accumulated in soil at pH 6.6 when urea or aqua ammonia were banded at rates of 200 and 800kg N ha^{-1}. This nitrite accumulation might be negative effect on root system. Fourth, even plants' major nutritious ions; ammonium and nitrate could harmful within plant system as toxicity when their source was over supplied (Goyal and Huffaker, 1984).

The several effect of ammonium and nitrate showed at the 400 kg N ha^{-1} treatment because plants lately recovered from the damage comparing to the others (Figure 4) while it had adversely affected on plant system in term of physiological and biochemical processes such as photosynthesis, respiration, synthesis of nitrogenous compounds, carbohydrate synthesis, enzymes activity and water uptake (Goyal and Huffaker, 1984).

Dry weight of root in observed soil volume had switched to increase dramatically since 55 DAS at 100 and 200 kg N ha^{-1}, and continuous rapid increase was found until the last stage under irrigation system. Similarly, however, late for rapid growth was found at 400 kg N ha^{-1}. The results will be discussed as follows. As morphological point of view, the phase of cane plants had entered into tillering stage at 55 DAS and maximum tillering reached at 85 DAS. Since new tillers produced their own shoot-root system vigorously by ambient supply of water and nutrients (Clements, 1980; Blackburn, 1984; Lingle, 1999). Moreover, most of ordinary sett-root-system was still alive until last stage (100 DAS) was found under observation. According to the results form the research findings conducted by Prammanee *et.al.,* (1999), ammonium and nitrate mineralized form urea application might be reached at peak level around two week after application (44 DAS). In addition, it continues to mineralize until four weeks after application (68 DAS). The transformation period of nitrogen minieralization could be matched with crop demand at tillering stages. Moreover, nitrogen mineralization could be continued through out observed period. Available N comes out from not only native nitrogen and added nitrogen sources but also via immobilized nitrogen and fixed-nitrogen between clay layers. Since native nitrogen source or organic matter and other cations were relative high, and soil contained respective clay percentage (Table 13). These physical and chemical properties could be sustained or stimulated longer for available nitrogen in rhizosphere (Prasad and Power, 1997; Haynes, 1986).

Root dry weights in observed soil volume at all nitrogen application under rainfed system were greatly lack behind from irrigated system, except 100 kg N ha^{-1} application rate. Plants under rainfed system could not be utilized applied nutrients for their growth since water is crucial element and solvent for other nutrients that stipulated for uptake mechanism of plant. It was obvious that soil water might not be substantial to stimulate plant growth under rainfed system although other sources of energy had probably sufficient supplied for plant growth. Moreover, over-supplied nitrogen might be effected on water movement not only in plant system but also in soil system (Kolek and Kozinka, 1992; Clements, 1980). Therefore, beyond 100 kg N ha^{-1} application, N applications were over supplied in rainfed system. The nitrate salts rose to the surface with the capillary water and such considerable extent of applied nitrogen might be lost into atmosphere as gaseous forms in the field under rainfed system. However, some extent of supplied nitrogen could be deposited as solid salts on many micro high spots and might be fixed within clay sheets (Canmeron and Haynes, 1986; Clements, 1980). When dry soil was rewetted by even small amount of precipitation, flush of mineralization of native soil organic nitrogen accompanied with a flush of nitrification created temporary accumulation of NO_3^-. This might be occurred in soil under rainfed system (Campbell and Biederbeck, 1982). This phenomenon reflected on the result of the experiment in rainfed system, that the root dry weight had sharply increased at 100 DAS at all application after sufficient rainfall had occurred in rainfed system. As summary, it was finally observed that root weight at all nitrogen application was greater than non-application in both water management systems. The result is slightly differed from results of the sugarcane experiment that conducted by Sampaio *et.al.,* (1987). They reported that root weight (fresh root weight) was significant differences between N treatments at sixth and tenth month after planting under rainfed. The result is similar to the study of Durieux *et.al.,* (1994). They found that corn root weight had increased by nitrogen application in early stages. Therefore, it can be inferred that nitrogen stimulated root growth in both size and mass, since nitrogen is mainly promote for cell division and synthesis of protein and carbohydrate leading to increase dry matter accumulation.

