International Journal on Emerging Technologies **11**(2): 266-270(2020)

ISSN No. (Print): 0975-8364
ISSN No. (Online): 2249-3255

QT68: A New Single Cross Maize Hybrid for the North Central Provinces of Vietnam

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(Received 14 December 2019, Revised 08 February 2020, Accepted 12 February 2020)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Due to population growth, pests and climate change, creating a maize variety with high yield and pests resistance in the North Central provinces of Vietnam is essential. This study was conducted to breed and test single-cross maize hybrid QT68 in Thanh Hoa, Nghe An and Ha Tinh provinces of Vietnam. QT68, a new maize hybrid (*Zea mays* L.) was created from the hybrid of D8//D54, whose maternal line D8 and paternal line D54 were created according to the traditional self-fertilization method to the S10 generation from tropical materials. The hybrid cultivar was tested in trial production in 2018 Autumn-Winter crop and 2019 Spring crop in maize cultivated places of North Central, Vietnam. The findings revealed that QT68's growing time lasted 118-120 days in 2018 Autumn-Winter crop and 120-133 days in 2019 Spring crop. Its mean yield was 7.995 tons ha^{-1}, higher than that of the control by 9.8%; the mean biomass yield (stalk, leaves, fresh corn) was 56.37 tons ha^{-1}/crop. The variety was rarely infected with the stalk borer, other diseases such as the banded leaf and sheath blight. It was also good at anti-falling, fairly drought tolerant and cold resistant. Therefore, QT68 had potential for cultivation in Spring and Autumn-Winter crops in North Central provinces of Vietnam.

Keywords: Breeding, single-cross maize hybrid QT68, testing, *Zea mays*, high yield, North Central, Vietnam.

I. INTRODUCTION

Recognized as the two most important cereal crops, after rice, in Vietnam, maize is human foods, animal feed and raw material for processing ethanol biofuels [1-3]. Currently, maize is being cultivated in almost seven agro-ecological regions in Vietnam. In 2019, the cultivated area of maize in Vietnam was recorded to reach 990.9 thousand hectares with the mean yield of 4.8 tons ha^{-1} and the output of 4756.7 thousand tons [4]. However, maize cultivation in Vietnam has still failed to meet its domestic consumption demand, leading to annual import of millions of tons of maize for animal feed processing.

Provinces in the North Central, Vietnam are agriculture-oriented, in which maize is an important crop. The cultivated area of maize in 2018 in these provinces was 116.6 thousand hectares with the mean yield of 4.26 tons ha^{-1}and the output of 496.4 thousand tons. The constraints and challenges in maize cultivation faced by farmer households in these regions stem mainly from poorly fertile soil, mostly drought soil with water deficiency happening in 70% of the total cultivated area. The majority of current cultivated maize varieties are imported hybrid maize cultivars at high prices, which is hard to be active in seeding seasonally. Some maize cultivars are suffering from pests and diseases at serious rate and tending to be degenerated. Plus, there is a lack of suitable cultivation techniques for each cultivar. Existing maize varieties have not met the requirements of farmers, therefore, it is necessary to study and create new maize varieties with short length of growing time, high yield, high resistance to pests and diseases in order to supplement the production structure of the North Central region. There have been many studies on cultivating techniques, irrigation, fertilizing, breeding to increase maize productivity [5-17]. Among those, breeding is widely known and applied as the first measure to increase yield and resistance to pests and diseases for maize [10-15]. In this study, we conducted (1) creating single-cross maize hybrid QT68 and (2) testing this variety in the North Central provinces of Vietnam.

II. MATERIALS AND METHODS

A. Research materials

Origin of materials: Using 8 pure maize lines: D4, D6, D8, D54, D100, D1, D25, D61. Single-cross maize hybrid QT68 is the result of hybrid of D8/D54. The maternal line D8 and the paternal line D54 were created according to the traditional self-fertilization method to the S10 generation from tropical materials.

Testing varieties: QT68 and control cultivars: DK9901, DK6919 (breeder testing, basic testing) and CP.333, NK7328 (trial production). The control maize cultivars are widely cultivated in localities where experiments were carried out.

