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STUDY ON GROWTH, YIELD AND HETEROSIS OF VEGETABLE CORN HYBRIDS

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ABSTRACT

This study was conducted to evaluate growth, physiological, yield, and cob quality traits and to estimate heterosis for yield traits of vegetable corn hybrids in spring cropping seasons in 2014 and 2015. Five inbred lines and 7 hybrids produced from these lines together with 2 checks (LVN23 and Lao 450) were laid out in RCBD experiment with 3 replications. The results showed that hybrid having higher LAI, SPAD index, dry matter accumulation and crop growth rate at 7-9 leaf and tasseling stages produced better marketable cob number and yield. These traits are important indicators for breeding high yielding hybrid vegetable corn variety. The hybrid D7xD10 was the most superior genotype with total yield comparable to LVN23 and surpassed LVN23 in biomass and quality, having positive heterosis for total and marketable yield as well as green biomass.

Keywords: Heterosis, vegetable corn, yield, and quality.

Nghiên cứu sinh trưởng, năng suất và ưu thế lai của các tổ hợp ngô bao tử

TÓM TẮT

Nghiên cứu được tiến hành trong hai vụ ngô xuân năm 2014 và 2015 nhằm đánh giá sinh trưởng, năng suất và chất lượng của các dòng ngô bố mẹ và tổ hợp ngô bao tử và ưu thế lai một số tính trạng năng suất. Năm dòng bố mẹ và 07 tổ hợp lai cùng với 02 giống đối chứng (LVN23 là giống ngô bao tử lai được trồng phổ biến tại Việt nam và Lao 450 là giống ngô bao tử lai nhập nội của Lào) được bố trí theo khối ngẫu nhiên với 3 lần nhắc lại. Kết quả nghiên cứu chỉ ra rằng LAI, SPAD và khả năng tích luỹ chất khô tại các thời điểm 7-9 lá và trỗ cờ có mối tương quan thuận và chặt với năng suất bắp bao tử và năng suất bắp thương phẩm. Đây là những tính trạng quan trọng có thể sử dụng trong chọn tạo giống ngô bao tử lai. Tổ hợp lai D7xD10 được đánh giá là ưu tú có tổng năng suất tương đương và chất lượng cao hơn LVN23 đồng thời có ưu thế lai dương cao về tính trạng năng suất bắp bao tử và năng suất chất xanh (sau thu bắp bao tử), đây là tổ hợp lai có triển vọng để phát triển ngoài sản xuất.

Từ khoá: Chất lượng, ngô bao tử, ngô rau, năng suất, ưu thế lai.

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most important food crops in the world agriculture. It plays an important role in food security, especially in the developing countries (Dhasarathan *et al.*, 2012). In recent years, maize has been used as a high-grade foodstuff crop such as waxy corn, sweet corn and vegetable or baby corn.

Vegetable corn is nutritious with high vitamin, mineral and protein. It has been growing widely in Thailand, Taiwan and China, etc. with high economic efficiency. As baby corn is harvested at early silking stage (usually without chemical pesticide use), it is a fresh and safe product. Moreover, a large amount of green biomass after harvesting is used as green or fermented feed for livestock, especially for dairy cows (Nguyen Phung Duong, 2007).

Recently, vegetable corn is found more popular in the Vietnamese market. However, the productivity of this crop does not meet the demand for the local markets and the product is only found around great urban neighborhoods (Nguyen Ba Loc and Nguyen Thi Quynh Trang, 2009). The seeds as well as other baby corn products in Vietnam are mostly imported from Thailand and/or China. The area of baby corn production in Vietnam is small, because seed importing from Thailand and China is expensive, resulting in increased input cost. It is necessary to breed new baby corn hybrid with high yield, good quality and lower production cost for Vietnam. Although previous studies have shown that LVN23 is a good domestic variety (Nguyen Thi Luu 1999, Nguyen Phung Duong, 2007) and hybrids such as R1xR6, R1xR8, R4xR6 and R5xR6 (Nguyen Thi Luu, 1999; Nguyen Viet Long *et al.*, 2008) are of potential, information on physiological traits and heterosis for yield of baby corn hybrids are lacking. The research objectives were to evaluate growth, yield, and cob quality of hybrids and their heterosis in yield, to determine growth traits related to yield and total biomass and to identify potential hybrids for production.

