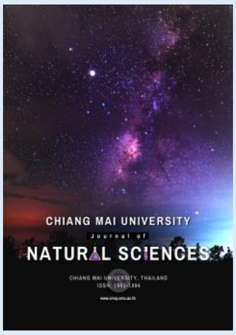

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Corresponding author:
Songyos Chotchutima,
E-mail: fagrsyc@ku.ac.th

Research article

Influence of Varieties and Spacings on Growth, Biomass Yield and Nutritional Value of Corn Silage in Paddy Field

Songyos Chotchutima[1,*], Phoompong Boonsaen[3], Sujin Jenweerawat[1], Sutus Pleangkai[4], Jutamas Romkaew[2], Choosak Jompuk[2], Ed Sarobol[1] and Sayan Tudsri[1]

1 Department of Agronomy, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand
2 Department of Agronomy, Faculty of Agriculture at Kamphaeng Saen, Kasetsart University, Nakhon Pathom 73140, Thailand
3 Department of Animal science, Faculty of Agriculture at Kamphaeng Saen, Kasetsart University, Nakhon Pathom 73140, Thailand
4 Lopburi Research Station, Faculty of Agriculture, Kasetsart University, Lopburi 15250, Thailand

Abstract The objectives of the experiment were to determine plant spacing and variety to produce the suitable growth, yield components, biomass yield of field corn and nutritional value of corn silage in paddy field condition. The field experiment was conducted at the Lopburi Research Station, Khok Charoen district, Lopburi province, Thailand in 2018-2019 and was arranged in a split plot design in randomized complete block design (RCBD) with 4 replications. The main plot contained 3 plant spacings viz. 75×15, 75×20 and 75×25 cm and sub plot consisted of 5 field corn varieties (CP888, NS3, S7328, SW4452 and SW5). The results showed that wide spacing tended to produce higher ears per plant than narrow spacing. CP888 was the highest ears per plant variety. NS3 was the highest leaf/stem ratio variety. SW5 showed high leaf, stem and fresh biomass yield and it also produce ear yield closing to a high ear yield variety at 75×25 cm spacing. Moreover, SW5 also had high crude protein (CP) content, while plant spacing did not significantly affect acid detergent fiber (ADF), acid detergent lignin (ADL), ash, and lactic acid of corn silage. The widest spacing (75×25 cm) showed lower NDF than the narrowest spacing (75×15 cm). It was evident that SW5 and 75×25 cm spacing may be considered optimum for biomass yields without negatively affecting the corn silage quality.

Keywords: Nutritional value, Paddy field, Plant spacing, Silage corn, Variety

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INTRODUCTION

Corn is one of the economic crops which is often grown as part of a rice-based cropping system because it has a lower water requirement than off-season rice (Ekasingh et al., 2004). Growing silage corn during the dry season increases good quality feed production. In Thailand, a major constraint in raising ruminants is inadequate feed, especially in the dry season. Corn silage production, by using both stalks and ears of field corn, is another alternative in helping to increase the quality of roughage, which can bring about good quality dairy and beef production. Corn is a forage crop with high nutritional value and can be easily digested by ruminants (Tudsri, 2004). Corn silage is thus a roughage which can be used to lower the cost of dairy and beef cattle farming as it can be used to replace the quantity of expensive concentrate feed. Research on the improvement of a variety of field corn conducted by both government and private sectors in Thailand has led to the continuous development and breeding of several new varieties of field corn with high grain yields. The most of farmers lacks information regarding which corn variety can provide high biomass yield and optimum quality for ruminants, especially the variety of field corn which is suitable for corn silage production. Traits of the corn variety used in making good corn silage production should have high leaf/stem ratio yield, wide and long leaves, fewer dead leaves, or more green leaves, and stays green until the corn ear has matured. In Thailand, standard plant spacing used in growing field corn is 75×20 cm, with corn planting density approximately at 66,667 plants/ha. For corn silage production, Chayanont et al. (2021) reported that plant spacing did not significantly affect plant height (cm) and ears per plant, while the narrower 75×20 cm spacing produced a higher fresh leaf yield (13 ton/ha) and dry stalk yield (4.5 ton/ha) than 75×25 cm spacing. Abuzar et al. (2011) found that plant spacing of 75×22.7 cm (planting density of 40,000 plants/ha) provides a dry matter yield higher than plant spacing of 75×9.6 cm (planting density of 140,000 plants/ha). This is because high plant density increases competition among plants, and can help in increasing the amount of light, water, and food nutrients. Narrow spacing can increase the height of corn stalks, but tall corn stalks can result in lodging (Douglas et al., 1982). By increasing plant density, this tends to result in the reduction of quantity of kernels per row in the corn ear.The number of kernels in each row is an important factor in determining yield output and quality of corn. Low quantity of kernels per row of corn ear will indicate a low amount of starch and high amount of fiber (low energy) (Tetio-Kagho and Gardner, 1998; Echarte et al., 2000). However, Chayanont et al. (2021) reported that the CP of corn silage did not significantly differ between 75x20 and 75x25 cm (6.64 and 6.80%, respectively). The fiber content of corn silage increased with an increase in plant density, whereas fiber digestibility will be decreased (Cuomo et al., 1998). Similar results were also found in Stanton et al. (2007), the increasing plant density can reduce CP percentage, but increase NDF and ADF percentage. However, many studies have shown that increasing plant density has minimum effects on the nutritive value and digestibility of corn silage (Cuomo et al., 1998). However, the optimum planting density of corn silage for increased yield output is between 45,000-125,000 plants/ha. This also depends on the variety of corn (Stanton et al., 2007). From the above research, it is shown that corn variety and plant spacing are factors that require investigations to identify the optimal corn variety and plant spacing for corn silage production. Therefore, the objective of the present study was to determine the optimal variety and plant spacing to produce the suitable growth, yield components, biomass yield of field corn and nutritional value of corn silage in paddy field conditions.

