

## Comparisons of Pericarp Thickness And Sugar Content on New Waxy Corn Hybrids

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**ABSTRACT** For waxy corn hybrid development, 23 waxy corn hybrids were planted and surveyed in both pericarp thickness and sugar content. Pericarp thickness showed average 50 to 49  $\mu\text{m}$  in field and greenhouse. Results like these advanced than previous other hybrids. Also, sugar content in developed waxy corn evaluated as 13.6 to 15.3 brix. Here, we concluded that edible quality of waxy corn depended on combing of two factors. Especially, CNU11H8 hybrid at field and CNU11H-38 at greenhouse were good in both factors. Accordingly, these hybrids will be planted in next time for productivity and area adaptation.

**Keywords** : pericarp thickness, sugar content, waxy corn, hybrids

**Waxy** corn, a single recessive gene (*wx*) was located on the short arm of chromosome 9, codes for the waxy endosperm of the kernel(Collins, 1909).These fresh waxy corn was a very popular food in Asian countries including Korea.

Hong (1994) suggested that it is necessary to study on waxy corn hybrids in order to improve its quality and nutritional composition cultivated traditionally. Zhu *et al.* (2014) reported that the pericarp mechanical properties of waxy corn inbred lines is one of important factors affecting the fresh corn eating quality. Besides, Lee *et al.* (2009) reported sugar content is also one among factors for increasing quality of edible waxy corn. Therefore, this study was conducted to gain the prospective hybrids through basic informations and to identify possible hybrids by assessing agronomic characteristics and physico-chemical traits for the development of waxy cornhybrid with high table quality.

## MATERIALS & METHODS

### Plant Materials

This experiment used 23 hybrids developed in Genetics and Breeding Lab. of Chungnam Nat'l Univ. and five controls including Yeonnonng1 as shown in Table 1.

**Table 1.** Hybrids and their parents of waxy corn hybrids.

Hybrids	Cross parent		Kernel color
	Male	Female	
CNU11H-1	CNU 889 $\otimes$	CNU 989 $\otimes$	Yellow
CNU11H-2	CNU 897 $\otimes$	CNU 960 $\otimes$	Yellow
CNU11H-4	CNU 955 $\otimes$	CNU 995 $\otimes$	Yellow
CNU11H-8	CNU 964 $\otimes$	CNU 989 $\otimes$	Yellow
CNU11H-11	CNU 94 $\otimes$	CNU 305 $\otimes$	Purple
CNU11H-29	CNU 1190 $\otimes$	CNU 1285 $\otimes$	Purple
CNU11H-3	CNU 1059 $\otimes$	CNU 1135 $\otimes$	Yellow
CNU11H-6	CNU 1061 $\otimes$	CNU 163 $\otimes$	Purple
CNU11H-12	CNU 1051 $\otimes$	CNU 867 $\otimes$	Yellow
CNU11H-17	CNU 1080 $\otimes$	CNU 1000 $\otimes$	Yellow
CNU11H-19	CNU 1097 $\otimes$	CNU 1021 $\otimes$	Yellow
CNU11H-28	CNU 1191 $\otimes$	CNU 1120 $\otimes$	Yellow
CNU11H-31	CNU 1248 $\otimes$	CNU 1331 $\otimes$	White
CNU11H-34	CNU 1281 $\otimes$	CNU 1285 $\otimes$	White
CNU11H-38	CNU 47 $\otimes$	CNU 819 $\otimes$	Purple
CNU11H-39	CNU 79 $\otimes$	CNU 735 $\otimes$	Purple
CNU11H-53	CNU 458 $\otimes$	CNU 147 $\otimes$	Purple
CNU11H-59	CNU 532 $\otimes$	CNU 651 $\otimes$	Purple
CNU11H-63	CNU 724 $\otimes$	CNU 724 $\otimes$	Purple
CNU11H-69	CNU 824 $\otimes$	CNU 1120 $\otimes$	Purple
CNU11H-73	CNU 903 $\otimes$	CNU 399 $\otimes$	Yellow
CNU11H-75	CNU 905 $\otimes$	CNU 399 $\otimes$	Purple
CNU11H-91	CNU 2246 $\otimes$	CNU 994 $\otimes$	Yellow