2. MATERIALS AND METHODS

The research was conducted in spring cropping seasons in 2014 and repeated in 2015 using the same inbred lines and hybrids in the experimental field at the Faculty of Agronomy, Vietnam National University of Agriculture. The experimental materials were 14 genotypes including 5 superior inbred lines, D6, D7, D8, D9 and D10 (high yield and uniform) (Nguyen Viet Long *et al.*, 2008), 7 hybrid hybrids and two check varieties, LVN23 (popular baby corn hybrid produced by Vietnam National Maize Research Institute) and Lao 450 (a hybrid introduced from Lao People's Democratic Republic) (Table 1).

The experimental design was a Randomized Complete Block Design with 3 replications. Each experimental plot area was 15 m^2 (5 x 3m) with a plant density of 111 thousand plants/ha (60 x 15cm). Two seeds were sown in a hill and thinned to single plant/hill at 3-4 leaf stage.

The same set of data were collected in both growing seasons including: i) growth duration (days): emergence date, the harvesting date of 1^{st}, 2^{rd},... and the last young cob; ii) growth and physiological traits: leaf area index (LAI), Chlorophyll content via SPAD index measurement, dry matter accumulation (g/plant), iii) morphological traits: plant height (cm), total leaves/plant, ear height (cm); yield traits (tons/ha); iv) cob quality traits: cob length and width (cm), Brix (%), baby cob uniformity (visual scoring) (Nguyen Viet Long et al., 2008, 2009); and lodging tolerance traits according to QCVN 01:56:2011 standard. LAI, dry matter accumulation and yields were measured from 10 individual plants.

Data of two growing seasons were averaged and statistically analyzed by IRRISTAT 5.0. Yield traits were calculated for mid-parent heterosis (Hmp), best parent heterosis (Hbp) and standard heterosis (Hs).

3. RESULTS AND DISCUSSION

3.1. Growth duration of hybrids and their parents

There was no clear difference between the hybrids, their parents and the checks in growth duration from sowing to emergence (1 day) and

Table 1. List of hybrids and parental lines in the experiment

No.	Hybrid combination	No.	Inbred line/check
1	THL1 (D7xD6)	8	D6
2	THL2 (D7xD8)	9	D7
3	THL3 (D7xD9)	10	D8
4	THL4 (D7xD10)	11	D9
5	THL5 (D8xD10)	12	D10
6	THL6 (D8xD9)	13	LVN23
7	THL7 (D9xD10)	14	Lao 450

from sowing to harvest (1-2 days), and the number harvesting times (similarly, 6 times) (Table 2). No difference or negative heterosis in growth duration was observed in the hybrids compared to their parents (Nguyen Thi Luu,1999; Nguyen Viet Long *et al.*, 2008; Dhasarathan *et al.*,2012).

3.2. Leaf area index (LAI) and SPAD index of hybrids and their parents

The results showed that all of the baby corn hybrids had higher LAI than their parents and were similar to the checks. At 7-9 leaf stage, THL1, THL4 and THL6 had higher LAI than both checks. THL4 and THL6 also had higher LAI than both checks at tasseling stage. At the early harvesting time, THL2, THL4, THL7 and THL6 had higher LAI than LVN23, but only THL4 was higher than Lao 450. Most of the inbred lines had lower SPAD reading than the hybrids, except for D7 and D8. At 7-9 leaf stage, all of the hybrids had higher SPAD reading than Lao 450, but only THL1 and THL7 had higher SPAD than LVN23. At tasseling stage, only THL7 and THL5, but at harvesting time, all hybrids had higher SPAD than the checks (Table 3). This study suggests that SPAD is an important indicator to identify hybrids that produce higher cob yield and total green biomass as well.

There were a significant positive correlations between LAI and SPAD with the number of market cobs and market cob yield at all stages. Specifically, the correlations between yield and LAI at 7-9 leaves stage (r=0.73**) and tasseling stage (r=0.79***) , between LAI, SPAD at 7-9 leaves stage (r=0.78** and r=0,84**, respectively) and the number of cobs were highly significant (P>99.9%) (Table 6). This results indicated that hybrids that had more vigorous vegetative growth and high photosynthetic capacity at early stages produced higher baby cob yields.