MATERIALS AND METHODS

The field experiment was conducted in a paddy field at Lopburi Research Station, Faculty of Agriculture, Kasetsart University, Khok Charoen district, Lopburi province during 2018-2019. Soil analyses of the 0-30 cm depth was a clay soil with low to medium acidity (pH 6.5–7.2), medium organic matter (2%), and high available phosphorus and exchangeable potassium (210 and 127 ppm, respectively).

The experiment was arranged in a split plot design in RCBD with 4 replications. The main plot contained 3 plant spacings viz. 75×15 cm (88,888 plants/ha), 75×20 cm (66,667 plants/ha) and 75×25 cm (53,333 plants/ha). The sub-plot consisted of 5 open pollinated varieties and hybrids, which are CP888 (control), SW5 (Suwan 5), NS3 (Nakhon Sawan 3), S7328 and SW4452 (Suwan 4452). The experiment was planted in February 2018. Each variety was planted in four rows, with the row length of 5 m. Chemical fertilizer of 16-20-0 formula was applied as a basal fertilizer in the rate of 156 kg/ha. After planting, the pre-emergence herbicide (atrazine and pendimethalin) was sprayed to control weeds. At the 10 days after germination, the seedlings were thinned according to the experimental treatment. Urea fertilizer (46-0-0) was used at rate of 156 kg/ha and hand weeding was done to control weeds at 3 weeks after germination. Sprinkler irrigation was provided to the crop when the humidity of the soil reached below 50% field capacity (once a week). There was 20 mm of rainfall at early the planting stage (early February 2018). Two weeks after planting, the rainfall declined. The rainfall increased again after the corn reached the age of approximately 4 weeks. The rainfall started to decrease from March to April 2018 and increased in a small amount until the harvesting period. At the end of April 2018, rainfall had increased to the amount of 100 mm.

In April 2018, data of plant height, ear height, tasseling, silking, and ears/plant were collected. Each plot's two center rows were harvested at 85–90 days after planting, (75% of kernel milk-line), leaf greenness was measured on harvesting day, biomass yield, leaf, stem, ear, total biomass, dead leaves, and leaf/stem ratio were collected. Three plants per plot were randomly selected and were placed in a hot air oven at a temperature of 80°C for 72 hours to observe their dry matter. The 15 random plants/plot were chopped to ensile in a plastic bag. After 28 days of ensiling, corn silages were opened for analysis of the pH level, lactic acid content, and nutritional value (i.e. crude protein), according to the method of the Association of Official Analytical Chemists (AOAC, 1990). Furthermore, analysis of the amount of neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) was performed according to the method of Van Soest et al. (1991) by using a Fiber analyzer (Ankom200). Ash was analyzed content according to the method of the AOAC (1990). All of the collected data were then used to perform analysis of variance and mean difference at the confidence level of 95 percent using the method of DMRT.

