Effects of Nitrogen Fertilizer Rates and Irrigation Methods on Growth and Yield of Sweet Corn in Chiang Mai Province

ผลของอัตราปุ๋ยไนโตรเจนและวิธีการให้น้ำต่อการเติบโตและผลผลิตของข้าวโพดหวานในจังหวัดเชียงใหม่

Panitnart Mungmoon and Choochad Santasup*

พนิตนาถ มั่งมูล และ ชูชาติ สันธทรัพย์*

Department of Plant and Soil Sciences, Faculty of Agriculture, Chiang Mai University, Chiang Mai 50200, Thailand

ภาควิชาพืชศาสตร์และปฐพีศาสตร์ คณะเกษตรศาสตร์ มหาวิทยาลัยเชียงใหม่ จ. เชียงใหม่ 50200

**Corresponding author: Email: santasup@gmail.com*

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บทคัดย่อ: การศึกษาการจัดการปุ๋ยไนโตรเจนร่วมกับวิธีการให้น้ำสำหรับการปลูกข้าวโพดหวาน ได้ดำเนินการทดลองในพื้นที่ปลูกข้าวโพดหวานของเกษตรกร อำเภอแม่อาย และในแปลงวิจัย คณะเกษตรศาสตร์ มหาวิทยาลัยเชียงใหม่ อำเภอเมือง จังหวัดเชียงใหม่ ในระหว่างเดือนพฤศจิกายน 2560 ถึง มีนาคม 2561 โดยวางแผนการทดลองแบบสุ่มสมบูรณ์ในบล็อค (randomized complete block design, RCBD) จำนวน 4 ซ้ำ 4 กรรมวิธีทดลอง ได้แก่ (1) ใส่ปุ๋ยไนโตรเจนในอัตรา 190.75 กิโลกรัม/เฮกตาร์ และให้น้ำแบบปล่อยตามร่องปลูก (กรรมวิธีที่เกษตรกรนิยมปฏิบัติ) (2) ใส่ปุ๋ยไนโตรเจนในอัตรา 156.25 กิโลกรัม/เฮกตาร์ (ใส่ปุ๋ยตามความต้องการของพืชและตามค่าวิเคราะห์ดิน) และให้น้ำแบบปล่อยตามร่องปลูก (3) ใส่ปุ๋ยไนโตรเจนในอัตรา 156.25 กิโลกรัม/เฮกตาร์และให้น้ำแบบระบบน้ำหยด (4) ไม่ใส่ปุ๋ยและให้น้ำแบบปล่อยตามร่องปลูก (กรรมวิธีควบคุม) ผลการศึกษาพบว่า อัตราการใส่ปุ๋ยไนโตรเจนที่ประเมินจากความต้องการของข้าวโพดหวานและค่าวิเคราะห์ดิน ไม่ทำให้ความสูง ค่าความเข้มสีเขียวในใบพืช และความเข้มข้นของธาตุอาหารหลัก ปริมาณและคุณภาพผลผลิต แตกต่างกันอย่างมีนัยสำคัญทางสถิติเมื่อเปรียบเทียบกับกรรมวิธีที่เกษตรกรนิยมปฏิบัติ ทั้งในระบบปล่อยน้ำตามร่องปลูกและระบบน้ำหยด โดยข้าวโพดหวานที่ปลูกในแปลงของเกษตรกร มีน้ำหนักฝักเฉลี่ย 410.48-430.10 กรัม/ฝัก และผลผลิตฝักสดอยู่ระหว่าง 19.85-20.79 ตัน/เฮกตาร์ และข้าวโพดหวานที่ปลูกในแปลงวิจัย มีน้ำหนักฝักเฉลี่ย 319.85-367.65 กรัม/ฝัก และผลผลิตฝักสดอยู่ระหว่าง 16.87-18.33 ตัน/เฮกตาร์ และมีปริมาณของแข็งที่ละลายได้มากกว่า 14 องศาบริกซ์ ทั้งสองแปลงทดลอง อย่างไรก็ตาม ระบบน้ำหยดสามารถลดการใช้น้ำลงได้ 40 และ 58 เปอร์เซ็นต์ ทั้งที่ในแปลงของเกษตรกรและในสถานีวิจัย ตามลำดับ