Control Chalok 1 (1994), Yeonnonng 1 (1998), Daehakchal Gold (2010), Miheukchal (2004), Ilmichal (2002)

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### Cultivation methods

In order to identify the botanical characteristics of colored corn hybrids, three kernels per hill were planted at Corn Genetic & Breed. Farm on April 28 and August 1 in 2011, respectively. Plant density was 70cm x 30cm. Herbicides after sowing and pesticides were applied at 5th leaf stage for ear worm control, and then followed by mulching. Also, they were thinned remaining one plant per hill at the 3th leaf stage. Fertilizer level of N-P<sub>2</sub>O<sub>2</sub>-K<sub>2</sub>O per 10a was 20-15-10kg. For pest control pesticides were injected at approximately 30 days after sowing.

### Examination of botanical characteristics

Botanical characteristics such as stem height and ear height were examined in 23 waxy corn hybrids. Ear characteristics as ear length, ear diameter, kernel setting ratio, pericarp thickness and sugar content were examined about 30 days after fertilization.

### Statistical analysis

Comparison of traits related to yield and other components were analysed using SAS (v. 9.2).

## RESULTS & DISCUSSION

### Botanical characteristics

The major agronomic characteristics of the cultivated 23 hybrids are presented in Table 2 and 3. The stem height showed a range from 152.8 to 248.3cm. Those of CNU11H-4 and CNU11H-63 showed the highest value of 183.7cm at field and 248.3cm at greenhouse, respectively. But that of CNU11H-8 was 152.8cm at field and CNU11H-6 was 191.6cm at greenhouse, which was the lowest value. Days to tasseling had average 65 days in hybrids grown at field, but that of hybrids grown at greenhouse was remarkably fast as 49days. About these facts, we thought that short days to tasseling results from increasing temperature of the greenhouse. Meanwhile, Chalok1 as a check which is representative of early maturing cultivar in 2000s, was average 56 days at the field and 41 days at the greenhouse. Compared to Chalok 1, other hybrids were approximately 8 days later than the field and the greenhouse. However, those of CNU11H-8 and CNU11H-11 were about 5-6 days faster than Yeonngong 1 as a control at the field. CNU11H-6 and CNU11H-31 grown in the greenhouse were similar to Chalok 1, About these facts, we thought that this hybrid will be advantageous in terms of cropping system. Range of ear height of used hybrids showed 35 to 107 cm. The