RESULTS

Germination percentage, plant height, ear height, tasseling and silking

Table 1 shows statistically significant results that plant spacing of 72×25 cm combination with corn variety CP888 has a higher germination percentage than that of plant spacing of 75×25 cm combination with SW5. At the age of 60 days after planting, it was found that plant spacing of 75×25 cm combination with CP888 had taller plant height than those of plant spacing of 75×15 cm with all other corn varieties, as well as plant spacing of 75×20 cm combination with NS3 and SW4452. Furthermore, plant spacing of 75×20 cm combination with CP888 also showed higher ear height than those of all other plant spacings that were grown with corn varieties NS3, S7328, and SW5. Plant spacing of 75×15 cm combination with NS3 and S7328, and plant spacing of 75×25 cm with CP888, would have 57 days of tasseling, which is longer than plant spacing 75×15 cm combination with SW4452 (54 days). In addition, plant spacing of 75×20 cm combination with SW4452 have longer silking days than those of plant spacing of 75×20 cm combination with NS3, and plant spacing of 75×25 cm combination with NS3 and SW5.

Table 1. Germination percentage, plant height, ear height, tasseling and silking of field corn under different spacings and varieties.

Spacing (A)	Varieties (B)	Germination (%)	Plant height (cm)	Ear height (cm)	Tasseling (days)	Silking (days)
75×15	CP888	$93^{ab1/}$	157^{bc}	93^{abcd}	56^{ab}	55^{ab}
	NS3	87^{ab}	153^{bc}	88^{cd}	57^{a}	55^{ab}
	S7328	90^{ab}	149^{c}	89^{bcd}	56^{a}	55^{ab}
	SW4452	93^{ab}	148^{c}	94^{abc}	54^{b}	55^{ab}
	SW5	91^{ab}	156^{bc}	87^{cd}	56^{ab}	55^{ab}
75×20	CP888	92^{ab}	168^{ab}	102^{a}	56^{ab}	54^{ab}
	NS3	95^{ab}	148^{c}	84^{d}	55^{ab}	54^{b}
	S7328	93^{ab}	158^{abc}	92^{bcd}	56^{ab}	55^{ab}
	SW4452	92^{ab}	154^{bc}	94^{abc}	56^{ab}	56^{a}
	SW5	88^{ab}	161^{abc}	91^{bcd}	55^{ab}	55^{ab}
75×25	CP888	99^{a}	173^{a}	98^{ab}	57^{a}	55^{ab}
	NS3	88^{ab}	159^{abc}	88^{cd}	55^{ab}	54^{b}
	S7328	97^{ab}	148^{c}	91^{bcd}	55^{ab}	55^{ab}
	SW4452	93^{ab}	155^{bc}	94^{abc}	56^{ab}	55^{ab}
	SW5	83^{b}	167^{ab}	92^{bcd}	55^{ab}	54^{b}
CV (%)	A×B	12.53	5.12	5.32	1.92	2.45
LSD 0.05	A	2.66^{ns}	10.29^{ns}	5.64^{ns}	1.40^{ns}	1.63^{ns}
	B	2.77^{ns}	8.91^{**}	5.45^{**}	0.87^{*}	1.10^{ns}
	A×B	4.81^{ns}	15.43^{**}	9.43^{**}	1.52^{**}	1.92^{*}

Note: 1/ Means followed by different letters in each column at 95% by Duncan's Multiple Range Test. ns = non-significant, * = significantly different at 95%, ** = significantly different at 99%

Leaf greenness, ears/plant, and leaf/stem ratio

Table 2 indicates that plant spacing of 75×20 cm combination with CP888 is found to produce more leaf greenness than those of plant spacing of 75×15 cm combination with CP888 and S7328, as well as plant spacing of 75×20 cm combination with S7328. Plant spacing of 75×20 cm combination with CP888 (1.6 ears/plant), which is statistically significantly higher ears/plant than those of all other plant spacings with different varieties, except plant spacing of 75×25 cm combination with CP888 (1.4 ears/plant). Plant spacing of 75×15 combination with NS3 produced leaf/stem ratio of 0.86, which is higher than those of plant spacing of 75×15 cm combination with SW4, plant spacing 75×20 cm combination with CP888, and plant spacing 75×25 cm combination with CP888, S7328 and SW4452.

Table 2. Leaf greenness, ears/plant and leaf/stem ratio of field corn under different spacings and varieties.

