韓作誌(Korean J. Crop Sci.) 34(2):192～197(1989)

Effects of Planting Density and Tiller Removal on Growth and Yield of Sweet Corn Hybrids

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栽植密度와 蘗子除去가 단옥수수의 生育 및 收量에 미치는 影響

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ABSTRACT

Two sweet corn hybrids, 'Tanok 1' and 'Golden Cross Bantam 70 (GCB 70)' were grown at five plant densities, of 4,167, 5,556, 6,667, 8,333, and 11,111 plants per 10 ares, with or without tiller removal, to determine effects of tiller removal on growth and yield of sweet corn hybrids at various plant densities. Tillers were pulled when less than 15 cm tall.

The number of tillers per plant linearly decreased as plant density increased. The two hybrids had similar plant height, ear length and diameter, ear weight and the number of ears per plant and 10 ares. Tanok 1 lodged approximately 20% at above 8,333 plants per 10 ares, while GCB 70 did not lodge at all, at any plant density. Tanok 1 had higher leaf area index (LAI), ear and stover yields than GCB 70. Except for root lodging and LAI, hybrid x plant density interaction was not significant at 5% probability level. Plant density did not affect silking data. Increasing plant density linearly increased plant height, LAI, and stover yield, but linearly decreased ear length, ear weight, and the number of ears per plant. Increase in LAI was greater in Tanok 1 than in GCB 70, with increasing plant density. The relationships between the number of ears and ear yield per 10 ares and plant density were quadratic. The optimum plant density was estimated to be approximately 6500 plants per 10 ares, using the equation based on ear yield. Except for ear height and LAI, hybrid x tiller removal and plant density x tiller removal interactions were not significant. Hybrid x plant density x tiller removal interaction was not significant for any characters. When averaged over hybrids and plant densities, tiller removal reduced plant height and ear and stover yields by about 3, 10, and 16%, respectively, but did not significantly affect silking date, root lodging, ear length and diameter and the number of ears per plant and per 10 ares. The results indicate that the optimum plant density is approximately 6500 plants per 10 ares, regardless of tiller removal and tillers are not to be removed at any plant density.

INTRODUCTION

The tillers of corn plants are basal branches of the main plant and retain a vascular connection with it, but develop an independent root system[12].

Tillers of corn is both genetically and environmentally controlled. Nearly all cultivars of sweet corn tiller more or less abundantly[2,4,7,9]. However, modern dent corn cultivars tiller relatively infrequently and usually senesce before silking under intensive cultural conditions[13]. The optimal amount of available nutrient (especially nitrogen)

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markedly promotes tiller production[3]. Tiller production of corn is greatest when soil moisture is plentiful[7]. Tiller production is reduced by increased plant density[2,3,14].

In Korea, manual removal of tillers has been practiced in sweet corn production[9]. Growers believe that plant performance is better if tillers is removed. However, removal of tillers has usually reduced yield of sweet corn[4,5]. Also, there is some evidence that the presence of active, barren tillers may be an important characteristic for reducing maize yield losses, where environmental stress limits nutrient absorption and assimilation during late vagative and early reproductive growth[1,13,16].

Studies on plant density for sweet corn were generally conducted without tiller removal. Park et al[10]. found that the optimum plant density for sweet corn hybrid at Suwon, Korea was around 6500 plants pcr 10 ares. Tiller removal effects on agronomic characteristics of sweet corn grown at various plant populations were not determined. The objective of this study was to determine the effects of tiller removal on growth and yield of sweet corn grown at different plant populations, hybrid x tiller removal, and plant density x tiller removal interactions.

MATERIALS AND METHODS

A field trial was conducted on an upland field of the Crop Experiment Station at Suwon in 1984. The experiment consisted of all combinations of two hybrids ('Tanok 1' and 'Golden Cross Bantam 70'), five plant densities (4167, 5556, 6667, 8333, and 11111 plants per 10a), and two tiller removal treatments (control and removal) in a split-split design. Each sub-subplot (tiller removal treatment) was replicated four times within each subplot of plant density rate of each hybrid. The smallest experimental unit was four rows with 5 meter length. Plant spacings of 40, 30, 25, 20, and 15 cm in 60 cm row gave 4167, 5556, 6667, 8333, and 11111 plants per 10 ares, respectively. Tillers were pulled when less than 15 cm tall.

Seeds were planted by corn jabber, two kernels per hill, and plants were thinned to one per hill at 3 to 4 leaf stage. At planting, fertilizer was applied at the rate of 15, 13 and 13 kg per 10 ares for N, P_2O_5, and K_2O, respectively. Weeds were controlled by preemergence application of alachlor and simazine at 74 and 35 g per 10 ares, and by hand-weeding as necessary.