7.7.2. Root Length, root density and its distribution pattern

The result was obvious that nitrogen application accelerated to vigorous root system while it response to nitrogen had highly significant level ($P<0.01$) at all observations, the interaction effect of nitrogen and water as well. It indicates the fact that the total mean of root-length was greatly different between irrigation-system and rainfed-system. Irrigation water at particular time increased in soil water content within the certain level in profile that lead to increase the elongation rate of roots, consequently, increased shoot growth and functions to result in increased yield (Klepper, 1990). Generally, when the water effect on the root length and its density was mainly concerned, the greater percentages of root in deeper soil layer were found in rainfed system than irrigated system. The results was similar as the results of the experiment conducted by Batchelor *et.al.,* (1989).

The greatest root length and density was found at 200 kg N ha^{-1} application, however, it not significant from 100 kg N ha^{-1}, finally. It may probably due to the limited soil volume since root density had reach peak level, another word; lesser space for extends, in irrigation system. Root growth in total length at 400 kg N ha^{-1} had greatly lesser than the other application, but greater than none application level (Table 17). The causes of effects on the results were similar as previous; the results of root dry weight. Thus, nitrogen stimulated on root system in aspects of size and length. Moreover, better gaseous exchange might be occurred in irrigation system by drying-rewetting process. In addition, irrigated water movement within soil profile that created favorable environment; soil temperature, availability of other nutrients may positively effect on root metabolism and development, promoting to vigorous root system (Klepper, 1990). NH_4 source fertilizer application may increase the number of P carriers in plant roots. Thomas and Scott (1990), who observed that N fertilization resulted in increased P and K uptake gave additional evidence. It is likely that N addition stimulated growth of roots and shoots and, so that increased area of nutrients uptake.

Generally, Root extent and its density had evenly distributed at all observed layers under irrigation system when plants had been getting more developed. This finding is also agreed with the results of Durieux *et.al.,* (1994). They found that corn root length was significantly responded to applied N and the greatest was found at intermediate N rate (140 kg N ha^{-1}).

In rainfed system, root growth and its distribution patterns had changed with observed time. The extent of root in the first layer (0-5 cm) had decreased, however sharply increased at the last stage. Mostly, the greater density was found in second layer (5-10 cm) at all sampling under rainfed system. Root length and its density had slowly increased in the third layer (Table 17). At this standing point, perhaps in the early period was drought, bulk density of soil may be restricted on root development while the soil bulk density (1.79), measured before transplanting was high (Blackburn, 1984). The sharp increase in root wight and extent was found at the last stage (100 DAS), after sufficient rain had occurred. The effect was also proved by Fernando Garcia *et.al.,* (1988). Later, deterrent root growth was ameliorated due to sufficient rainfall had occurred and then root had faster development (Srivastava and

Ghosh, 1970; Evan, 1964). Based on the substantiated results, the root distribution pattern is greatly depended on the rainfall, particularly distribution and physical environment of rhizosphere under rainfed system.