B. Research venue and time

Self-pollination, maintenance and evaluation of combining abilities among maize lines were conducted at the National Center for Plant Variety and Product and Fertilizer Testing in Tu Liem, Hanoi. Breeder Testing was conducted in Thanh Hoa; basic testing in Thanh Hoa, Nghe An; trial production in Thanh Hoa, Nghe An, Ha Tinh. Experiments were carried out from Autumn-Winter crop in 2012 to Spring crop in 2019.

C. Research methods

(a) *Self-pollination, maintenance and evaluation combining abilities among maize lines*: Self-pollination and maintenance of maize lines were conducted using traditional self-fertilization method, together with self-pollination by full-sib, half-sib selection methods.

Evaluation of combining abilities covered general combining ability (GCA) and specific combining ability (SCA) among 08 pure-line maize cultivars in diallel crossing as mentioned in Experimental method 4 by Griffing (1956) [18].

Evaluation of hybrid lines (Breeder testing) was conducted in accordance with "National technical regulation on testing for Value of Cultivation and Use of Maize varieties" – QCVN 01-56:2011/BNNPTNT by Ministry of Agriculture and Rural Development, Vietnam [19].

(b) *Testing single-cross maize hybrid QT68in different ecological regions*: Basic testing was conducted in accordance with "National technical regulation on testing for Value of Cultivation and Use of Maize varieties" – QCVN 01-56:2011/BNNPTNT by Ministry of Agriculture and Rural Development, Vietnam [19].

Basic testing of biomass maize for biomass feed stocks in ecological regions, applying "Basic standards for testing Value of Cultivation and Use of Maize varieties as biomass feed stocks" by the Maize Research Institute of Vietnam (2017) [20], plant population density of 71 thousand plants ha^{-1} (70 cm × 20 cm × 1 plant).

Trial production of QT68 was carried out based on the process of local hybrid maize cultivation in those localities, included trial production of QT68 in a sequential manner without repetition and control varieties: CP.333 and NK7328. Trial area was 1000 m2/cultivar/site/crop with a plant population density of 57 thousand plants ha^{-1} and fertilizer rate per ha of 2 tons of micro-organic fertilizer + 160 kg N + 90 kg P_2O_5 + 100 kg K_2O (2 tons of Song Gianh micro-organic fertilizer + 350 kg of urea + 500 kg of superphosphate Lam Thao + 166 kg of potassium chloride).

D. Statistical analysis

Combining ability (including GCA and SCA) of maize cultivars was analysed based on the dry grain yield of hybrid using IRRISTAT 5.0/ Linetest/Dialen 2 software of Tinh and Hien (1996) [21]. Yield data from breeder testing and basic testing was statistically processed with IRRISTAT 5.0 and Excell 3.2. In trial production, the mean yield value was calculated with Excell 3.2.

III. RESULTS AND DISCUSSION

A. Breeding selection and evaluation of combining ability among maize cultivars

(a) *Evaluation of combining ability among 08 maize cultivars*: Analyses of the general combining ability (GCA) (gi) and the variance of specific combining ability (σ^2sij) in 3 diallel cross experiments are presented in Table 1. Maize lines with high value of GCA include D54 (gi: +18.65), D100 (gi: +17.63), followed by D4 (gi: +10.69), D8 (gi: +9.03) và D6 (gi: +7.26). The ones with the highest value of SCA were D25 (σ^2sij: +83.209), D61 (σ^2sij: +51.205), D54 (σ^2sij: +49.209), D1 (σ^2sij: +37.726), D6 (σ^2sij: +34.503), D8 (σ^2sij: +27.340).

Table 1: Values of GCA (gi) and variance of SCA (σ^2 sij) among pure lines of maize in 3 diallel cross experiments conducted in Hoang Hoa, Thanh Hoa, Vietnam[1].

S. No.	Maize line	General combining ability (gi)	Variance of specific combining ability (σ^2sij)
1.	D4	+ 10.69	+ 12.048
2.	D6	+ 7.26	+ 34.503
3.	D8	+ 9.03	+ 27.340
4.	D54	+ 18.65	+ 49.209
5.	D100	+ 17.63	+ 28.809
6.	D1	- 16.81	+ 37.726
7.	D25	- 22.67	+ 83.209
8.	D61	- 21.76	+ 51.205

[1]The mean value gained from 2012 Autumn-Winter crop, 2013 Spring crop and 2013 Autumn-Winter crop

The two pure lines with high value of GCA and high variance of SCA were D54 (gi: +18.65 and σ^2si: +49.209) and D8 (gi: +9.03 and σ^2sij: +27.340). This single hybrid D8//D54 generated a new single-cross maize hybrid named QT68, which is put to the breeder testing in different ecological regions.