The green leaf areas of four plants per plot were determined at silking. Leaf area was calculated as length x width x 0.75[8]. At 25 days after silking, date were recorded for plant height, ear height and lodging, and two center rows were harvested for ear and stover yields. Ears were husked and graded by size as either marketable or cull. Marketable ears had at least 13 cm of grains earlength. Ear characters were determined using marketable husked ears.

RESULTS AND DISCUSSION

Tanok 1 tillered approximately twice as many as GCB 70, regardless of plant density (Table 1). The number of tillers per plant in the control plants decreased linearly as plant density increased. Tiller production has previously been reported to decrease with increasing plant density in corn[2,3,14]. The production of tillers is believed to be associated with endogenous hormones and the availability of carbohydrates[11]. Our observed reduction in tiller production at the higher plant densities can probably be explained on a basis of low available carbohydrate supplies due to mutual

Table 1. The number of tillers of two control sweet corn hybrids at silking.

Plant density (plts./10a)	No. of tillers per plant		
	Tanok 1	GCB 70	Mean
4167	3.0	1.5	2.3
5556	2.2	1.0	1.6
6667	2.3	0.9	1.6
8333	1.6	0.8	1.2
11111	1.4	0.6	1.0
Coeffecients of equations relating plant density			
Intercept	3.67	1.77	2.76
Linear	-2.19E-4	-1.13E-4	-1.72E-4
r^2	0.86	0.82	0.85

shading.

Tanok 1 and GCB 70 silked on July 6 and June 28, respectively. Silking date of the two hybrids was not affected by either plant density or tiller removal.

Mean squares from the analysis of variance for various agronomic characters are presented in Table 2. Since hybrid x plant density, hybrid x tiller removal, plant density x tiller removal, hybrid x plant density x tiller removal interactions are not significant at 5% probability level except for ear height, root lodging and leaf area index, only main effects of the treatments for the other characters are shown in Table 3.

Plant heights of Tanok 1 and GCB 70 were 165 and 154 cm, respectively. Plant height linearly increased with increasing plant density and was reduced by tiller removal. Tanok 1 had greater ear height than GCB 70. Ear height was not consistently affected by plant density and tiller removal.

Tanok 1 lodged approximately 20% at above 8333 plants per 10 ares, but GCB 70 did not, at any plant density (Table 4). Lodging was not affected by tiller removal (Table 2). It has been known that when any lodging occurs, the thick stands lodge more than medium and thin stands[3].

Leaf area index (LAI) increased more markedly in Tanok 1 than GCB 70 with increasing plant density (Table 2 and 5). Tiller removal decreased LAI in Tanok 1 more than in GCB 70, since percent of total leaf area in tillers of control plants was greater in Tanok 1 than in GCB 70 (Talbe 5).

Table 2. Mean squares from analysis of variance for various agronomic characters of two sweet corn hybrids.

Source of variation	df	Plant height	Ear height	Root lodging	Leaf area index	Ear length	Filled ear length
Block	3	56.5	99.3	246.7	2.75	2.50	4.80
Hybrid (H)	1	2050.3	3013.5*	2942.3**	124.13**	3.37	78.09**
Error A	3	481.6	125.6	246.7	0.47	0.88	1.78
Plant density (PD)	4	333.1*	61.0	492.7*	15.02**	7.72*	15.87*
H x PD	4	99.1	36.5	492.7*	2.51*	2.74	0.87
Error B	24	58.7	27.9	139.1	0.38	1.90	2.13
Tiller removal (TR)	1	382.8*	46.5	28.8	64.96**	0.42	0.02
H x TR	1	46.5	82.0*	28.8	21.27**	1.35	0.49
PD x TR	4	72.9	49.6*	15.9	0.40	2.70	0.83
H x PD x TR	4	53.8	18.2	15.9	0.22	0.34	0.17
Error C	30	44.4	18.0	71.2	0.67	1.49	2.05

Source of variation	df	Ear diameter	Ear weight	No. of ears/ plant	No. of ears/ 10a	Ear yield	Stover yield.
Block	3	0.09	680	0.14+	7110306*	141375**	1481660*
Hybrid (H)	1	0.08	726	0.00	508805	36040	10212349**
Error A	3	0.07	292	0.02	291463	3586	142037
Plant density (PD)	4	0.14	4834**	0.57*	3763333*	76985**	3224410**
H x PD	4	0.14	768	0.02	629319	3502	552633
Error B	24	0.09	407	0.02	1136090	17762	211981
Tiller removal (TR)	1	0.00	25	0.04	2201825	90317+	5496237**
H x TR	1	0.09	946	0.00	182596	69620	8591
PD x TR	4	0.04	1222	0.02	902458	20035	148023
H x PD x TR	4	0.01	62	0.01	113782	5582	138368
Error C	30	0.07	450	0.02	801038	29933	241122

[1] Ear characters were measured using marketable husked ears.