7.7.3. Number of tillers per hill and leaf area

The results of field experiment revealed that number of tillers per hill and leaf area had significantly responded to applied nitrogen stimulated by water. Both of them had increased with increasing rate of nitrogen, up to 200 kg N ha^{-1} in irrigated water management system. However, the highest number of tillers and leave area was found at 100 kg N ha^{-1} under rainfed. Number of tillers per hill had grater number at all nitrogen application under both water management systems comparing with none application in general. Since, adequate supply of nitrogen and water encourage for the plant growth at the same time increased in longevity and persistent of green leave, reduced in tiller mortality (Yadav, 1981). Despite, in another experiment conducted by Robertson *et.al.,* (1999), highlighted on deficits imposed during the tillering phase having large impacts on leaf area, tillering and biomass accumulation had little impact on final yield. This result was primarily responded due to the length of time required to impose significant water deficit, when the canopy is small. The comparatively small amount of biomass accumulation lost through water deficit, and the ability of the crop to produce leaves and tillers at a rapid rate during subsequent well-watered conditions. On the other hand, water deficit imposed when the canopy was well-established had a more deleterious impact on final yield of total biomass, stalk biomass, and stalk sucrose. Wiedenfeld (1995) pointed out that fresh cane yield and quality was mainly dependent on irrigation level rather than nitrogen application in planted crop. However, he agreed on the fact that was native available N source might be adequate for the planted crop. Therefore, the experiment result proved that nitrogen is the one of the most prime factor influencing on initiation, development, maintenance of tillers and leaf area, which was well confirmed in many experiments (Yadav, 1981; Verma *et.al.,* 1985; Singh, 1977). However, it has been pointed out by many researchers that N application had negative effect on juice purity, sugar content and sugar yield (Robertson *et.al.,* 1990) via its several impacts on physiological processes (Alexander, 1973). As commercial yield is commonly expressed on a fresh weight basis, Muchow *et.al.,* (1996a) highlighted the major influence that stalk dry matter content has on the relationship between sucrose yield and commercial yield. Muchow *et.al.,* (1996b) suggested that modest N application adjusting based on rate and timing of N application, and harvesting time or maturity of crop can maximize both CCS (Commercial Cane Sugar) and cane yield.

7.7.4. Sugarcane above ground dry weight

The results of the above ground dry weight responses were very similar to the responses of root dry weight. The above ground dry weights had significantly responded to nitrogen and water management systems at all N application level comparing with none application. The highest dry matter of above ground obtained from 200 kg N ha^{-1} application under irrigation management system. Dry matter weight obtained from 400 kg N ha^{-1} had lack behind from the others, but ahead than non application. The result is similar to results of Yadav and Sharma (1980). They reported that the basal high N application damage to the crop, but, it compensate at late period, application of 250 kg N ha^{-1} was lower in dry matter than 75 and 150 kg N ha^{-1}. The dry matter at all applications had sharply increased since 70 DAS in irrigation system. The sharp increase in above ground dry weight had coincided with boost production of tillers and leaves. The accumulated dry matter had increased due to increased in number of tillers and leave area, which mainly speeded by photosynthesis through ambient supply of nitrogen and water.

The results of the field experiment, the dry weight obtained from irrigation was quite higher than form rainfed. It may be mainly due to available water for plant growth and development. Perhaps, there was a drought in early stages during the field experiment. When water deficit occurred water potential of plants decreased leading to water uptake, consequently several physiological functions, hormones and enzymes activities had been adjusted in the plant system, results in leave growth and expansion had obviously reduced (Kirkham, 1990). According to the experiment results, finally, the highest dry matter (11.85 gm $hill^{-1}$) obtained from 100 kg N ha^{-1} under rainfed system while 0 kg N ha^{-1} had 5.49 gm $hill^{-1}$. Although the dry matter obtained from 400 kg N ha^{-1} (7.37 gm $hill^{-1}$) was higher than none application, it was lack behind to the others. It reflected that plants had suffered from adverse effect of over supplied N, resulted in slow growth rate (Rhoads, 1990; Goyal and Huffaker, 1990), and it may be more effect when lack from sufficient water supply.