**Table 2.** Agronomic characteristics of waxy corn hybrids cultivated at the field in 2011

Hybrids	Characters	Stem height (cm)	Ear height (cm)	Ear length (cm)	Ear dia. (mm)	Kernel setting (%)	Day to tass. (days)	Kernel color
CNU11H-1		182 <sup>ab</sup> ±2.9*	48 <sup>bc</sup> ±2.7	18.2 <sup>abc</sup> ±0.1	42.2 <sup>ab</sup> ±0.9	95	65	Yellow
CNU11H-2		172 <sup>ab</sup> ±3.2	47 <sup>bc</sup> ±1.0	16.4 <sup>a-d</sup> ±0.7	38.4 <sup>ab</sup> ±0.5	97	68	Yellow
CNU11H-4		183 <sup>ab</sup> ±3.9	46 <sup>bcd</sup> ±3.3	16.3 <sup>a-d</sup> ±1.3	36.8 <sup>b</sup> ±1.2	87	63	Yellow
CNU11H-8		152 <sup>c</sup> ±5.0	35 <sup>d</sup> ±3.7	18.4 <sup>ab</sup> ±0.7	38.4 <sup>ab</sup> ±0.7	71	61	Yellow
CNU11H-11		168 <sup>bc</sup> ±5.0	50 <sup>bc</sup> ±4.6	13.3 <sup>cd</sup> ±0.4	37.6 <sup>ab</sup> ±0.6	93	62	Purple
CNU11H-29		171 <sup>ab</sup> ±4.4	52 <sup>b</sup> ±2.8	13.1 <sup>d</sup> ±1.1	37.8 <sup>ab</sup> ±1.3	75	70	Purple
Chalok 1 <sup>†</sup>		150 <sup>c</sup> ±4.4	55 <sup>ab</sup> ±4.2	16.5 <sup>a-d</sup> ±1.1	37.0 <sup>b</sup> ±1.3	95	56	White
Yeonngong1 <sup>†</sup>		177 <sup>ab</sup> ±0.8	39 <sup>cd</sup> ±1.2	14.8 <sup>bcd</sup> ±0.2	31.2 <sup>c</sup> ±0.4	98	67	White
Daehackchal Gold <sup>†</sup>		187 <sup>a</sup> ±6.0	58 <sup>ab</sup> ±2.4	21.2 <sup>a</sup> ±0.9	40.7 <sup>ab</sup> ±0.9	98	70	Yellow
Mihuekchal <sup>†</sup>		181 <sup>ab</sup> ±1.4	68 <sup>a</sup> ±2.3	17.4 <sup>a-d</sup> ±0.6	42.9 <sup>a</sup> ±0.5	97	68	Purple
Mean		172.7	50.1	16.5	38.3	90.6	64	-
CV(%)		6.11	15.18	10.82	4.53	-	-	-