+, *, ** Signficant at the 0.10, 0.05 and 0.01% probability levels, respectively.

Table 3. The agronomic characters of sweet corn at harvest for different hybrids, plant densities and tiller removals[1]/.

Treatment	Plant height (cm)	Ear height (cm)	Ear length (cm)	Filled ear length (cm)	wt. (g)	No. of ears/plant	No. of ears/10a	Ear yield (kg/10a)	Stover yield (kg/10a)
Hybrids									
Tanok 1	164.5	68.2	17.6	16.9	166	0.70	4529	743	3830
GCB 70	154.4	56.0	18.0	14.9	154	0.70	4689	701	3116
LSD (0.05)	NS	8.0	NS	0.9	NS	NS	NS	42	268
Plant densities (plants/10a)									
4167	152.4	60.3	18.6	16.9	183	0.90	3753	685	2956
5556	159.0	61.6	18.3	16.5	168	0.86	4764	812	3145
6667	159.9	63.3	17.9	16.4	162	0.71	4959	775	3446
8333	160.9	60.4	17.5	15.1	152	0.58	4794	695	3750
11111	165.1	64.8	16.8	14.6	136	0.46	4775	643	4068
LSD (0.05)	5.6	NS	1.0	1.0	7	0.10	778	97	336
Coeffecients of equations relating plant density									
Intercept	148.1	62.1	19.7	18.5	206	1.19	725	453	2286
Linear	1.59E-3	NS	-2.62E-4	-3.75E-4	-6.5E-3	-6.78E-5	1.01	0.09	0.17
Quadratic	NS	NS	NS	NS	NS	NS	-5.87E-5	-6.91E-6	NS
R_2	0.86	0.47	0.99	0.93	0.98	0.96	0.81	0.62	0.98
Tiller removal									
Control	161.7	62.9	17.8	15.9	161	0.72	4775	756	3735
Removal	157.3	61.3	17.9	15.9	160	0.68	4443	688	3211
LSD (0.05)	3.0	NS	NS	NS	NS	NS	NS	NS+	224

[1]/ Ear characters were measured using marketable husked ears.
NS=Not significant at the 5% probability level.
+ Significant at 10% probability level.

Table 4. Percent root lodging of two sweet corn hybrids at various plant densities.

Plant density (plts./10a)	GCB 70	Tanok 1
4167	0.0	0.0
5556	0.0	4.5
6667	0.0	3.9
8333	0.0	26.1
11111	0.0	19.6

Tanok 1 and GCB 70 had similar ear length, but Tanok 1 had greater filled ear length (Tables 2 and 3). As plant density increased, ear and filled ear length decreased linearly. They were not affected by tiller removal. Ear diameter was approximately 4.1 cm and was not affected by the treatments (Table 2). Ear weights of Tanok 1 and GCB 70 were 166 and 154 g, respectively. Ear weight decreased from 183 to 136 g, as plant density increased from 4167 to 11111 plants per 10 ares. Ear weight was not affected by tiller removal. This generally agrees with the observation of Mack[6] that ear weight decreased with increased plant densities. Also, in field corn, ear weight has been known to decrease with increased plant densities except in the case of cultivars which tend to produce more than one ear at low plant density levels[3]. However, Park et al[10]. did

Table 5. Leaf area index of two sweet corn hybrids as afected by plant density and tiller removal.

Plant density (plts./10a)	Tanok 1 Control	Tanok 1 Removal	GCB 70 Control	GCB 70 Removal
4167	4.9 (61)[1]/	2.0	2.3 (48)	1.1
5556	4.9 (49)	2.6	2.4 (32)	1.5
6667	6.2 (48)	3.2	2.5 (22)	1.8
8333	6.4 (43)	3.9	2.6 (14)	2.3
11111	8.6 (37)	5.2	3.7 (14)	2.8
Coeffecient of equations of equations relating plant density				
Intercept	2.3	0.1	1.3	0.2
Linear	5.48E-4	4.54E-4	1.93E-4	2.36E-4
r^2	0.93	0.99	0.83	0.98

[1]/ ; Values in parenthesis indicate percent of total green leaf area in tillers of control plants.

not find a consistent trend at the plant density trial for sweet corn.