คำสำคัญ: ข้าวโพดหวาน ระบบน้ำหยด ปุ๋ยไนโตรเจน ผลผลิต คุณภาพของข้าวโพดหวาน

Abstract: The study on nitrogen fertilizer management and irrigation methods for sweet corn, this study was conducted in farmer's field at Mae Ai district and in the research field of Faculty of Agriculture, Chiang Mai University, Chiang Mai province during November 2017 to March 2018. The experimental design was a randomized complete block design (RCBD) with 4 replications and 4 treatments as follows: (1) nitrogen application at the rate of 190.75 kg/ha and furrow irrigation system (farmer practice), (2) nitrogen application at the rate of 156.25 kg/ha (site-specific fertilizer management) with furrow irrigation, (3) nitrogen application at the rate of 156.25 kg/ha with drip irrigation and (4) control treatment, non-fertilization and irrigated by furrow. The results revealed that the rate of nitrogen application based on the nutrient requirement of sweet corn and soil analysis data (site-specific fertilizer management) did not affect plant height, leaf greenness value and primary nutrient content in ear leaf, fresh yield and yield quality significantly when compared to farmer practice treatment both in furrow and drip irrigations. The range of ear weight and fresh yield were 410.48-430.10 g/ear, 19.85-20.79 t/ha in farmer's field and 319.85-367.65 g/ear, 16.87-18.33 t/ha in the research field, respectively. Moreover, the total soluble solids in the kernel were higher than 14 °Brix in both experimental fields. However, the drip irrigation system saved 40% water usage compared to the furrow system in the farmer's field and saved 58% in the research field.

Keywords: Sweet corn, drip system, nitrogen fertilizer, yield, quality of sweet corn

Introduction

Sweet corn is a quality agricultural commodity of Thailand for its potential for fresh produce distribution and raw material in the food processing industry with a high volume of export. Sweet corn (*Zea mays* L. Saccharata) belongs to the family Poaceae. It is a naturally-occurring genetic mutation of field corn and consumed at the soft dough stage with succulent grains, emerges as an alternative dish of vegetable, roasted ears, soups and sweetness, etc. The sweet corn season is shorter than that of field corn because the marketable ears are harvested earlier from 35 to 45 days compared to the field corn (Bhatt, 2012) when kernel sugar content is optimal.

Nitrogen is one of the most important plant nutrients as it is required to produce proteins and chlorophyll, maintain photosynthetic efficiency, leaf area development and ultimately dry matter production (Muchow, 1998). Nitrogen fertilization and soil management practices are very important to enhance crop yield (Atkinson *et al*., 2005). Min *et al*. (2011) reported that the nitrogen fertilizer use efficiency was only 18% under the conventional application rate, increasing from 522 to 870 kg/ha and apparent nitrogen losses of 71-86% were caused by leaching, leaching was the primary nitrogen loss pathway. Some researchers noted that an increasing amount of nitrogen increased yield significantly (Maqsood *et al*., 2001; Sharar *et al*., 2003). Biswas and Ma (2016) also reported that corn yield, nitrogen in kernel and stover biomass increased with an increasing nitrogen rate. However, higher nitrogen rates (200 kg N/ha) did not provide a yield advantage as compared to 150 kg N/ha in 2010, but the highest grain yield was produced with 200 kg N/ha in 2011. The economic optimal nitrogen rate varied greatly from year to year, the average economic optimal nitrogen rate (170-180 kg/ha) did not change from 1992-2010 (Schlegel and Havlin, 2017). However, most of the cereal crops require a large amount of nitrogen to produce maximum yield and for which nutrient use efficiency (NUE) is estimated to be less than 50% (Raun and Johnson, 1999). NUE currently averages 33% for wheat and corn production around the world (Freeman and Raun, 2007). It varies from one situation to another due to variability in several factors such as crop health, soil types, years and locations, application timings, methods of application/incorporation of the fertilizer in the soil and nutrient responses of the cultivated variety (Nielsen, 2006). Thus, nitrogen management is one of the most extensively-researched topics in agriculture (Subedi *et al*., 2006).