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

\*Mean±Standard Error

<sup>†</sup>Control hybrids

**Table 3.** Agronomic characteristics of waxy corn hybrids cultivated at greenhouse in 2011

Hybrids	Stem height (cm)	Ear height (cm)	Ear length (cm)	Ear dia. (mm)	Kernel setting (%)	Day to tassell. (days)	Seed color
CNU11H-3	208 <sup>b-g</sup> ±4.1	63 <sup>gh</sup> ±2.4	12.6 <sup>f-i</sup> ±0.3	41.1 <sup>a-e</sup> ±1.1	95	43	Yellow
CNU11H-6	191 <sup>g</sup> ±2.0	67 <sup>e-h</sup> ±4.9	13.1 <sup>e-i</sup> ±0.0	38.0 <sup>c-h</sup> ±0.2	70	42	Yellow
CNU11H-12	205 <sup>c-g</sup> ±9.4	80 <sup>d-h</sup> ±4.2	9.9 <sup>i</sup> ±1.3	41.0 <sup>a-e</sup> ±1.2	82	45	Yellow
CNU11H-17	230 <sup>a-e</sup> ±2.8	84 <sup>c-h</sup> ±3.7	18.1 <sup>abc</sup> ±0.2	41.5 <sup>a-d</sup> ±0.6	88	43	Yellow
CNU11H-19	201 <sup>fg</sup> ±9.9	64 <sup>gh</sup> ±0.6	17.1 <sup>a-d</sup> ±0.6	41.7 <sup>abc</sup> ±0.4	90	44	Yellow
CNU11H-28	220 <sup>a-g</sup> ±9.5	95 <sup>bcd</sup> ±3.9	16.1 <sup>b-e</sup> ±0.1	37.8 <sup>e-h</sup> ±0.2	96	44	Yellow
CNU11H-31	212 <sup>a-g</sup> ±3.4	80 <sup>d-h</sup> ±1.8	15.5 <sup>c-f</sup> ±0.2	39.4 <sup>b-g</sup> ±0.5	97	41	Yellow
CNU11H-34	233 <sup>a-d</sup> ±2.8	62 <sup>h</sup> ±1.2	16.0 <sup>b-f</sup> ±0.7	43.3 <sup>ab</sup> ±0.2	77	43	Yellow
CNU11H-38	209 <sup>b-g</sup> ±8.4	69 <sup>e-h</sup> ±2.6	15.3 <sup>c-g</sup> ±0.8	40.6 <sup>f</sup> ±1.1	98	48	Purple
CNU11H-39	226 <sup>a-f</sup> ±0.3	84 <sup>c-h</sup> ±2.3	16.5 <sup>b-e</sup> ±0.5	41.1 <sup>a-e</sup> ±0.7	98	43	Purple
CNU11H-53	226 <sup>a-g</sup> ±9.1	86 <sup>b-g</sup> ±2.5	12.0 <sup>ghi</sup> ±0.7	36.7 <sup>gh</sup> ±0.9	86	56	Purple
CNU11H-59	202 <sup>d-g</sup> ±4.4	82 <sup>d-h</sup> ±4.0	13.6 <sup>e-h</sup> ±0.5	39.6 <sup>b-g</sup> ±0.8	80	43	Purple
CNU11H-63	248 <sup>a</sup> ±9.5	94 <sup>bcd</sup> ±2.1	15.0 <sup>c-g</sup> ±0.5	39.1 <sup>b-g</sup> ±0.4	73	46	Purple
CNU11H-69	247 <sup>a</sup> ±1.4	107 <sup>ab</sup> ±5.6	15.0 <sup>c-g</sup> ±0.5	40.4 <sup>b-f</sup> ±0.4	92	48	Purple
CNU11H-73	236 <sup>ab</sup> ±2.6	88 <sup>b-e</sup> ±2.1	14.3 <sup>d-h</sup> ±0.1	35.3 <sup>gh</sup> ±0.9	84	49	Yellow
CNU11H-75	224 <sup>a-g</sup> ±1.1	87 <sup>b-f</sup> ±1.0	13.8 <sup>d-h</sup> ±0.1	37.8 <sup>d-h</sup> ±0.3	93	49	Yellow
CNU11H-91	222 <sup>a-g</sup> ±6.3	98 <sup>bcd</sup> ±3.7	18.3 <sup>abc</sup> ±3.7	40.4 <sup>b-f</sup> ±0.2	88	50	Yellow
Chalok 1 <sup>†</sup>	202 <sup>efg</sup> ±5.5	66 <sup>e-h</sup> ±10.3	11.1 <sup>hi</sup> ±1.4	38.9 <sup>c-g</sup> ±0.7	91	41	White
Yeonong1 <sup>†</sup>	221 <sup>a-g</sup> ±6.0	106 <sup>abc</sup> ±8.0	18.9 <sup>ab</sup> ±0.1	34.0 <sup>h</sup> ±0.3	95	48	White
Daehackchal Gold <sup>†</sup>	234 <sup>abc</sup> ±0.3	127 <sup>a</sup> ±7.8	20.3 <sup>a</sup> ±1.0	44.9 <sup>a</sup> ±0.5	92	49	Yellow
Mihuekchal <sup>†</sup>	216 <sup>a-g</sup> ±3.5	125 <sup>a</sup> ±5.5	17.8 <sup>abc</sup> ±0.4	39.8 <sup>b-f</sup> ±0.3	90	48	White
Mean	220	86	15.2	39.6	88	45	-
CV(%)	5.97	9.30	7.96	3.79	-	-	-

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

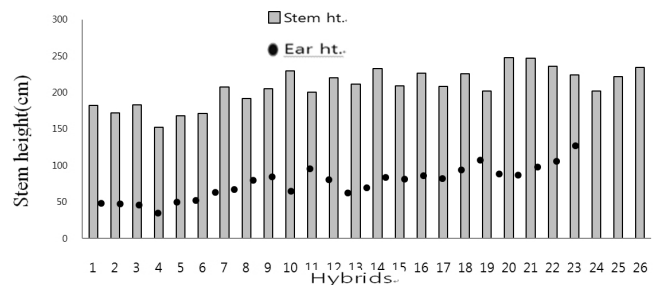
\*Mean±Standard Error

<sup>†</sup>Control hybrids

ear height of CNU11H-8 at the field and CNU11H-34 at the greenhouse were lower than that of other hybrids. Meanwhile, the ear height of CNU11H-29 at the field and CNU11H-69 at the greenhouse were higher than other check. About these results, Ryu *et al.* (2001) suggested that stability to lodging of corn was good approximately 50% below in terms of the ratio of stem height to ear height.