Both hybrids had 0.70 ears per plant (Table 2). The reduction in ear numbers per plant as plant density increased in this study, is analogous to the observations by Mack[6] and Warren[15]. Tiller removal did not significantly influence ear numbers per plant. There was no significant difference between Tanok 1 and GCB 70, for the number of ears per 10 ares (Tables 2 and 3). The relationship between the number of ears per 10 ares and plant density was quadratic (Table 3). This somewhat agrees with the observation by Park et al[10]. that the ear number per 10 ares increased up to 6500 plants per 10 ares and then decreased. Tiller removal did not significantly affect the ear number per 10 ares.

Ear yield of Tanok 1 was 6% higher than that of GCB 70 (Table 3). The relationship between ear yield and plant density was best described by quadratic model (Table 3). The optimum plant density for ear yield of sweet corn hybrids was estimated to be 6510 plants per 10 ares, using the quadratic equation ($Y=453+0.09X-6.91E\text{-}6X$, $R^2=0.62$). This somewhat agrees with the observation of Park et al[10]. that the highest ear yield was obtained at 6500 plants per 10 ares in early and ordinary seasons. Tiller removal reduced ear yield by 10% ($P<0.10$).

Sweet corn stover can be utiliized for cattle. Stover yields of Tanok 1 and GCB 70 were 3830 and 3116 kg per 10 ares, respectively. Stover yield increased from 2956 to 4068 kg per 10 ares as plant density increased from 4167 to 11111 plants per 10 ares. Tiller removal reduced stover yield by 16%.

The results indicate that the optimum plant density for sweet hybrids is approximately 6500 plants per 10 ares, on a basis of ear yield, whether tillers are removed or not. Based on our results and those of Hong et al[4]. and Jones et al[5]., tiller removal had no advantage at any plant density for sweet corn production. Howere, tiller removal may facilitate spray, or dusting, and harvesting.

摘 要

栽植密度를 달리할 때 蘖子除去가 단옥수수의 生育 및 收量에 미치는 影響을 究明하고자 단옥 1호와 Golden Cross Bantam 70 (GCB 70) 을 10a當 4167, 5557, 6667, 8333, 11111 個體 栽植하여 蘖子의 草長이 15cm 以內일 때 蘖子를 除去하는 구와 除去하지 않은 구의 生育 및 收量 等을 調査한 結果를 要約하면 다음과 같다.

1. 두 交雜種 모두 栽植密度가 增加할수록 個體當 蘖子數는 直線的으로 減少되었다.

2. 稈長, 穗長, 穗經, 個體當 및 10a當 이삭수는 交雜種間에 差異가 없었다. 단옥 1호는 10a當 8333本 以上 栽植區에서 約 20% 根倒伏이 되었으나 GCB 70은 栽植密度에 關係없이 倒伏이 전혀 되지 않았다. 葉面積指數 및 稈葉收量은 단옥 1호가 GCB 70보다 컸었다.

3. 根倒伏과 葉面積指數를 除外하고는 交雜種과 栽植密度間 交互作用이 없었다.

4. 栽植密度가 增加할수록 稈長, 葉面積指數 및 稈葉收量은 直線的으로 增加하였으나 穗長, 穗重, 本當 이삭수는 直線的으로 減少하였다. 栽植密度 增加에 따른 葉面積指數의 增加는 GCB 70보다 단옥 1호에서 컸었다.

5. 栽植密度와 10a 當 이삭수 및 이삭收量과는 二次曲線的인 增加 關係가 있었으며 이삭收量, 10a當 이삭수, 이삭크기 等을 고려한 適正栽植密度는 10a當 6500本 程度로 판단되었다.

6. 着穗高와 葉面積指數를 除外하고는 交雜種과 蘖子除去, 栽植密度와 蘖子除去間에 有意한 交互作用이 없었으며 交雜種, 栽植密度, 蘖子除去間에는 어떠한 形質에도 有意한 交互作用이 없었다.

7. 蘖子除去에 依하여 稈長, 이삭收量 및 稈葉收量이 각각 3, 10, 16% 減少되었으나 出絲期, 根倒伏, 穗長, 穗經, 穗重, 本當 및 10a當 이삭수 등은 크게 影響을 받지 않았다.

8. 따라서 蘖子除去를 하거나 除去를 하지 않거나 간에 適正栽植密度는 10a當 6500本 程度로 생각되며 交雜種, 栽植密度에 關係없이 蘖子를 除去하지 않은 것이 有利할 것으로 판단되었다.

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