In the current water crisis, sufficient available freshwater resources are becoming the binding constraint for food production. Limited water sources are among the reasons that force many farmers to reduce irrigation applications. The fact that water is one of the most important environmental factors that affect the growth, development and crop production of the plant, it is a critical issue limiting plant growth by having an impact on anatomical, morphological, physiological and biochemical processes (Setter *et al*., 2001). NeSmith and Ritchie (1992) reported that the yield of corn reduction ranged from 21% to 40% in the water-deficit treatment, with kernel weight being the most affected component. Thus, irrigation is an important practice for sustainable agriculture, especially in crop production to meet retailer demands for quality when rainfall is insufficient. Drip irrigation is the most effective method in terms of both maximizing yield and water conservation (Cetin and Bilgel, 2002) as well as providing efficient use of limited water (Viswanatha *et al*., 2002). It saved about 56.4% water compared to furrow irrigation method (Tagar *et al*., 2012). Ramamurthy *et al.* (2009) reported that water use efficiency with drip irrigation was 45-68% higher than the flood method. Hence, this study aimed to investigate drip irrigation and site-specific nitrogen fertilizer management (SSFM) to increase yield and save water.

Materials and Methods

Two field experiments were conducted in Chiang Mai province, Northern Thailand from November 2017 to March 2018. Sweet corns were planted in the area with different soil types and field managements including a farmer's field in Mae Ai district and research field at Mae Hia Agricultural Research, Demonstration and Training Center, Faculty of Agriculture, Chiang Mai University. The initial soil properties of the farmer's field were loam soil (35.3 % sand, 42.4 % silt, 22.3 % clay) and the chemical properties were as follows; pH 5.59 (pH meter; Rhoades, 1982), electrical conductivity (EC) 45 µS/cm (conductivity meter; Siwasin, 1984), organic matter (OM) 4.48% (titration; Nelson and Somners, 1980), available phosphorus (avai. P) 86 mg/kg (Bray II; Houba *et al.,* 1988) and exchangeable potassium (exch. K) 88 mg/kg (NH_4OAc 1M pH 7; Helmke and Sparks, 1996). While the soil texture of the research field was sandy loam (57.7 % sand, 31.7 % silt, 16.6 % clay). The soil properties were pH 6.06, EC 21 µS/cm, OM 1.60 %, avai. P 22.14 mg/kg and exch. K 99 mg/kg. Sweet corn seeds, Hi-Brix 53 variety were sown in the spacing of 75 x 25 cm by hand. Weed and pest controls were performed as necessary.

Experimental design: The experimental size was 0.16 ha (1,600 m^2). Sweet corn was planted in a randomized complete block design with 4 replications and 4 treatments as follows; (1) nitrogen application at the rate of 190.75 kg/ha with furrow irrigation (farmer practice rate, CP-Furrow), (2) nitrogen application at the rate of 156.25 kg/ha (site-specific fertilizer management) (Sanjunthong, 2017) with furrow irrigation, (3) nitrogen application at the rate of 156.25 kg/ha and drip irrigation and (4) control treatment, non-fertilization and water irrigated by furrow. P and K fertilizer were applied at the same rate, 46.75 kg P_2O_5/ha and 46.75 kg K_2O/ha. Urea and compound fertilizer (15-15-15) were used as N, P and K sources in the experiment. Fertilizer was applied 3 times; 10% of nitrogen fertilizer and 40% of phosphorus and potassium fertilizers were applied at 15 days after sowing (DAS). The second application, 60% of nitrogen, phosphorus and potassium fertilizers were applied at 27 DAS. In the last application, 30% of nitrogen fertilizer was applied at 45 DAS.

The fertilizer rate of SSFM treatment applied in this experiment was obtained from Sanjunthong (2017) who suggested that sweet corn which was grown in the farmer's field where the soil contained moderate level of OM (>1.5%), moderate to high level of available P (>20 mg/kg) and moderate level of exchangeable K (60-100 mg/kg), application of N at the rate of 156.25 kg/ha (minimum N requirement of sweet corn), P (P_2O_5) and K (K_2O) fertilizer at the rate of 47.75 kg/ha was sufficient for sweet corn production. Water management on the farmer's field was performed by the farmer and the amount of irrigation water was recorded using a water meter. For water management in the research field, the amount of irrigation water and irrigation frequency were controlled by tensiometer and recorded using the water meter as well.