7.7.5. Total Nitrogen content in plant parts

According to the results of the field experiment, the total nitrogen contents in above ground plant parts were not significant at the beginning. Generally, the higher content was found during early stages (40 DAS, 55 DAS). During those periods, either the plants had uptake high amount of nitrogen or the available forms of nitrogen had been transported to above ground plant parts while the soil had luxury supply for N through additional sources. It may mainly due to the facts: mineralized N from relative high content of soil organic matter, ambient supply from added N stimulated by sufficient moisture in both water management systems. However, that hight content might be mainly contributed by temporal accumulation of inorganic nitrogen forms (Haynes, 1986a; Goyal and Huffaker, 1984b) rather than organic forms that come out from assimilates, while the crop had not significantly increased in dry matter accumulation (Figure 7). In addition, due to Prammanee *et.al.,* (1999), the peak total nitrogen content at 55 DAS might be coincided with the highest available forms of nitrogen (NH_4^+ and NO_3^-) through minineralization in soil system, in both water management systems. In irrigation system, the gradual decrease in the total nitrogen content at the later stages from 55 DAS, showed that the transported nitrogen might be decreased due to amount of available nitrogen had declined in soil system. In addition, the soil might be slowly released available nitrogen for plant that indicated by gradual decrease pattern of the total nitrogen content. The team of researchers also pointed on that fact. Moreover, since the plant spacing was set up at (30x30 cm) so that the competition for N up take among plants might be strong in later stages. It may lead to reduce the N uptake in individual, as become as a possible of gradual decrease in the total N content of the above ground plant parts. Nevertheless, it was found that the total nitrogen content in above ground parts had significantly responded to applied nitrogen at later stages (70 DAS, 85 DAS and 100 DAS). However, there were not significant among nitrogen applications excepted at 100 DAS, which had significant difference between 100 kg N ha^{-1} and the other applications. This means that plant might keep the balance by several physiological adjustments, even, while the source of available nitrogen was well adequate to supply for the demand (Engels and Marschner, 1995). However, generally, the higher nitrogen content was found with increased nitrogen application. It might be contributed by organic N source since nitrogen encourages cell division and assimilation of organic compounds to proteins (Hutz, 1972; Clements; 1980). Yet, temporal accumulation of NO_3 in cell vacuoles and chloroplasts of leaves is a possible effect regarding to high demand of shoots for the growth whilst it was coupling with increased root surfaces (Engels and Marschner, 1995).

Nitrate accumulation occurs where the energy sources for enzyme synthesis and other metabolic need such as soil moisture, mineral nutrient, is limited (Oaks and Hirel, 1985). Comparative uptake and utilization of N, under field conditions is strongly influenced by environmental conditions throughout the growing season including the position of any available N in the rooting zone relates to water supply and consequent roots activities. The nitrogen content in above ground plant parts under rainfed system was higher than irrigation system at 40 DAS but it was not significant (Figures 10 and 11). This reflected that the plants had more accumulation of inorganic nitrogen forms, stipulated by lower water potential in plant system. Contrasty, at 100 DAS, the higher nitrogen content under rainfed system than irrigation system was mainly responded by flush supply of nitrogen, suddenly released by soil due to sufficient rainfall, because it was leading to rapid growth and development (Clements, 1980).