3.3. Dry matter accumulation (DM) and crop growth rate (CGR) of hybrids and their parents

DM at all growth stages and CGR from 7-9 leaf stage to tasseling stage (CGR1) of all hybrids and checks were higher than those of inbred lines. CGR from tasseling to milking stage of all hybrids were higher than those of D10 and D6 only, except THL6 with CGR from tasseling to milking stage (CGR2) was higher than the parents and the checks. In comparison to the checks, most of the hybrids had lower DM than LVN23 (except THL6), but higher than Lao 450 (Table 4).

Table 2. Growth duration of baby corn hybrids and parental lines in the experiment (days)

Genotype	Date of emergence	Harvesting time					
		1st	2nd	3rd	4th	5th	6th
THL1	5	49	51	54	57	60	64
THL2	5	49	51	54	57	60	64
THL3	5	49	51	54	57	60	64
THL4	5	49	51	54	57	60	64
THL5	5	49	51	54	57	60	64
THL6	5	49	51	54	56	59	63
THL7	6	50	52	55	58	61	65
D6	6	50	52	55	58	61	65
D7	6	50	52	55	58	61	65
D8	6	50	52	55	58	61	65
D9	6	51	53	55	58	61	65
D10	6	50	52	55	58	61	65
LVN23	5	49	50	54	57	60	64
Lao 450	6	50	52	55	58	61	65

Note: 1st and 6th were the first baby cob and 6th baby cob harvesting time respectively.

Table 3. Leaf area index and SPAD index at different growing stages

Genotype	7-9 leaf stage		Tasseling stage		Harvest	
	SPAD	LAI	SPAD	LAI	SPAD	LAI
THL1	49.6	4.1	51.4	6.0	50.8	6.4
THL2	47.7	3.8	47.2	6.1	52.6	8.1
THL3	48.8	3.7	52.1	6.0	53.5	7.5
THL4	48.4	4.1	52.9	6.8	51.9	9.7
THL5	48.7	3.1	53.4	5.1	52.1	6.6
THL6	48.5	4.1	49.6	6.9	48.1	8.3
THL7	51.6	3.4	53.7	6.1	55.2	8.9
D6	43.9	1.9	44.0	3.5	41.9	8.0
D7	48.3	2.5	50.1	3.2	49.5	5.0
D8	49.9	3.1	51.7	5.2	50.4	6.5
D9	41.1	2.5	41.3	3.5	42.4	5.3
D10	35.9	0.7	39.8	1.0	36.1	5.9
LVN23	46.9	3.5	49.0	6.1	48.5	7.2
Lao 450	45.1	3.4	47.9	5.9	48.1	9.0
CV%	6.8	16.6	10.8	16.9	5.1	4.3
$LSD_{0.05}$	2.5	0.5	4.5	0.1	1.3	0.5

The correlations between DM at all growth stage, CGR1 and the number of marketable cob number and yield were positive and significant (Table 6). The genotypes performed well at early stages (7-9 leaf and tasseling stage) gained a higher number of cob and yield (Table 4).

3.4. Morphological characteristic of hybrids and their parents

The results showed that most of the hybrids were taller than their parents, but not significant. In comparison to the checks, the plant height of the hybrids was similar to LVN23, but significantly lower than that of Lao 450. Parental lines had total number of leaves/plant comparable to the hybrids, except D9 (significantly lower than all hybrids). In comparison to the checks, total leaves of hybrids were similar to LVN23, and higher than Lao 450 (except THL1 and THL4). Most of the genotypes produced 3 cobs/plant, except LVN23 (4 cobs/plant) and D6, D10 (2 cobs/plant). This result agreed with Nguyen Thi Luu (1999) and Nguyen Viet Long (2008) that baby corn hybrid inherited the ability to produce multiple cobs from parent. Parental lines had ear height lower than the hybrids and check cultivars, except D8 and the THL5. The hybrids had ear height higher than LVN23 (except THL5), but lower than Lao 450 (Table 5).

There were no significant positive correlations between total leaf number and marketable cob number and yield. The plant height had significant positive correlation with marketable cob number (P>95%) (Table 6).