Data collection: The height of sweet corn was measured (from the soil surface to top of fully-developed leaf) at 20, 40 and 60 days after sowing, using a measuring tape. When sweet corn was in the V6 growth stage (50 DAS), leaf greenness (SPAD) was measured by chlorophyll meter (Konica, SPAD-502). At the silking stage, ear leaf was collected for nutrient analysis. Sweet corn ear was harvested at the R3 stage (milk stage, 101 DAS) by sampling 40 plants (7.5 m^2), then marketable yield and yield component (ear weight, ear diameter, ear length and the number of row/ear) were recorded. (Ministry of Agriculture and Cooperatives, 2012). In addition, total soluble solids (TSS) by Otago Digital Brix Refractometers, nitrogen (N) (Novozamsky *et al.,* 1974), phosphorus (P) (Walinga *et al.,* 1995) and potassium (K) (Kalra, 1998) in the kernel were analyzed.

Data analysis: Data analysis was performed using Statistix 9.0. All parameters were analyzed using analysis of variance (ANOVA) and mean separation was performed by the least significant difference (LSD) test. Unless noted otherwise, statistical tests were performed at the α= 0.05 level of significance.

Results

Plant growth: Results in Table 1 showed that the plant height of sweet corn was influenced by different fertilizer and water management. In the farmer's field, plant heights of the treated plants were in the range of 14.79-15.46 cm, 33.06-35.98 cm and 166.23-179.24 cm at 30, 50 and 70 DAS, respectively. In the research field, plant heights of the treated plants were in the range of 15.25-16.65 cm, 55.25-59.59 cm and 197.36-202.56 cm at 30, 50 and 70 DAS, respectively. The minimum plant height was found in the control treatment at 70 DAS in both experimental fields.

Table 1. Effect of fertilizer and water management on plant height of sweet corn

Treatment	Plant height (cm)					
	Farmer's field			Research field		
	30 DAS	50 DAS	70 DAS	30 DAS	50 DAS	70 DAS
CP-Furrow	14.79 a	33.06	166.23 a	15.80	59.59	202.56 a
SSFM-Furrow	15.46 a	35.98	179.24 a	16.65	57.66	200.37 a
SSFM-Drip	14.85 a	35.69	170.00 a	15.25	55.25	197.36 a
Control	12.38 b	28.31	134.86 b	16.26	47.44	143.01 b
CV (%)	7.77	11.85	12.06	9.53	10.04	5.33
$LSD_{0.05}$	1.79	ns	31.35	ns	ns	15.84

Means within the same column followed by different letters are significantly different according to LSD test at $P \leq 0.05$, ns = non-significant, DAS = day after sowing

Plant nutrient status: Fertilizer and water management did not affect the SPAD and plant nutrient concentration in ear leaf significantly (Table 2). In the farmer's field, the SPAD was in the range of 57.33-59.34 SPAD units. However, in the research field, the SPAD was in the range of 45.78-47.57 SPAD units. The minimum SPAD was found in the control treatment in both fields. N, P and K concentrations in ear leaf of farmer's field were in the range of 1.98-2.30%, 0.23-0.26% and 2.10-2.28%, respectively. On the other hand, N, P, and K concentrations in ear leaf in the research field were in the range of 2.43-2.54%, 0.20-0.24% and 1.88-2.09%, respectively. The minimum N concentration in ear leaf was found in the control treatment in both experimental fields (1.69% in the farmer's field and 1.61 in the research field). In contrast, the control treatment showed maximum P concentrations (0.55%) in ear leaf in both fields. Moreover, the concentrations of K in the ear leaf of sweet corn were not significant in the farmer's field while the lowest potassium content (1.52%) was noted in control treatment in the research field.

Biomass: The data in Table 3 showed that fertilizer and water management did not affect biomass significantly. The stem and ear dry weights of sweet corn planted in the research field were 172.78-216.79 and 87.91-99.29 g/plant, respectively. In the farmer's field, the stem and ear dry weights were 134.87-143.55 and 80.71-87.77 g/plant, respectively. On the other hand, most of the control treatments showed the lowest dry weight of stem and ear. The dry weight was 38.58 g/plant in stem and 29.31 g/plant in ear in farmer's field. For the research field, the dry weights were 22.70 and 16.87 g/plant in the stem and ear, respectively.