The total nitrogen content in the roots was generally lower than that in above ground plant parts in both water management systems. It might be related due to allocation and partitioning of assimilates, in other word, nitrogen uptake and distribution depend on internal plant regulation system (Gastal and Lemaire, 2002). The trend of the total nitrogen content in the roots over the observed period was similar as the content in above ground plant parts, especially in the irrigation system. However, the slightly different trends of the total nitrogen content in the roots between above ground plant parts and roots under rainfed system had been observed. In addition, it was more fluctuated due to not only dynamic transformation of nitrogen and dynamic retention of soil water but also water deficit and rainfall occurrence during the period. The nitrogen content in roots under rainfed system was higher than irrigation system at later stages: 70 DAS, 85 DAS and 100 DAS (Figures 12 and 13), and fluctuated. It was obvious that the root might be delayed in reduction process and transportation process, it might be mainly affected due to low water potential in xylem and phloem. Yet, the period; during 70 DAS and 85 DAS, might be coincided with the lowest soil moisture since the environment for rhizosphere was dry and there was no rain occurrence and relative high soil temperature. Sugarcane can assimilate nitrate and ammonium by both mass flow and diffusion through root hairs. Most of the ammonium has to be incorporated into organic compounds in the roots whereas nitrate is mobile in the xylem (Marschner, 1986). Nitrates taken up by plants need to be reduced to NH_3 before it can be combined with carbon skeletons to form amino acids (Jones, 1985). This reduction is catalyzed by two enzymes namely nitrate reductase (NR), which reduces nitrate to nitrite, and nitrite reductase (NiR), which nitrite to ammonia. Normally, the activity of NiR is several fold-higher to ensure a low concentration of nitrite, which is toxic to plants. In sugarcane, NR activity is lower in roots than shoots (Maretizki and Dela Cruz, 1967 *cited in* Hunsigi, 1993). Abayomi *et.al.,* (1988) found that water stress dramatically reduced NR activity. Therefore, nitrate accumulation might be occurred in roots during 70 and 85 DAS.

As contrast from the result during above period, at 100 DAS, the significant difference ($p<0.05$) content of the total nitrogen in roots was more higher in roots, under rainfed system than roots under irrigated system. It was might be mainly contributed by rapid growth of roots since growing organs usually have higher nitrogen content (Clements, 1980).

As summary, the total Nitrogen contents in both above ground plant parts and roots, mostly, there were no significant between water management systems. The results of field experiment had general agreement with the results of Pandy *et.al.,* (2000), reported that nitrogen uptake was seen to be more dependent on applied N than water supply.

7.8. Effect of nitrogen application and irrigation on soil pH and residual total nitrogen content in soil at observed stage (100 DAS)

According to results of soil tests, showed that the effect of urea nitrogen application on soil pH was highly significant. Since all nitrogen source fertilizers application result in acidic condition through chemical reactions in soil system, as for urea, the carbonic acid remains in soil solution or it may break up to form carbondioxide and water (Clements, 1980). The application of nitrogen affected to decrease soil pH with increased nitrogen application in both water management systems (Figure14). As addition, dropping pH value was greater in irrigation system. Of cause, the dropping pH value resulted from a number of factors. Since the phenomenon; absorbed cations by plant, leaching cations, organic residues and their decomposition and nitrogen transformation, had been occurred with greater momentum and greater extent in irrigation system. These are leading to decline in soil pH (Prasad and Power, 1997). Due to dropping soil pH, consequently, undesirable conditions will be changed in soil system for crop production is well documented. Since the soils under continuous cultivation had a corresponding decrease pH but also CEC, exchangeable cations, organic matter, and aggregation ability corresponding in bulk density of soils (Qongqo and Antwerpen, 2000). Therefore, nitrogen application under continuous cultivation practice have to be concerned in its drawback or negative feed back, and it should be practiced with integrated approach for the long term sustainability of soil.

On the other hand, there was no significance for total nitrogen content in soil among the applications under different water management systems at observed stage (100 DAS). However, in generally, the total nitrogen content in soil had higher content with the increasing nitrogen application rate. Moreover, both of nitrogen contents at the final observed stage was still slightly higher than initial stage (average of total nitrogen content was 0.032% in two layers, Table 13). In addition, residual total N content in rainfed was higher than irrigation at observed stage. Although the amount of irrigation water and timing in the experiment was attempted to reduce nitrogen losses, resulted in increased the total nitrogen content in above ground plant parts and root in irrigation system (Figures 10 and 11) to yield. However, it may be occurred more or less mainly due to the rate of N application. Generally, nitrate, has more mobility, it can be increasingly leached out with the increasing nitrogen rate and increasing amount of irrigated water and frequencies that demonstrated in numerous studies. Verburg *et.al.,* (1998) suggested that the residual N content in soil have to be consider and rate of N fertilization have to be matched with crop demand to nitrate leaching could be reduced.