Spacing (A)	Varieties (B)	Leaf greenness	Ears/plant	Leaf/stem ratio
75×15	CP888	$14.23^{bc1/}$	1.2^{bc}	0.75^{abc}
	NS3	19.60^{abc}	1.0^{c}	0.86^{a}
	S7328	11.03^{c}	1.1^{c}	0.73^{abc}
	SW4452	17.58^{abc}	1.0^{c}	0.70^{abc}
	SW5	16.90^{abc}	1.1^{bc}	0.59^{c}
75×20	CP888	24.35^{a}	1.6^{a}	0.69^{bc}
	NS3	21.53^{ab}	1.0^{c}	0.80^{ab}
	S7328	13.15^{bc}	1.0^{c}	0.75^{abc}
	SW4452	18.25^{abc}	1.1^{bc}	0.77^{ab}
	SW5	17.05^{abc}	1.1^{bc}	0.71^{abc}
75×25	CP888	20.45^{abc}	1.4^{ab}	0.66^{bc}
	NS3	21.53^{ab}	1.3^{bc}	0.73^{abc}
	S7328	16.55^{abc}	1.1^{bc}	0.66^{bc}
	SW4452	19.78^{abc}	1.1^{c}	0.66^{bc}
	SW5	21.63^{ab}	1.2^{c}	0.74^{abc}
CV (%)	A×B	27.56	9.89	11.94
LSD 0.05	A	12.61^{ns}	10.29^{ns}	5.64^{ns}
	B	12.19^{*}	8.91^{**}	5.45^{**}
	A×B	21.11^{**}	15.43^{**}	9.43^{**}

Note: 1/ Means followed by different letters in each column at 95% by Duncan's Multiple Range Test. ns = non-significant, * = significantly different at 95%, ** = significantly different at 99%

Fresh weight yield and yield components

Plant spacing of 75×75 cm combination with S7328, plant spacing of 75×15 cm combination with NS3, and plant spacing of 75×25 cm combination with SW5, produced fresh weight yield higher than that of plant spacing of 75×25 cm combination with S7328 (5.99 tons/ha). Moreover, it is found that plant spacing of 75×25 cm combination with SW5 produced higher fresh stem yield (17.51 tons/ha), than those of plant spacings of 75×15 cm and 75×20 cm combination with NS3, and plant spacing of 75×25 cm combination with NS3 and S7328. Furthermore, plant spacing of 75×15 cm combination with S7238, plant spacing of 75×20 cm combination with CP888, and plant spacing of 75×25 cm combination with SW4452, all produced higher fresh ear yields than those of plant spacing of 75×15 cm with variety SW5, plant spacing of 75×20 cm combination with NS3, and plant spacing of 75×25 cm combination with CP888 and S7328. It was also found that plant spacing of 75×25 cm combination with SW5 produced fresh biomass yield of 40.22 tons/ha, which is more than that of plant spacing of 75×20 cm combination with NS3. Plant spacing of 75×20 cm combination with S7328 also produced higher dead leaf yield than that those of plant spacing of 75×25 cm with variety NS3 (0.21 tons/ha) (Table 3).

Table 3. Fresh weight yield and yield components of field corn under different spacings and varieties.

Spacing (A)	Varieties (B)	Leaf	Stem	Ear	Total	Dead leaf
				(ton/ha)		
75×15	CP888	7.62$^{ab1/}$	15.05^{abc}	13.22^{abc}	36.34^{ab}	0.45^{ab}
	NS3	7.92^{a}	14.13^{bc}	14.33^{abc}	37.02^{ab}	0.64^{ab}
	S7328	8.08^{a}	15.39^{ab}	15.30^{a}	39.14^{ab}	0.37^{ab}
	SW4452	6.74^{ab}	13.57^{abc}	14.43^{abc}	35.26^{ab}	0.51^{ab}
	SW5	6.94^{ab}	15.88^{ab}	12.26^{bc}	35.75^{ab}	0.67^{ab}
75×20	CP888	7.66^{ab}	15.85^{ab}	15.10^{a}	39.39^{ab}	0.79^{ab}
	NS3	6.70^{ab}	10.91^{c}	12.16^{bc}	30.14^{b}	0.37^{ab}
	S7328	6.92^{ab}	14.28^{abc}	13.94^{abc}	36.03^{ab}	0.89^{a}
	SW4452	7.18^{ab}	14.04^{abc}	14.62^{abc}	36.16^{ab}	0.33^{ab}
	SW5	7.16^{ab}	15.77^{ab}	13.44^{abc}	37.06^{ab}	0.69^{ab}
75×25	CP888	7.18^{ab}	14.15^{abc}	11.89^{c}	33.54^{ab}	0.33^{ab}
	NS3	7.10^{ab}	10.99^{c}	12.68^{abc}	30.98^{ab}	0.21^{b}
	S7328	5.99^{b}	12.39^{bc}	12.08^{bc}	31.01^{ab}	0.56^{ab}
	SW4452	7.27^{ab}	13.78^{abc}	15.38^{a}	36.95^{ab}	0.53^{ab}
	SW5	7.98^{a}	17.51^{a}	13.94^{abc}	40.22^{a}	0.79^{ab}
CV (%)	A×B	17.05	15.8	13.88	13.70	17.05
LSD 0.05	A	0.72^{ns}	1.45^{ns}	2.03^{ns}	3.93^{ns}	0.72^{ns}
	B	1.02^{ns}	1.87**	1.57*	4.06*	1.02^{ns}
	A×B	1.77*	3.24**	2.72*	7.03**	1.77*