3.5. Major pest, diseases incidence and lodging rate of baby corn hybrids and their parents

The results showed that the genotypes suffered slight damages by insects ranging from 0.0 to 4.6%. With leaf blight, most of the genotypes were slightly infected, except THL1 and LVN23 showing no leaf blight infection) whereas D10 had a moderate infection (90% of leaf area infected). THL1 had the highest lodging rate with high rates of stem sloping and collapsing (40% and 10%, respectively), whereas others hybrids showed a small rate of stalk lodging (Table 7).

Table 4. Dry matter accumulation and crop growth rate of baby corn hybrids and parental lines

Genotype	Dry matter accumulation (g/plant)			Crop growth rate (g/plant/day)	
	7-9 leaf stage	Tasseling stage	Harvest	CGR1	CGR2
THL1	3.8	16.0	28.7	5.2	14.0
THL2	5.9	19.4	30.7	5.7	12.6
THL3	3.7	19.7	30.6	6.6	12.1
THL4	5.2	19.6	34.4	6.7	14.7
THL5	3.3	17.2	27.4	6.0	11.4
THL6	5.3	19.8	35.5	6.2	17.5
THL7	2.7	18.4	28.4	6.7	11.1
D6	1.8	10.3	18.1	3.6	8.7
D7	2.5	12.7	23.5	4.4	12.0
D8	2.8	12.5	23.5	4.2	12.2
D9	1.3	10.5	23.5	4.0	14.4
D10	1.0	8.2	15.8	3.7	8.4
LVN23	5.4	22.2	35.7	7.2	15.0
Lao 450	3.0	17.6	27.0	6.2	10.4
CV%	7.9	8.4	6.5	3.8	4.5
$LSD_{0.05}$	0.26	4.82	5.3	1.2	2.6

Table 5. Plant height, total leaf number and ear height of the hybrids and the parental lines in the experiment

Genotype	Plant height (cm)	Total leaves per plant	Ear height (cm)			
			1^{th}	2^{nd}	3^{rd}	4^{th}
THL1	143.6	15.0	74.8	61.7	50.3	-
THL2	139.6	18.0	75.9	64.3	52.9	-
THL3	139.1	17.0	77.9	64.9	49.9	-
THL4	142.1	15.4	77.6	65.2	53.8	-
THL5	134.0	16.6	66.8	55.2	43.1	-
THL6	142.2	18.0	84.1	73.1	61.8	-
THL7	130.2	16.0	69.4	56.3	42.7	-
D6	126.2	17.0	42.4	32.4	-	-
D7	93.7	16.6	49.9	41.0	33.0	-
D8	135.3	15.4	67.1	54.0	36.5	-
D9	122.2	13.0	55.0	44.1	44.5	-
D10	92.4	18.0	40.9	34.9	-	-
LVN23	130.0	16.6	69.3	57.7	45.9	34.0
Lao 450	175.6	14.0	98.1	84.9	74.6	-
CV%	13.9	6.6	-	-	-	-
$LSD_{0.05}$	30.9	1.8	-	-	-	-

Table 6. Correlation between morphological, physiological and growth traits with marketable cob number and yield of baby corn hybrids

Traits	Marketable cob number	Marketable cob yield (tons/ha)
SPAD at 7-9 leaf stage	0.78**	0.58*
SPAD at tasselling stage	0.59*	0.60*
SPAD at harvest	0.62**	0.64**
LAI at 7-9 leaf stage	0.84**	0.73**
LAI at tasselling stage	0.58*	0.79***
LAI at harvest	0.66**	0.53ns
Plant height (cm)	0.59*	0.14
Leaf number/plant	0.51ns	0.14
DM at 7-9 leaf stage (g/plant)	0.84***	0.83***
DM at tasselling stage (g/plant)	0.97***	0.93***
DM at harvest (g/plant)	0.86***	0.83***
CGR1 (g/plant/day)	0.94***	0.90***
CGR2 (g/plant/day)	0.33 ns	0.33 ns

*Note: *,**,*** and ^{ns} -significant at α = 0.05. 0.01, 0.001 and not significant, respectively*