7.9. Efficiencies of nitrogen fertilization at different water management systems, under given environmental circumstances

The efficiencies, namely, agronomic or economic efficiency, physiological efficiency and nitrogen use efficiency, were examined in order to comprehend over the nitrogen application in sugarcane cultivation, in stead of economic aspect. According to the results of the field experiment, although the yield obtained by nitrogen application under both water management systems had increased, the efficiencies were relatively low. The low NUE of the experiment might be contributed by many factors, but, mainly, the high native nitrogen source, hight plant density. However, the experiment demonstrated that nitrogen use efficiency was higher in irrigation system (Table 23). Since many factors have to be synchronized to get higher nutrient use efficiency while it is paramount important due to escalating costs and the hazards of environmental pollution.

In the comprehensive review paper on nutrient use efficiency (Jassen, 1998), pointed out that improving the use of a particular nutrient can best be achieved by improving growth factors than the supply of that nutrient. When this is achieved by increasing the supplies of other nutrient, it increases the expanse of the use efficiencies of those other nutrients. Balance nutrition is the best guarantee for the simultaneous optimum use of all nutrients. Prasad and Power (1997) categorized the factors effecting on nutrient use efficiency, namely, soil factors, crop factors, environmental factors, agronomic practices, and fertilizer management. Soil tests and varieties of plant diagnosis methods are still useful in fertilizer management (Strong, 1995). Adopting an appropriate cropping systems in combination with soil testing, measuring the residual N after upland cropping, and adjusting the application of fertilizer N for the subsequent crop, may increase the efficiency of absorption and consequently of the production system. Methods and timing of application, and cultural practices which improve the condition of plant and soil are also effective in increasing efficiencies of absorption, and consequently, the yield of the crop. In addition, nitrogen use efficiency affected by many factors, mostly, genetic, but the interaction between genetic and character of variety and the environment is also important (DACTARI, 2001).

Since nitrogen deficiencies is major barrier to crop yield all over the world, particularly in developing countries. An effective integrated approach employing organic manures, biofertilizers, chemical fertilizers, nitrification inhibitors, and coat and long-persisting fertilizers is the key to sustainable agriculture (Prasad and Power, 1997). Therefore, the specific plan should be developed in the area based on climate, soil, labor supply, knowledge base, financial resource and the others for the better efficiency in nitrogen fertilization.

7.10. Applications of CANEGRO-DSSAT Model

Since the nitrogen transformation in both soil and plant systems is too complex, it is interacting with exogenous variables in the real system. Therefore, it was difficult to point out the reasons of the high difference between the predicted yields and observed yields. It may be affected by many possible factors. However, simulation with such model can be developed through system analysis (Nix,1986 *cited in* Jintrawet, 1995b). The results of comparison between simulated and observed yields, and statistical analysis revealed that the model had low accuracy in prediction on the crop response to nitrogen application under both water management systems, in general. However, model could simulate dynamism of carbon and nitrogen in soil–plant system.

According to simulated results in this study, as for biomass accumulation, involving nitrogen transformations through physiological and metabolic functions, there was the higher Mean of Standard Deviation (MSD) had obtained at the highest nitrogen application in both water systems. In addition, the MSD value was relatively higher in irrigation system than rainfed system. It may require accurate observations on water management for both irrigation and rainfed conditions in order to improve the fraction of biomass partitioning and accumulation rate for given circumstances, interacting with soil water status (Singles *et.al.,* 2000). Moreover, generally, the model had weaker at predictions on nitrogen concentration in leaf (LN%D) rather than in root (RN%D). It was found that nitrogen concentration in root had relatively lower MSD comparing to the nitrogen concentration leaf. In addition, the prediction on RN%D had more closer to observed values in irrigation treatments. The MSD for LN%D was high at all treatments in both water management systems. Reasons for the varied uptake response need further investigations (O'leary *et.al.,* 2000).