(b) *Yield of potential diallel cross hybrids*: Yield of potential hybrids in 3 diallel cross experiments is presented in Table 2. In 2012 Autumn-Winter crop, the yield of QT68 (D8 × D54) was recorded at 7.75 tons ha^{-1}, which was higher than that of the C919 control cultivar with the significance level of 95%. The yield of other hybrids, D4 × D54 and D100 × D54, ranged from 7.14-7.15 tons ha^{-1}, which were similar to that of C919. In 2013 Spring crop, all three hybrids including D4 × D54, D8 x D54 and D100 × D54 had high yield ranging from 8.15 to 8.61 tons ha^{-1}, which was similar to that of C919. In 2013 Autumn-Winter crop, D4 × D54 achieved the highest yield (7.16 tons ha^{-1}), surpassing that of C919 with the significance level of 95%. The yield of the other hybrids were similar to that of C919. The mean number of yield in three crops of D8xD54 was the highest (7.7 tons ha^{-1}), which higher than that of the control cultivars C919 (6.62 tons ha^{-1}) and other hybrids.

Table 2: Yield of potential diallel cross hybrids.

S. No.	Hybrid	Yiled (tons ha^{-1})			
		2012 Autumn-Winter crop	2013 Spring crop	2013 Autumn-Winter crop	Mean of three crops
1.	D4 x D54	7.15	8.15	7.16	7.48
2.	D8 x D54	7.75	8.61	6.74	7.70
3.	D100 x D54	714	8.21	6.92	7.42
4.	C919 *(control)*	6.67	7.47	5.74	6.62
	CV (%)	*3.9*	*5.5*	*5.0*	
	LSD 0.05	*1.12*	*1.89*	*1.37*	

B. Breeder testing on QT68

(a) *Dry grain yield of QT68 in breeder testing*: Dry grain yield of QT68 in 2017 Spring crop and 2018 Spring crop ranged from 7.050 to 8.020 tons ha^{-1}. Five out of six trial sites recorded higher yield when compared to the control cultivar DK9901 with the significance level of 95%. The rest had similar yield to that of DK9901. In 2017 Autumn-Winter crop, the dry grain yield of QT68 ranged from 6.790 to 7.310 tons ha^{-1}. All three trial sites recorded higher yield than that of DK9901 with the significance level of 95%. In short, mean yield of QT68 in three crops (02 Spring crops and 01 Autumn-Winter crop) was 7.294 tons ha^{-1}, surpassing that of DK9901 (6.667 tons ha^{-1}) (Table 3).

(b) *Biomass yield of QT68 in breeder testing*: Biomass yields of maize (stalk, leaves, fresh corn) of QT68 in the main maize growing areas of Thanh Hoa province in the 2018 Autumn-Winter crop are shown in Table 4. Maize biomass (stems, leaves, corn) was harvested after 90-day post-sowing period (milk stage). The yields of QT68 in three sites were higher than that of the control cultivars DK9901 and CP.333 with the significance level of 95%. The mean yield at 3 trial sites was 56.37 tons ha^{-1}, higher than that of DK9901 and CP.333 by 20.4% and 45.5% respectively.

Table 3: Dry grain yield of QT68 breeder testing locations.

Crop	Location	Yield (tons/ha)		CV (%)	$LSD_{0.05}$
		QT68	DK9901		
2017 Spring	Hoang Thang, Hoang Hoa, Thanh Hoa	7.053	6.706	7.4	0.353
	Thieu Nguyen, Thieu Hoa, Thanh Hoa	7.050	6.700	5.8	0.260
	Cam Tan, Cam Thuy, Thanh Hoa	7.226	6.706	6.8	0.420
2017 Autumn-Winter	Hoang Dao, Hoang Hoa, Thanh Hoa	6.790	6.450	3.6	0.041
	Thieu Nguyen, Thieu Hoa, Thanh Hoa	7.310	6.910	5.4	0.280
	Cam Tan, Cam Thuy, Thanh Hoa	7.226	6.293	5.9	0.360
2018 Spring	Hoang Dao, Hoang Hoa, Thanh Hoa	7.340	6.360	4.4	0.056
	Thieu Nguyen, Thieu Hoa, Thanh Hoa	8.020	7.030	5.2	0.360
	Cam Tan, Cam Thuy, Thanh Hoa	7.630	6.850	5.8	0.340
	Mean value	***7.294***	***6.667***		

Table 4: Maize biomass yield (stalk, leaves, fresh corn) of QT68 in 2018 Autumn-Winter crop.