Conclusion gained from this study was also evaluated as lodging resistance in most of hybrids grown in the field and the greenhouse. The relationships of stem height and ear height in 23 waxy corn hybrids are presented in Fig. 1.

In order to compare productivity of used hybrids, ear length, ear diameter, and kernel setting were examined after drying



Remark : 1: CNU11H-1 2: CNU11H-2 3: CNU11H-4 4: CNU11H-8  
 5: CNU11H-11 6: CNU11H-29 7: CNU11H-3 8: CNU11H-6  
 9 : CNU11H-12 10: CNU11H-17 11: CNU11H-19 12: CNU11H-28  
 13: CNU11H-31 14: CNU11H-34 15: CNU11H-38 16: CNU11H-39  
 17 :CNU11H-48 18: CNU11H-53 19: CNU11H-59 20: CNU11H-63  
 21: CNU11H-69 22: CNU11H-73 23: CNU11H-75 24: CNU11H-91  
 25: Yeonong1 26: Daehackchal Gold

**Fig. 1.** Comparison of stem and ear height of waxy corn hybrids at field in 2011.

**Table 4.** Sugar content and pericarp thickness of waxy corn hybrids cultivated at the field

Hybrids	Sugar content (brix%)	Pericarp thickness ( $\mu\text{m}$ )
CNU11H-1	11.6 <sup>c</sup> ±0.1*	48 <sup>abc</sup> ±1.0
CNU11H-2	11.0 <sup>c</sup> ±0.7	52 <sup>ab</sup> ±2.0
CNU11H-4	13.2 <sup>bc</sup> ±0.4	42 <sup>c</sup> ±1.0
CNU11H-8	18.4 <sup>a</sup> ±0.8	49 <sup>bc</sup> ±0.0
CNU11H-11	15.9 <sup>ab</sup> ±0.9	58 <sup>a</sup> ±2.0
CNU11H-29	12.9 <sup>bc</sup> ±1.4	49 <sup>bc</sup> ±1.0
Chalok 1†	13.1 <sup>bc</sup> ±0.4	59 <sup>a</sup> ±1.0
Yeonong1†	13.6 <sup>bc</sup> ±0.1	46 <sup>bc</sup> ±0.0
DaehakchalGold†	13.0 <sup>bc</sup> ±0.1	51 <sup>ab</sup> ±1.0
Mean	13.6	50
CV(%)	7.80	7.37

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

\*Mean±Standard Error

†Control hybrids

the hybrids matured. The kernel setting ratio showed a range of 71~97% in hybrids grown in the field, and 70~98% at the greenhouse, respectively. That of CNU11H-2 among hybrids grown in the field was 97%, which was similar CNU11H-38 and CNU11H-39 grown in the greenhouse. Accordingly, we expected that productivity of these hybrids will be good at next planting. Pericarp thickness showed average 50  $\mu\text{m}$  and 49  $\mu\text{m}$  in hybrids grown at field (Table 4) and greenhouse (Table 5), respectively. The sugar content estimated average 13.6 brix and 15.3 brix in hybrids grown at the field (Table 4) and the greenhouse (Table 5). Among the hybrids, sugar contents of CNU11H-8 grown at the field and CNU11H-31 and CNU11H-75 grown at the greenhouse were higher than Yeonong1 check hybrid.