Note: 1/ Means followed by different letters in each column at 95% by Duncan's Multiple Range Test. ns = non-significant, * = significantly different at 95%, ** = significantly different at 99%

Dry weight yield and yield components

Plant spacing of 75×25 cm combination with NS3 produced higher dry leaf yield (2.76 tons/ha), than those of plant spacing of 75×15 cm combination with SW4452, plant spacing of 75×25 cm combination with NS3 and S7328 (2.01, 2.00 and 1.94 tons/ha, respectively), with statistical significance. Moreover, plant spacing of 75×15 cm combination with SW5 produced higher dry stem yield (3.96 kg/ha) than those of plant spacing of 75×20 cm and plant spacing of 75×25 cm combination with NS3 (2.77 and 2.73 ton/ha, respectively). It was also found that plant spacing of 75×20 cm combination with CP888 produced dry ear yield of 5.05 tons/ha, which is more than those of plant spacing of 75×15 cm combination with SW5, and plant spacing of 75×25 cm combination with NS3 and SW5 (3.59, 3.68 and 3.76 tons/ha, respectively). In addition, plant spacing of 75×20 cm combination with CP888 also produced higher dry biomass yield (11.16 tons/ha) than that of plant spacing of 75×25 cm with variety NS3 (8.41 tons/hectare), with statistical significance (Table 4).

Table 4. Dry weight yield and yield components of field corn under different spacings and varieties.

Spacing (A)	Varieties (B)	Leaf	Stem	Ear	Total
		(ton/ha)			
75×15	CP888	$2.54^{ab1/}$	3.39^{ab}	4.94^{ab}	10.88^{ab}
	NS3	2.76^{a}	3.23^{ab}	4.62^{abc}	10.61^{ab}
	S7328	2.41^{ab}	3.34^{ab}	4.98^{ab}	10.73^{ab}
	SW4452	2.01^{b}	2.94^{ab}	4.4^{7abc}	9.43^{ab}
	SW5	2.25^{ab}	3.96^{a}	3.59^{c}	9.80^{ab}
75×20	CP888	2.48^{ab}	3.64^{ab}	5.05^{a}	11.16^{a}
	NS3	2.20^{ab}	2.77^{b}	3.81^{abc}	8.78^{ab}
	S7328	2.35^{ab}	3.23^{ab}	4.76^{abc}	10.34^{ab}
	SW4452	2.29^{ab}	3.01^{ab}	4.50^{abc}	9.80^{ab}
	SW5	2.34^{ab}	3.28^{ab}	4.23^{abc}	9.84^{ab}
75×25	CP888	2.14^{ab}	3.27^{ab}	4.50^{abc}	9.91^{ab}
	NS3	2.00^{b}	2.73^{b}	3.68^{c}	8.41^{b}
	S7328	1.94^{b}	2.93^{ab}	3.81^{abc}	8.68^{ab}
	SW4452	2.15^{ab}	3.23^{ab}	4.74^{abc}	10.11^{ab}
	SW5	2.41^{ab}	3.31^{ab}	3.76^{bc}	9.48^{ab}
CV (%)	A×B	15.42	18.03	14.89	13.88
LSD 0.05	A	0.29^{ns}	0.47^{ns}	0.56^{ns}	1.22^{ns}
	B	0.29^{ns}	0.48^{*}	0.72^{**}	1.13^{*}
	A×B	0.68^{**}	1.12^{**}	1.25^{**}	2.63^{**}

Note: 1/ Means followed by different letters in each column at 95% by Duncan's Multiple Range Test. ns = non-significant, * = significantly different at 95%, ** = significantly different at 99%

pH Level, lactic acid content and nutritional value of corn silage

Table 5 indicates that the pH level of corn silage from plant spacing of 75×25 cm combination with CP888 is 3.85, which is similar to all of plant spacing combination with CP888, plant spacing of 75×20 cm combination with NS3 and S7328, and plant spacing of 75×25 cm combination with SW5. Furthermore, all treatments showed lactic acid content in corn silage with no statistical difference, with the value ranging between 0.10–1.84%. Plant spacing of 75×25 cm combination with SW5 produced higher crude protein CP (6.87%), which is more than that those of plant spacing of 75×15 cm combination with SW4452 (5.27%). Plant spacing of 75×15 cm combination with NS3 produced NDF (62%) more than that of plant spacing of 75×20 cm combination with CP888 (57%). Lastly However, all treatments showed ADF, ADL and Ash content with statistically no difference (ranging between 29–31, 2.50–3.60 and 5.27%, respectively).