Table 7. Pest and disease incidence and lodging of the hybrids and their parents

Genotype	Black cutworm (%)	Leaf miner (%)	Leaf blight (%)	Root lodging (%)	Stalk lodging (%)
THL1	0.8	3.6	-	40.0	10.0
THL2	0.8	1.5	4.5	-	2.3
THL3	-	4.6	4.6	10.0	0.5
THL4	1.5	1.0	4.6	1.0	0.5
THL5	1.0	1.2	9.2	2.0	-
THL6	1.0	4.0	10.0	20.0	2.3
THL7	1.0	4.6	6.7	5.0	-
D6	-	-	7.5	10.0	-
D7	1.2	-	13.6	-	-
D8	-	-	5.8	-	-
D9	1.0	2.3	8.7	-	-
D10	-	3.6	90.0	-	-
LVN23	-	1.4	-	-	-
Lao 450	1.5	1.2	6.7	5.0	0.45

3.6. Cob production of hybrids and their parents

Hybrids had average cob weight comparable to D9, D10 and Lao 450, but lower than LVN23 and other inbred lines. The number of total cobs of the hybrids was 2.5 to 3.5 times higher, whereas marketable cobs were 3.0 to 5.0 times higher than those of the parents. In comparison to the checks, the number of cobs of hybrids were comparable to that of Lao 450, but lower than LVN23 (Table 8).

Table 8. Cob weight and the number of cobs of baby corn hybrids and parental lines in the experiment

Genotype	Average cob weight (g)	Number of cobs (1000 cobs/ha)		Percentage of marketable cobs (%)
		Total cob	Marketable cob	
THL1	12.4	352.8	235.2	66.7
THL2	12.7	361.1	272.9	75.6
THL3	11.3	360.3	260.2	72.2
THL4	12.8	472.0	393.1	78.8
THL5	12.7	362.3	273.8	75.6
THL6	10.7	362.1	286.2	76.7
THL7	13.9	362.0	261.4	72.2
D6	14.5	133.7	57.9	43.3
D7	15.2	130.0	78.0	60.0
D8	16.2	128.5	83.5	65.0
D9	11.7	130.0	26.0	20.0
D10	12.7	105.0	16.3	15.5
LVN23	14.0	495.9	413.2	83.3
Lao 450	11.9	348.7	259.6	74.4

Table 9. Ear, cob yield and green biomass (tons/ha) of baby corn hybrids and parental lines

Genotype	Ear yield	Cob yield		Percentage of marketable yield (%)	Green biomass
		Total yield	Marketable yield		
THL1	13.9	4.1	3.0	60.8	39.6
THL2	13.2	4.2	3.6	72.1	53.7
THL3	12.9	3.8	2.8	61.7	46.7
THL4	19.6	5.9	5.6	77.5	47.5
THL5	12.7	4.2	3.4	67.3	35.2
THL6	11.6	3.9	3.2	74.5	44.0
THL7	13.0	4.6	3.6	64.7	40.5
D6	4.5	2.4	0.9	45.6	22.2
D7	5.6	2.5	1.2	38.9	31.5
D8	6.0	2.7	1.4	44.5	28.1
D9	8.6	2.0	0.3	13.8	23.1
D10	5.3	2.1	0.2	12.6	26.3
LVN23	21.8	6.2	6.0	81.7	43.1
Lao 450	13.7	4.0	3.0	62.9	63.8
CV%	6.9	11.1	8.1	3.9	11.2
$LSD_{0.05}$	0.60	0.78	0.34	5.57	3.46

Table 10. Cob quality traits of baby corn hybrids and parental lines

Genotype	Length (cm)	Diameter (cm)	Brix (%)	Color	Cob Uniformity
THL1	7.30	1.27	5.6	Ivory	Moderate
THL2	7.76	1.26	5.3	Ivory	Moderate
THL3	7.66	1.18	5.3	Ivory	Medium
THL4	7.94	1.23	5.8	Ivory	Moderate
THL5	7.96	1.30	5.3	Ivory	High
THL6	7.83	1.23	5.3	Ivory	High
THL7	8.39	1.45	5.7	Ivory	Moderate
D6	7.35	1.49	5.3	Ivory	Medium
D7	7.98	1.66	5.8	Ivory	Moderate
D8	9.12	1.37	4.8	Ivory	High
D9	8.35	1.75	5.0	Ivory	High
D10	7.50	1.55	4.5	Ivory	High
LVN23	8.25	1.45	5.6	Ivory	High
Lao 450	8.64	1.23	6.4	Ivory	Medium