Corn yield: The results in Table 3 clearly showed that fertilizer application treatments increased fresh yield of sweet corn significantly compared to the no fertilization treatment (control treatment). However, the different fertilizer rates and water management did not affect the yield of sweet corn at both experimental fields significantly. The sweet corn yields in the farmer's field were in the range of 19.85-20.79 t/ha while in the research field ranged from 16.87 to 18.33 t/ha. The minimum fresh yield (8.19 t/ha) was observed in the control treatment in the farmer's field. It should be noted that, in the research field, the fresh yield of sweet corn was not available because the ear of sweet corn was incomplete in the kernel setting.

Table 2. Effect of fertilizer and water management on SPAD and nutrients concentration in ear leaf of sweet corn

Treatment	SPAD (SPAD unit)		Concentration (%)					
			Farmer's field			Research field		
	Farmer's field	Research field	N	P	K	N	P	K
CP-Furrow	57.33 a	45.99	2.30 a	0.25 bc	2.10	2.43 a	0.20 c	1.91 a
SSFM-Furrow	59.34 a	45.78	2.29 a	0.26 b	2.28	2.44 a	0.20 c	1.88 a
SSFM-Drip	58.76 a	47.57	1.98 b	0.23 c	2.23	2.54 a	0.24 b	2.09 a
Control	30.32 b	45.38	1.69 c	0.55 a	1.81	1.61 b	0.55 a	1.52 b
CV (%)	5.86	3.34	8.67	4.95	10.38	8.96	7.00	8.59
$LSD_{0.05}$	4.87	ns	0.29	0.03	ns	0.32	0.03	0.25

Means within the same column followed by different letters are significantly different according to LSD test at $P \leq 0.05$, ns = non-significant, DAS = days after sowing, ear leaf = ear leaf at silking stage

Table 3. Effect of fertilizer and water management on fresh yield and biomass of sweet corn

Treatment	Fresh yield (t/ha)		Biomass (g/plant)			
			Farmer's field		Research field	
	Farmer's field	Research field	Stem	Ear	Stem	Ear
CP-Furrow	20.75 a	16.93	139.72 a	87.77 a	216.79 a	90.05 a
SSFM-Furrow	19.85 a	16.87	143.55 a	82.92 a	172.78 b	87.91 a
SSFM-Drip	20.79 a	18.33	134.87 a	80.71 a	181.01 b	99.29 a
Control	8.19 b	N/A	38.58 b	29.31 b	22.70 c	16.87 b
CV (%)	7.12	4.41	14.86	13.61	13.43	10.84
$LSD_{0.05}$	1.98	ns	27.13	15.28	34.55	12.75

Means within the same column followed by different letters are significantly different according to LSD test at $P \leq 0.05$, ns = non-significant, N/A = not available

Yield quality: The fertilizer and water managements did not affect yield quality of sweet corn at the harvest stage significantly. In the farmer's field (Table 4), ear weights of sweet corn were in the range of 410.48-430.10 g/ear. Ear lengths ranged from 31.35 to 32.25 cm and ear diameters were in the range of 63.77-64.95 mm. The number of rows per ear was in the range of 17.58-18.45 and TSS was 14.57-14.60 °Brix. Moreover, the lowest quality of all parameters showed in the control. The ear weight was only 154.00 g/ear. Ear length was 22.45 cm and ear diameter was 45.11 mm. The number of rows per ear was 15.60 and TSS was 14.48 °Brix. For the research field, the fresh yield was not available because the ear of sweet corn was incomplete in the kernel setting, so the quality of sweet corn was calculated from the fertilizer treatment. Ear weights of sweet corn were 319.85-367.65 g/ear. For ear lengths and diameters, they were in the range of 29.24-29.76 and 59.95-60.48 mm, respectively. The number of rows per ear was 16.13-18.10 and TSS was 14.78-15.06 °Brix.

Nutrient concentration in kernels: In the farmer's field trial, drip irrigation treatment showed a positive effect on the nitrogen concentration (3.19%) in the ear significantly (Table 5). In contrast, the concentrations of phosphorus in the ear were not significant among fertilizer treatments. The concentrations of phosphorus were observed in the range of 0.49-0.51 %. In contrast, the highest phosphorus concentration (0.54%) in the kernel was recorded in the control treatment. However, the concentration of potassium in the ear was not significant for all treatments, it was found in the range of 1.67-1.85%. For the research field, the fertilizer and water management did not affect N, P and K concentration in kernels. The concentrations of nitrogen, phosphorus and potassium were observed in the range of 2.15-2.30%, 0.34-0.35 % and 1.13-1.15%, respectively.