S. No.	Variety	Yield (tons/ha)			Mean yield (tons/ha)	Comparing to control variety (%)	
		Hoang Dao, Hoang Hoa	Thieu Nguyen, Thieu Hoa	Cam Tan, Cam Thuy		DK9901	CP.333
1.	QT68	56.95	57.00	55.17	56.37	+20.4	+45.5
2.	DK9901(control 1)	48.32	47.42	44.68	46.80	—	+20.7
3.	CP.333 (control 2)	39.66	38.76	37.84	38.75	-17.2	—
	CV%	*4.6*	*4.2*	*4.0*	—	—	—
	$LSD_{0.05}$	4.43	1.17	1.87	—	—	—

C. Basic testing on QT68

Thanks to some positive results from breeder testing, QT68 was registered for national testing in some key maize growing regions of North Central. The basic testing results are summarized in Tables 5 and 6.

The yield of maize varieties depends on many factors such as number of corn cobs per plant, number of rows per cob, the number grain per row, 1000-grain weight, cob length and cob diameter [9]. In addition, it depends on external factors including climate, soil, cultivating techniques and pest and disease management measures. The results in Table 5 show that QT68 belongs to the same group of long-day varieties, 6 days longer than DK6919. QT68 has the mean plant height of 214.0 cm, higher than that of the control variety DK6919 (209.3 cm); The mean cob height was 109.1 cm, which was also higher than that of DK6919 (103.1 cm).The mean cob length was 18.5 cm, 1.1 cm higher than that of DK6919; the number of rows per cob was is about 12-16 rows; the number of grains was 36.4 grains, higher than that of DK6919 (35.5 grains/row).

Looking at Table 6, it can be seen that the yield of QT68 in basic testing in Thanh Hoa and Nghe An in 2018 Autumn-Winter crop ranged from 6.37 to 6.96 tons ha^{-1}, which was similar to that of DK6919; The mean yield is 6.665 tons ha^{1}, higher than the control variety DK6919 (6.585 tons ha^{-1}) (Table 6). These results were consistent with the ones in Tuong *et al.*'s study, in which maize yield depends on yield components [9].

Table 5: Some main agronomic characteristics of QT68 in basic testing sites in 2018 Autumn-Winter crop.

S. No.	Criteria	Variety	
		QT68	DK6919 *(control)*
1.	Length of growing period (day)	118	112
2.	Plant height (cm)	214.0	209.3
3.	Cob insertion height (cm)	109.1	103.1
4.	Cob length (cm)	18.5	17.4
5.	Number of rows per cob	12-16	12-16
6.	Number of grains per row	36.4	35.5
7.	1000-grain weigh (gam)	237.0	256.3
8.	Grain percentage per cob (%)	48.8	55.0

Table 6: Yield of QT68 in basic testing in North Central provinces.

Crop	Variety	Yield (tons/ha)		Mean yield (tons/ha)
		Thanh Hoa	Nghe An	
2018 Autumn-Winter	QT68	6.37	6.96	6.665
	DK6919 *(control)*	6.46	6.71	6.585
	CV (%)	*5.3*	*5.2*	
	$LSD_{0.05}$	0.569	0.659	

Table 7: Trial production of QT68.