Table 5. pH, lactic acid content, CP, NDF, ADF, ADL and Ash of corn silage at different spacings and varieties.

Spacing (A)	Varieties (B)	pH	Lactic acid	CP	NDF	ADF	ADL	Ash
			(%)					
75×15	CP888	$3.76^{ab1/}$	0.13	5.37^{ab}	61^{ab}	31	2.50	2.50
	NS3	3.68^{b}	0.90	6.06^{ab}	62^{a}	31	2.64	2.64
	S7328	3.64^{b}	1.06	5.68^{ab}	61^{ab}	31	2.79	2.79
	SW4452	3.69^{b}	0.10	5.27^{b}	61^{ab}	31	3.00	3.00
	SW5	3.67^{b}	0.70	5.75^{ab}	60^{ab}	30	2.72	2.72
75×20	CP888	3.75^{ab}	1.19	6.15^{ab}	57^{b}	29	2.69	2.69
	NS3	3.72^{ab}	1.84	5.59^{ab}	62^{ab}	32	2.70	2.70
	S7328	3.77^{ab}	1.10	5.42^{ab}	60^{ab}	31	3.37	3.37
	SW4452	3.68^{b}	0.63	5.67^{ab}	59^{ab}	30	3.11	3.11
	SW5	3.71^{b}	1.14	6.20^{ab}	60^{ab}	31	2.77	2.77
75×25	CP888	3.85^{a}	0.74	5.71^{ab}	56^{ab}	29	2.65	2.65
	NS3	3.65^{b}	0.19	6.22^{ab}	58^{ab}	30	2.55	2.55
	S7328	3.68^{b}	0.48	5.66^{ab}	58^{ab}	30	2.71	2.71
	SW4452	3.66^{b}	1.25	6.09^{ab}	59^{ab}	30	3.60	3.60
	SW5	3.74^{ab}	0.24	6.87^{a}	59^{ab}	29	2.59	2.59
CV (%)	A×B	2.56	146.69	10.63	4.23	5.66	23.59	34.31
LSD 0.05	A	0.09^{ns}	1.14^{ns}	0.91^{ns}	1.96^{*}	1.54^{ns}	0.58^{ns}	3.19^{ns}
	B	0.07^{*}	1.11^{ns}	0.60^{*}	4.22^{*}	1.67^{ns}	0.65^{ns}	1.03^{*}
	A×B	0.14^{*}	1.92^{ns}	1.41^{**}	5.75^{**}	2.90^{ns}	1.12^{ns}	2.04^{ns}

Note: 1/ Means followed by different letters in each column at 95% by Duncan's Multiple Range Test. ns = non-significant, * = significantly different at 95%, ** = significantly different at 99%

DISCUSSION

Plant growth

Plant spacing does not affect height growth of corn. The average height of 60 days after planting, corn was found to be between 152 to 160 cm. Given the clay soil condition of the experimental paddy field, even if it is an upland area, this resulted in low drainage during continuous rainfalls (March - April 2018) which caused flooding in the field experimental for two weeks and led to poor growth of corn plants (at 45 days after planting). In this experiment, plant spacings of 75×15, 75×20 and 75×25 cm had population of 88,888 plants/ha, 66,667 plants/ha and 53,333 plants/ha, respectively, which is in accordance with Carpici et al. (2010) reported that different plant densities (60,000, 100,000, 140,000, 180,000 and 222,000 plants/ha) do not affect plant height (277.84–285.28 cm). Opuku (2017) also found similar results, planting spacing does not affect plant height. The said study found the plant height to be between 243.8–252.8 cm, at different population densities of 54,825, 73,100, 109,650, 146,200 and 219,300 plants/ha. However, increasing plant spacing from narrow to wide, this tended to promote plant height. In case of corn variety, it was found that CP888 produced higher plant height than other varieties, except SW5, especially when grown at plant spacing of 75×25 cm. At the 75×25 cm spacing, it was found to produce the highest plant height comparing with all other varieties grown at plant spacing of 75×15 cm. SW5 showed a tall plant height when grown at plant spacing starting from 75×20 cm onwards. Moreover, SW5 not only has plant height close to CP888, but it also has significantly lower ear height. This is a desirable trait as it reduces the risk of lodging.