Water usage: For the amount of irrigation water, water irrigation by furrow system was to low efficiency (Figure 1). In the farmer's field, approximately 1,989-2,064 m^3/ha/crop of water was applied for producing sweet corn while the amount of irrigation water by drip irrigation was only 1,238 m^3/ha/crop. Similar to the research field experiment, 5,740-5,840 m^3/ha/crop of water was applied to sweet corn under the furrow system compared to the drip irrigation that was applied only 2,407 m^3/ha/crop.

Table 4. Effect of fertilizer and water management on sweet corn qualities

Treatment	Ear weight (g/ear)		Ear length (cm)		Ear diameter (mm)		No. of row/ear		TSS (°Brix)	
	Farmer's field	Research field	Farmer's field	Research field	Farmer's field	Research field	Farmer's field	Research field	Farmer's field	Research field
CP-Furrow	430.10 a	325.83	32.00 a	29.41	64.95 a	59.95	18.18 a	16.38	14.60	14.78
SSFM-Furrow	410.48 a	319.85	31.35 a	29.24	63.77 a	60.14	18.45 a	16.13	14.58	14.85
SSFM-Drip	427.70 a	367.65	32.25 a	29.76	64.84 a	60.48	17.58 a	18.10	14.57	15.06
Control	154.00 b	N/A	22.45 b	N/A	45.11 b	N/A	15.60 b	N/A	14.48	N/A
CV (%)	7.09	12.02	3.01	2.49	2.47	3.35	3.75	12.33	1.17	1.28
$LSD_{0.05}$	40.35	ns	1.42	ns	2.35	ns	1.05	ns	ns	ns

Means within the same column followed by different letters are significantly different according to LSD test at $P \leq 0.05$, ns = non-significant, TSS = total soluble solid, N/A = not available

Table 5. Effect of fertilizer and water management on nutrient concentration in the kernel of sweet corn

Treatment	Nutrient concentration in kernel (%)					
	Farmer's field			Research field		
	N	P	K	N	P	K
CP-Furrow	2.78 b	0.51 b	1.67	2.28	0.35	1.14
SSFM-Furrow	2.56 b	0.49 b	1.77	2.15	0.34	1.13
SSFM-Drip	3.19 a	0.50 b	1.79	2.30	0.34	1.15
Control	2.60 b	0.54 a	1.85	N/A		
CV (%)	6.75	2.95	6.37	7.94	6.46	5.22
$LSD_{0.05}$	0.30	0.02	ns	ns	ns	ns

Means within the same column followed by different letters are significantly different according to LSD test at $P \leq 0.05$, ns = non-significant, N/A = not available