Table 11. Heterosis for yield traits of baby corn hybrids and parental lines in the experiment

Genotype	Ear yield			Cob yield						Green biomass		
				Total yield			Marketable yield					
	Hmp	Hbp	Hs	Hmp	Hbp	Hs	Hmp	Hbp	Hs	Hmp	Hbp	Hs
THL1	160.0	61.6	-21.7	67.3	64.0	-19.6	215.6	150.0	-33.3	63.4	25.7	-25.9
THL2	126.4	53.5	-25.6	57.7	55.6	-17.6	154.9	157.1	-20.0	47.3	70.5	0.5
THL3	84.9	50.0	-27.3	82.2	52.0	-25.5	341.9	133.3	-37.8	60.8	48.3	-12.6
THL4	240.9	99.8	-0.7	108.3	156.0	-2.5	973.5	800.0	-2.0	81.9	90.8	-1.1
THL5	132.4	47.7	-28.5	70.8	55.6	-17.6	314.3	142.9	-24.4	61.3	25.3	-34.1
THL6	167.9	34.9	-34.6	82.2	62.5	-23.5	502.6	255.6	-28.9	81.0	67.3	-17.7
THL7	88.9	51.2	-26.8	100.0	119.0	-9.8	1225.7	1100.0	-20.0	77.7	54.0	-24.2

3.7. Ear and cob yields of hybrids and their parents

The results showed that ear yield, cob yield and percentage of marketable yield of hybrids were much higher than those of their parents, similar to Lao 450, but lower than LVN23. THL4 had total number of cobs and marketable cops comparable to LVN23. Lao 450 had highest green biomass yield. THL2, THL3 and THL4 had green biomass yield comparable to LVN23 (Table 9).

3.8. Young cob size and cob quality of hybrids and their parents

All hybrids had cob diameter and length lower than LVN23 (except THL7). In comparison to Lao 450, hybrids had shorter cob length, but higher cob diameter (except THL3). Hybrids had cob lengths similar to their parents (but shorter than D8), and lower cob diameter (Table 10).

All hybrids had Brix higher than their parent, but lower than that of Lao 450. In comparison with the check LVN23, THL1, THL4 and THL7 had higher Brix. The values of quality traits found in this study are in agreement with Vu Van Liet and Pham Van Toan (2007) and Nguyen Viet Long *et al.* (2009).

All experiment genotypes had ivory color. THL5, THL6, D8, D9, D10 and LVN23 had high number of uniformity cobs, whereas other genotypes had moderate uniformity (Table 10).

3.9. Heterosis for yield traits of baby corn hybrids

The results showed that all hybrids had positive heterosis in comparison with their parents, whereas negative standard heterosis was found in comparison to the mean of the checks. THL1 had high heterosis for ear yield, whereas THL3 and THL7 were of lowest this character. However, THL7 and THL4 had highest values for heterosis in total and marketable yield, and green biomass (Table 11). In the previous study, Dhasarathan *et al.* (2012) found only 6/21 crosses had positive heterosis for baby corn yield. Heterosis values greater than both mid-parent and best parent heterosis are a result of dominant genes (Somkiat Kasikranan, 1999). THL4 (D7 x D10) could be exploited as promising hybrid for baby corn production. THL2 is promising for dual production of cobs and green biomass that can be used as animal feed.

4. CONCLUSIONS

The ability to produce multiple ears of the parental inbred lines was found in their hybrids. There is no difference between parental lines and their hybrid in days from sowing to harvest. However, the hybrids showed higher growth, dry matter accumulation, LAI and chlorophyll contents than their parents and positive Hmp and Hbp. This study suggests that LAI, SPAD index, dry matter accumulation and crop growth rate at early stages (7-9 leaf and tasseling stage) were important traits for breeding high yielding baby corn variety. All the hybrids show better yield than the introduced hybrid from Lao but not better than LVN23. Among studied hybrids, D7 x D10 was the most superior hybrids with highest cob yields (comparable to LVN23) and quality better than LVN23, good heterosis for total, marketable yield and green biomass.

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