A pericarp thickness of CNU11H-4 was the thinnest as 42  $\mu\text{m}$  among the hybrids grown at the field and had high sugar contents as 13.2 brix (Table 4). Meanwhile, pericarp thickness of CNU11H-38 grown at the greenhouse had 32  $\mu\text{m}$  and sugar content was 15.5 brix. Zhu *et al.* (2014) and Teri *et al.* (2004) reported that the pericarp mechanical properties of waxy corn inbred lines are important factors affecting the fresh corn eating quality. We also estimated that these two hybrids will be good for the new cultivar of colored corn hybrid.

**Table 5.** Sugar content and pericarp thickness of waxy corn hybrids cultivated at the greenhouse

Hybrids	Sugar content (brix%)	Pericarp thickness ( $\mu\text{m}$ )
CNU11H-3	14.2 <sup>fg</sup> ±0.0*	39 <sup>gh</sup> ±0.0
CNU11H-6	12.4 <sup>h</sup> ±0.2	55 <sup>b-e</sup> ±0.1
CNU11H-12	14.0 <sup>fg</sup> ±0.7	43 <sup>fgh</sup> ±7.2
CNU11H-17	16.7 <sup>bcd</sup> ±1.2	45 <sup>efg</sup> ±4.6
CNU11H-19	14.6 <sup>ef</sup> ±0.2	59 <sup>abc</sup> ±0.8
CNU11H-28	14.5 <sup>ef</sup> ±0.3	48 <sup>c-g</sup> ±4.8
CNU11H-31	18.3 <sup>a</sup> ±0.3	56 <sup>a-e</sup> ±0.0
CNU11H-34	14.6 <sup>ef</sup> ±1.2	54 <sup>b-f</sup> ±0.8
CNU11H-38	15.5 <sup>de</sup> ±0.3	32 <sup>h</sup> ±1.0
CNU11H-39	13.1 <sup>gh</sup> ±0.7	38 <sup>gh</sup> ±1.0
CNU11H-53	15.5 <sup>de</sup> ±0.3	63 <sup>ab</sup> ±0.5
CNU11H-59	13.0 <sup>gh</sup> ±0.1	48 <sup>c-g</sup> ±0.0
CNU11H-63	17.2 <sup>bc</sup> ±0.2	54 <sup>b-f</sup> ±3.6
CNU11H-69	13.6 <sup>fgh</sup> ±0.0	46 <sup>d-g</sup> ±0.0
CNU11H-73	16.0 <sup>cd</sup> ±0.1	53 <sup>b-f</sup> ±0.5
CNU11H-75	18.8 <sup>a</sup> ±0.4	66 <sup>a</sup> ±2.0
CNU11H-91	14.0 <sup>fg</sup> ±0.2	39 <sup>gh</sup> ±1.8
Ilimchal†	17.6 <sup>ab</sup> ±0.3	53 <sup>b-f</sup> ±0.5
Chalok 1†	14.4 <sup>ef</sup> ±0.4	40 <sup>gh</sup> ±1.0
Yeonong1†	17.1 <sup>bc</sup> ±0.2	39 <sup>gh</sup> ±0.5
DaehakchalGold†	12.5 <sup>h</sup> ±0.2	59 <sup>a-d</sup> ±0.5
Mean	15.3	49
CV(%)	2.95	8.32

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

\*Mean±Standard Error

†Control hybrids

Edible corns including waxy corn go through many physical and chemical changes during silking and harvest stage, which greatly influences flavor and also keeping quality of the kernels (Garwood *et al.*, 1976; Lee *et al.*, 1987a). Sweet corn hybrids are harvested in 20 days after silking when sugar content is highest (Kientz *et al.*, 1965). Generally, according to maturation advances, sugar content of sweet corns decreases, starch accumulates, and pericarp thickens. Kang *et al.* (1988), Lee *et al.* (1999) and Creech (1965) reported that waxy corn between 21 and 27 days after silking contained about 4% total sugars and decreased thereafter. But these results in CNU

waxy hybrids showed large difference in both increased sugar contents and decreased pericarp thickness by the advanced methods.

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