Crop	Location	Length of growing period (day)		Yield (tons/ha)		Comparing to control variety (%)
		QT68	CP.333 *(control)*	QT68	CP.333 *(control)*	
2018 Autumn-Winter	Hoang Dao, Hoang Hoa, Thanh Hoa	119	112	8.47	7.36	
	Thieu Nguyen, Thieu Hoa, Thanh Hoa	119	116	7.92	6.70	
	Cam Tan, Cam Thuy, Thanh Hoa	118	114	7.62	6.29	
	Huong Thuy, Huong Khe, Ha Tinh	120	114 (**)	6.82	6.70 (**)	
	Mean value	*118-120*	*112-116*	*7.707*	*6.762*	*+13.97*
2019 Spring	Hoang Dao, Hoang Hoa, Thanh Hoa	120	114	9.56	8.21	
	Thieu Nguyen, Thieu Hoa, Thanh Hoa	120	115	9.32	8.70	
	Cam Tan, Cam Thuy, Thanh Hoa	120	115	8.15	7.55	
	Thanh Van, Thanh Chuong, Nghe An	133	127 (**)	7.10	7.00 (**)	
	Huong Thuy, Huong Khe, Ha Tinh	133	127 (**)	7.00	7.00 (**)	
	Mean value	*120-133*	*114-127*	*8.226*	*7.692*	*+6.9*
	Mean value of 2 crops			***7.995***	***7.278***	***+9.8***

Note: *(**) NK7328*

D. Trial production of QT68

Yield is an important indicator in breeding because this is an integrated indicator reflecting overall growth, development, resistance to pests and diseases as well as ability to adapt to external factors [9]. QT68 produced higher yield than that of varieties widely cultivated at trial production sites. The results are shown in Table 7.

In 2018 Autumn-Winter crop, growing time of QT68 was 118-120 days. The cultivar grew strongly, obtained medium plant height, medium insertion, orange yellow and semi-stone grains. QT68 was rarely infected with the stalk borer, corn earworm, banded leaf, sheath blight and stalk rot. The cultivar was good at anti-falling, fairly drought tolerant and cold resistant. QT68 was also good at adapting to various living conditions; it was recorded of yield at 6.82-8.47 tons ha^{-1}, with mean yield at 7.707 tons ha^{-1}, higher than that of the control cultivars by 13.97% (Table 7).

In 2019 Spring crop, growing time of QT68 was 120-133 days. The cultivar grew strongly, obtained medium plant height, medium insertion, beautiful and long corn cob. QT68 was rarely infected with the stalk borer, corn earworm, banded leaf, sheath blight and stalk rot. The cultivar wasgood at anti-falling, fairly drought tolerant and cold resistant. QT68 was also good at adapting to various living conditions; it was recorded of yield at 7.00-9.56 tons ha^{-1}, with mean yield at 8.226 tons ha^{-1}, higher than that of the control cultivars by 6.9% (Table 7).

In short, after trial production of QT68 in two crops (2018 Autumn-Winter crop and 2019 Spring crop) in nine sites in North Central Vietnam, it could be recorded yield at 6.82-9.56 tons ha^{-1}, with mean yield at 7.995 tons ha^{-1}, higher than that of the control cultivars by 9.8%. The results of the study showed that the average yield of QT68 was higher than the reported yield of QT55 [15].

IV. CONCLUSIONS

Single-cross maize hybrid QT68 owned valuable agronomic characteristics such as medium growing time, medium plant height and insertion, good plant shape, big corn, mean corn cob length at 18.5 cm, orange yellow and semi-stone grains. The variety was rarely infected with the stalk borer, corn earworm, banded leaf, sheath blight and stalk rot. It was *also* good at anti-falling, fairly drought tolerant and cold resistant. The dry grain yield in breeder testing was 7.294 tons ha^{-1}, higher than that of the control cultivar (6.667 tons ha^{-1}); the mean biomass yield (stalk, leaves, fresh corn) in breeder testing was 56.37 tons ha^{-1}/crop. The mean yield in basic testing was 6.665 (that of the control cultivar was 6.585 tons ha^{-1}). The figure in trial production was 7.995 tons ha^{-1}, higher than that of the control by 9.8%. Therefore, QT68 was a potential hybrid for North Central regions in Vietnam.

ACKNOWLEDGMENTS

The authors thank Center for plant evaluation and seed testing and plant products in Vietnam for their assistance to this research. The authors would also like to thank all participants in this research.

Conflicts of Interest. The authors declare no conflict of interest.

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How to cite this article: Tuong, L. Q., Tung, L. Q., Khoi, N. T., Vladimirovna, N. O. and Thinh, B. B. (2020). QT68: A New Single Cross Maize Hybrid for the North Central Provinces of Vietnam. *International Journal on Emerging Technologies*, *11*(2): 266–270.