Ear height is related to lodging of corn, especially in tall plant height and ear height variety. From the results, it was found that plant spacing does not affect ear height. CP888 was found to produce an ear yield higher than other varieties, except SW4452 at all plant spacings. However, no lodging was found, even though CP888 had more ear yields than other varieties. The lodging of corn plants will most likely occur with varieties with high ear height and tall plant height, especially in strong wind condition. Chayanont et al. (2021) found that a corn plant would fall over due to tall plant height during the rainy season and there was no lodging during the dry season. Moreover, it was observed that lodging has a higher occurrence with varieties that produce a high ear/stem ratio (1.6–1.8 ear/plant), and when accompanied with a tall plant height and high ear height, this will lead to a higher chance of the plant lodging over.

Yield and yield components

By expanding the plant spacing from a narrow space of 75×15 cm (88,888 plants/ha) to a wider space of 75×25 cm (53,333 plants/ha) resulted in corn having significantly more green leaves. In narrow spacing, the leaves and canopy of each plant are close together and decrease the penetration of light into the plant canopies, which results in lower leaves of plants not being able to have full photosynthesis. This led to less cumulative nitrogen and caused leaves to mature and lower leaves to have less greenness quicker (Yan et al., 2017). CP888 and NS3 produce intense greenness in leaves. Both varieties tend to increase leaf greenness when grown at plant spacing of ≥75×20 cm (66,667 plants/ha). Leaf greenness is related to the amount of crude protein CP. In the sorghum variety with a high crude protein, it will also have a high value of nitrogen in leaves. The sorghum variety can maintain leaf greenness well because it can keep the protein in chloroplast and an amount of absorbed nitrogen better (Borrell et al., 2001). From the experiment, it was found that S7328 produces low leaf greenness as well as a low level of crude protein.

Plant spacing tends to increase ears per plant in certain varieties (NS3 and SW5), when plant spacing is expanded to 75×25 cm (53,333 plants/ha). CP888 produces significantly more ears per plant than any other varieties, because CP888 is a variety with genetics of two ears, especially at wider spacing. Frank and Hallauer (1997) also found that corn with prolific traits will produce more ears at wide spacing, whereas other varieties will not produce more ears per plant even if plant spacing has been increased. Ponrat (2006) found that corn variety SW5 cultivated at 75×30 cm plant spacing would provide the highest ears/plant. This is also confirmed by the study of Jampatong et al. (2000), which reported improvement in corn variety to increase ears/plant, and two ears/plant has the potential of increasing yield at wide plant spacing of 75×30 cm (44,444 plants/ha). Chayanont et al. (2021) also reported that corn variety tend to increase the ears/plant at wider spacing, varieties NSX982013, TE1719, WS6437, and WS6440 were found to have more ears/ plant. Plant spacing does not affect the leaf/stem ratio of corn. NS3 was found to produce high ratio of leaves to stem, because this variety has more leaves and less stem. Furthermore, NS3 also produced a higher leaf/stem ratio when grown at narrow spacing rather than wide spacing. Even though other varieties may have a similar plant height, they resulted in a lower leaf/stem ratio. A high leaf/stem ratio is a desirable trait in making corn silage. S7328 and SW4452 also tend to produce a high leaf/stem ratio at narrow spacing. This is opposite to SW5, which has a lower leaf to stem ratio when grown at narrow spacing. SW5 responds better in wide plant spacing resulting in a higher stem yield but lower leaf/stem ratio. Plant spacing does not affect leaf yield, stem yield, ear yield and fresh biomass yield. However, leaf yield, stem yield, ear yield and biomass yield tend to increase at narrow spacing compared to wide spacing. NS3 and S7328 produced a high leaf yield at the narrowest spacing of 75×15cm (7.92 and 8.08 ton/ha). S7328 produced a significantly lower leaf yield at wide spacing of 75×25 cm, whereas expanded plant spacing increased leaf yield of SW5. In addition, SW5 also produced the high stem yield and total biomass yield (17.51 and 40.22 kg/ha), especially at plant spacing of 75×25 cm (53,333 plants/ha). This is in accordance with the study of Abuzar et al. (2011), found that population density at 58,750 plants/ha (75×22.7 cm) produces a higher dry biomass yield than those of 40,400 plants/ha (75×33.33 cm), 71,681 plants/ha (75×18.60 cm), 117,756 plants/ha (75×13.5 cm), 99,066 plants/ha (75×13.5 cm), 120,481 plants/ha (75×11.10 cm) and 138,888 plants/ha (75×9.6 cm). SW4452 produced the highest ear yield (15.38 kg/ha), especially at the 75×25 cm plant spacing. CP888 and S7328 produced the high fresh ear yields when grown at plant spacing of 75×20 cm and 75×15 cm, respectively. Plant spacing and varieties do not affect the quantity of dead leaves. SW5 showed a high of dead leaves, especially under the wide plant spacing of 75×25 cm. Although NS3 produced as high a leaf yield as variety SW5, NS3 had fewer dead leaves at the widest plant spacing. However, NS3 tended to have more dead leaves at the narrowest spacing of 75×15 cm.