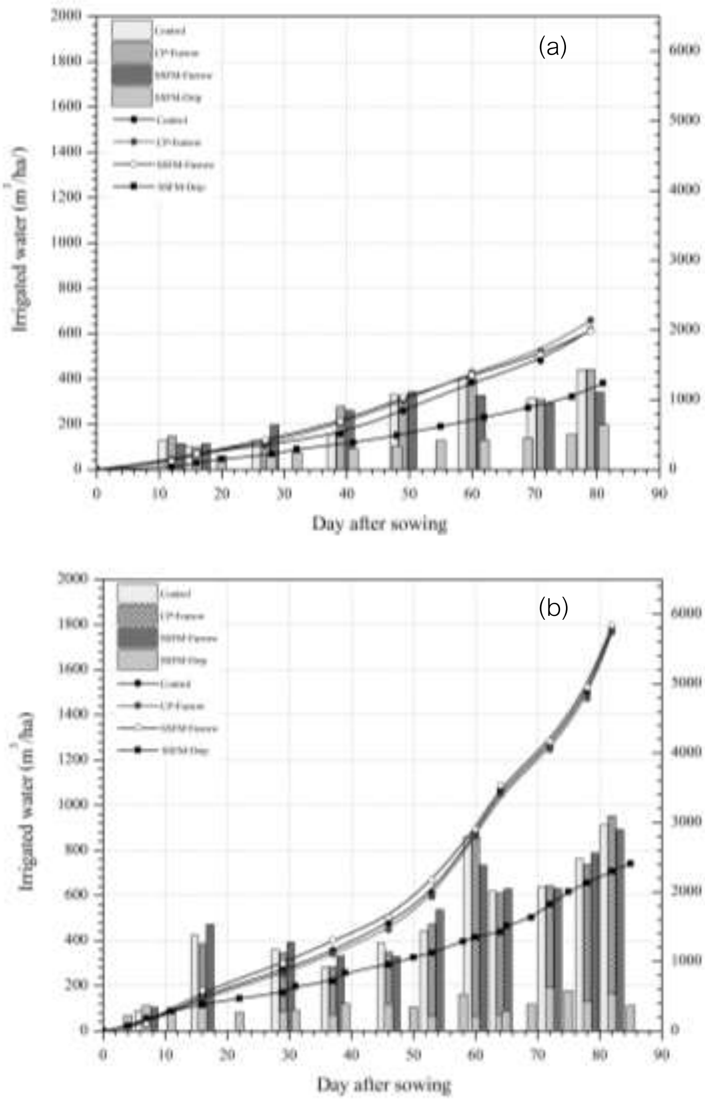

Figure 1. Irrigated water (bar) and accumulated water (line) for sweet corn planted in the farmer's field (a) and research field (b)

Discussion

The results of this study indicated that fertilizer still play and important role for plant growth, especially nitrogen fertilizer. Sweet corn that was cultivated without fertilizer (control treatment) gave low or no marketable yield. Asaduzzaman *et al*. (2014) reported that N-fertilizer had significant effect on plant height at all growth stage, the tallest plant was observed at 160 kg/ha which was statistically similar to 200 kg/ha and the shortest at 0 kg/ha. Significant variation was observed in respect of dry matter accumulation due to different N fertilizer rates. However, fertilization based on nutrient requirements and soil analysis data (SSFM) under different irrgatiion system (drip and furrow irrigation system) did not significantly affect the plant height, SPAD value and nutrient concentration in ear leaf of sweet corn in both areas. Chlorophyll meter is used worldwide in the corn-field for crop N status assessment because the SPAD value was highly correlated with leaf chlorophyll content determined with destructive measurements (Schaper and Chacko, 1991) and highly correlated with N concentration in corn leaf tissue (Schepers *et al.,* 1992). A positive response of leaf N concentration to photosynthetic rate has been widely reported, so nitrogen promotes foliage growth that is responsible for photosynthesis activities and accumulation of dry matter. At 50 DAS, the SPAD values of sweet corn leaf obtained from low N treatment (156.25 kg N/ha) and high nitrogen treatment (190.75 kg N/ha) were not significantly different in both drip and furrow irrigation systems. These results indicated that N fertilizer application at the rate of 156.25 kg/ha was sufficient for sweet corn growth, which was confirmed by the non-significant difference of N concentration in ear leaf at the silk stage. Ta and Weiland (1992) presented that leaves and stalk each contributed 45% of total N remobilized into the ear, and 10% was contributed by the root. At the harvest stage, N rate of 156.25 kg/ha with different irrigation systems could have the nitrogen concentration in the kernel not less than the N rate of 190.75 kg/ha. Since N content could be converted to crude protein, hence low N fertilizer rate (156.25 kg/ha) still maintained the level of crude protein, resulting in a great economic (fertilizer) costs and reducing environmental impact. In contrast, it was found that P concentration in ear leaf of the control treatment was higher than the other treatments in both experimental fields. Ziadi *et al.* (2007) and Riedell (2010) reported that under limiting N condition, P concentration was increased. However, increasing N concentration provided an increase of shoot biomass while the P concentration was also decreased.

Moreover, the fresh yield of sweet corn under application rates of 156.25 kg N /ha with a drip and furrow irrigation system was not significantly different compared to the common practice rate (190.75 kg N/ha). This result indicated that the rate of 156.25 kg N/ha was sufficient for sweet corn growth and good quality yield, the same as the rate of 190.75 kg N/ha. The obtained results conformed with Sanjunthong (2017) who observed that N requirement of sweet corn (var. Brightgene) was 158.5 kg N/ha and applying the 156.25 kg N/ha was the optimal rate of N fertilizer which resulted in the highest yield. A similar result was also observed that the recommended rate of 156.25 kg N/ha with 46.88 kg K_2O/ha was sufficient for yield and quality of sweet corn grown in farmer's field where soil contained a low level of exch. K (Chalernthai and Santasup, 2017). Pampolino *et al.* (2012) reported that the higher maize yield in Indonesia was obtained from 160 kg N/ha compared with 173 kg N/ha (farmer's fertilizer application rate). Noppan and Santasup (2016) reported that N fertilizer application at the rate of 125 kg/ha was sufficient for good yield and quality of field corn seed production compared to the higher rate of N (156.25 kg/ha) that farmers widely applied. These results suggested that N fertilizer at the rate of 156.25 kg/ha was sufficient for sweet corn production, the same as the rate of 190.75 kg /ha. The N fertilizer rate in this experiment (156.25 kg/ha) which was determined based on N requirement and soil analysis data showed great results, maintained the high amount and quality of productivity while minimizing waste, economic loss and environmental impacts. The low rate of N application (156.25 kg/ha) was not only the ability to maintain a high amount of yield but also the quality of sweet corn. The total soluble solids (TSS), one of the most important qualities of sweet corn, was still in the high value both in the farmer's field (14.57°Brix) and the research field (15.06 °Brix). These values were higher than the sweet corn's TSS value of Thai agricultural standard (> 9 °Brix) (Ministry of Agriculture and Cooperatives, 2012). Similar results were also reported by Chalernthai and Santasup (2018). Besides, the ear length (29.24 and 32.25 cm) and ear diameter (59.95 and 64.95 mm) were not significantly different as compared to the higher rate of N application, both in the farmer's field and researcher field. However, these properties were affected by the application of fertilizer and occasionally attributed to seasonal limitations (Okumura *et al*., 2014). For the control treatment, the fresh yield of sweet corn sowed the different results in different fields. The research field found that the yield of sweet corn was not available because the ear of sweet corn was incomplete in the kernel setting. Prempramote (2010) found that the experiment without fertilizing, corn yield is lower than the fertilizer application significantly. Noppan (2011) reported that in soil with low levels of organic matter (0.94%), mineralized N was not sufficient and corn unable to yield production. The soil with moderate levels of organic matter (1.55%), corn yield was only one third compared to the fertilizer treatment. Consistent with the farmer's field that the control treatment gave the yield 2.5 times lower than fertilizer treatment.

The 156.25 kg N/ha showed no significant differences in the sweet corn yield in drip and furrow irrigation systems. Using a drip irrigation system greatly reduced water usage than the furrow irrigation system in different soil types. In areas with limited water resources, sweet corn can be grown by using a drip irrigation system. However, the amount of water and frequency of irrigation was dependent on the soil texture. The farmer's field where the soil texture was to loamy characteristics, the water was approximately irrigated weekly. On the other hand, the research field where the soil texture was to sandy loam characteristics, the frequency of irrigation was approximately once in three days. Mojid *et al*. (2009) reported that loam soil saved more than 50% irrigation water compared with sandy loam soil. Omran *et al.* (2016) demonstrated that the amount of water applied by drip irrigation was found to be higher in the clay soil than in the sandy soil because it was dominated by large pores compared with fine texture clay soil. Sandy soil had a low pore space and a high infiltration was responsible for a low water-holding capacity, consequently led to higher frequency of irrigation. Low water-holding capacity resulting in each time that irrigation the water was lost. Thus, more frequent of the irrigation cycle, the water will lose more as well. However, drip irrigation is watering only around the root zone of plants, resulting in less water usage and reduced water loss. When compared with furrow irrigation using drip irrigation water usage in sandy soil, it can save more water than loam soil. Therefore, drip irrigation is a promising method, however, its cost is still high and needs a good quality source of water.

Conclusions

The results of the current study revealed that the application of nitrogen fertilizer at the rate of 156.25 kg/ha/crop based on the nutrient requirement and soil analysis data under drip and furrow irrigation system was suitable for producing sweet corn in Chiang Mai province. This rate was sufficient for providing good growth, yield and quality of sweet corn in both loam and sandy loam soil texture. Moreover, water irrigation by drip irrigation saved the amount of water more than 40% compared to the furrow system at both experimental sites.

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