pH Level, lactic acid content, and nutritional values

All plant spacings have no effect on the pH level of corn silage. CP888 showed high pH level, especially at the widest plant spacing of 75×25 cm and tended to have a high pH level in all plant spacings. However, the pH level of corn silage in all treatments was found to be a suitable level. Silage should have pH value ranges between 3.6–4.2 (Tudsri, 2004), which is the suitable pH level for the complete ensiling process. Plant spacing and corn variety do not affect the lactic acid content in corn silage, with the value ranging between 0.13–1.84%, which is lower than the standard level. The standard level of lactic acid content should be at least between 3–13% (Tudsri, 2004).

Plant spacing has no effect on the quantity of crude protein. Crude protein tends to increase with expanded plant spacing from 75×15 cm to 75×25 cm, whereas Opoku (2017) found that corn cultivation at spacing of 75×18 cm and 75×24 cm produced a similar quantity of crude protein with no statistical significance. SW5 produced a high crude protein level, even though it is not a high leaf/stem ratio variety. However, the crude protein of corn silage in all methods was found to be suitable in a medium level (5–7%) for ruminants (DLD, 2004).

Narrow plant spacing tends to produce a higher NDF content than wide plant spacing. Stanton et al. (2007) reported that increased population density would cause the percentage of cob, starch, and protein to decrease, whereas NDF and ADF content will increase. Increasing plant densities increased stem yield (more stemmy) and tented to decreased leaf /stem ratio. Increasing NDF and ADF may be correlated with the reduced leaf/stem ratio at high plant density (Baghdadi et al., 2016). NDF is mostly found in the leaf rather than the stem. Therefore, NS3 which has a high leaf/stem ratio will produce a high NDF content when compared to other stemmy varieties (CP888 and SW5). However, the NDF content should not exceed 60%. ADF can be digested by ruminants by microorganisms in the rumen, whereas ADL cannot be digested nor used by ruminants. All treatments produced an appropriate level of ADF, (NRC 1988), indicated that the ADF content should not exceed 35%. ADL should have the lowest level possible because it reduces the usefulness of corn silage. Normally the ADL content is less than 4% in corn plant, which the ADL content of the present study was found to be between 2.50–3.60%. Ash is also not usable for ruminants, and hence should be kept at a low level. Narrow plant spacing tends to produce a higher ash level than wide spacing. SW5 has a higher ash content, indicating that it has high minerals when compared to SW4452. However, all treatments produce ash at a low level in comparison with napier grass silage (Tudsri, 2004).

CONCLUSION

Corn variety SW5 is the optimal variety for cultivation in a paddy field, because it produces a high leaf yield, high stem yield, and high fresh biomass yield. In addition, it also produces an ear yield in the similar high quantity as that produced by varieties grown at the widest plant spacing of 75×25 cm. Moreover, SW5 also provides a level of nutritional value similar to other varieties. All varieties and all plant spacings produce similar nutritional values, except CP888, which gives the high pH level at the widest plant spacing of 75×25 cm. CP888 also tends to produce a high pH level at all plant spacings. It was also found that CP888 produces a lower NDF content at the widest plant spacing of 75×25 cm rather than the narrowest plant spacing of 75×15 cm. Plant spacing of 75×25 cm also produced an optimal level of NDF.

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AUTHOR CONTRIBUTIONS

Songyos Chotchutima: Performed the experiment; Analyzed and interpreted the data; Wrote the manuscript.

Phoompong Boonsaen: Contributed reagents, materials, chemical analysis tools.

Sujin Jenweerawat and Jutamas Romkaew: Contributed corn seeds; Wrote the manuscript.

Sutus Pleangkai: Assisted the field establishment and management, the data collection.

Choosak Jompuk, Ed Sarobol and Sayan Tudsri: Conceived and designed the experiment and were the adviser of this project.

All authors have read and approved of the final manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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