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Evaluation selection of purple waxy corn lines for new hybrid variety development

Summary

This study was carried out to evaluate and select the best purple waxy corn lines self-pollination in S3 to S6 generation with high grain yield, marketable husk yield, anthocyanin content, and good eating quality and appropriated agronomical characteristics. These lines were developed from exotic and domestic germplasm. Phenotype data collected from field trial on the growth and development characteristic, yield and yield components, marketable husk yield, measurement of total anthocyanins by the visible spectra pH method, quality measured by eating testing, pericarp thickness by micrometer, sugar content by Brix meter showed °Bx, tenderness and taste evaluated by eating testing and recording score rank 1 to 9. Selection index analysis based on distances from ideotype plant analysis with 12 traits. Result was selected the best 18 purple waxy corn lines from 46 lines, these lines have high anthocyanin content from 22.4 to 260.10 µg/L, grain yield was ranged from 2.0 to 3.5 t/ha and marketable husk yield from 3.8 to 6.4 t/ha respectively, good eating quality and appropriated agronomical characteristics to continuous self-pollination develop inbred lines for development hybrid of the purple waxy corn. This study provides information on the concentration of anthocyanin content in gene pool of purple waxy corn in Viet Nam.

Keywords: purple waxy corn, select, anthocyanin content

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Introduction

Purple waxy corn (*Zea mays* L. ceritina Kulesh.) is edible with high anthocyanin contents Harakotr et al.[1] Pigments may possess valuable potentials in health production industries as they also contain the bioactive compounds Sucharat & Limsitthichaikoon et al.[2] Corn has a wide range of kernel colors such as white, yellow, black and purple. There are numerous special cultivars that contain colored pigments and give rise to numerous varieties of black and purple corn. The dark purple color of corn is caused by high content of anthocyanins located in the pericarp layers and cob. Anthocyanin pigment was found in all parts of purple corn, but it was found at particularly high concentration in the husk and cob Li et al.[3] Kernel pigments like anthocyanins and carotenoids have numerous nutritional functions in animal and human beings. Increasing the levels of these compositional traits and pigments in kernels should increase the nutritional quality of maize Si Hwan Ryu MS.[4] High yield is still a primary goal of most plant breeding programs Ferh.[5] Pest resistance, stalk strength, uniformity, kernel quality and early maturity are also important in corn and waxy corn breeding programs. Currently, most corn varieties grown commercially are hybrids. However, some purple waxy corn varieties in Asian counties and Vietnam among them are open-pollinated varieties (OPVs) and imported from other countries. Therefore, improved OPVs and selection of national and exotic germplasm are important for purple waxy hybrid development. The objectives of this study were evaluation and selection of purple waxy corn lines for new hybrid variety development in Vietnam.

Materials and methods

Plant material

The materials were 45 of the purple colored waxy corn lines and one check is white waxy corn hybrid that grown in Vietnam. These lines were developed at CRDI (Crop Research and Development Institute) of VNUA (Vietnam National University of Agriculture) by self-pollination from S3 to S6 generation from traditional varieties and hybrid varieties imported from China, Korea and Thailand; they named code as follows

No.	Code	Pedigree	Gen.	Origin	No.	Code	Pedigree	Gen.	Origin
1	NT1	NNT.1	S6	Dienbien, Vietnam	24	NT24	NT11.2.6	S4	China
2	NT2	NNT.2	S3	China	25	NT25	NT11.4	S3	Lao Cai, Vietnam

Table Continued....

No.	Code	Pedigree	Gen.	Origin	No.	Code	Pedigree	Gen.	Origin
3	NT3	NNT.2.1	S4	China	26	NT26	NT12.2.1	S4	Thailand
4	NT4	NNT.2.6	S4	China	27	NT27	NT12.2.2	S4	Thailand
5	NT5	NNT.3	S3	Korea	28	NT28	NT12.2.3	S4	Thailand
6	NT6	NNT.5.1	S4	China	29	NT29	NT12.2.5	S4	Thailan
7	NT7	NNT.5.2	S4	Korea	30	NT30	NT13.1	S3	Thailand
8	NT8	NNT.5.3	S4	Korea	31	NT31	NT13.2	S3	Thailand
9	NT9	NNT10.1	S4	Thailand	32	NT32	NT13.3	S3	China
10	NT10	NNT10.2	S4	China	33	NT33	NT13.7	S3	Korea
11	NT11	NNT10.3	S4	China	34	NT34	NT4.1	S3	Korea
12	NT12	NNT10.4	S4	China	35	NT35	NT4.2	S3	China
13	NT13	NNT10.5	S4	Korea	36	NT36	NT4.3	S3	Thailand
14	NT14	NNT10.6	S4	China	37	NT37	NT4.5	S3	China
15	NT15	NNT10.7	S4	China	38	NT38	NT6.1	S3	China
16	NT16	NNT10.8	S4	Thailand	39	NT39	NT6.2	S3	China
17	NT17	NNT10.9	S4	Korea	40	NT40	NT6.2.4	S4	China
18	NT18	NNT11.1	S4	Korea	41	NT41	NT6.3	S3	Thailand
19	NT19	NNT11.2	S4	Thailand	42	NT42	NT6.6	S3	Thailand
20	NT20	NNT11.2.1	S4	China	43	NT43	NT6.8	S3	China
21	NT21	NNT11.2.2	S4	Thailand	44	NT44	NT7.5	S3	Thailand
22	NT22	NNT11.2.4	S4	China	45	NT45	NT9.1	S3	Thailand
23	NT23	NNT11.2.5	S4	China	46	Check	F46	S6	White waxy corn

Field experiment

The experiment was conducted in the autumn season 2014 at the CRDI, VNUA. Forty-six purple waxy corns lines (S3 to S4) were evaluated in a randomized complete block design with three replications. The plot size was four-row plot with five meters in length and spacing of 0.70 x 0.25 m. Conventional tillage was practiced for soil preparation and total dose of fertilizers consisted of 120 kg ha-[1] nitrogen, 70 kg ha-[1] phosphorus and 91 kg ha-1 potassium. Irrigation was supplied regularly to avoid drought stress, and insect pests, diseases and weed were appropriately managed to obtain optimum growth and yield of crop seasons. The Six of purple waxy corn elite lines were selected take into hybridization to specific combining ability in method 4 of Griffin with check variety is Fancy111 that is mega-variety in Vietnam. Fifty crosses was developed and evaluated in winter season 2014 at Gialam, Hanoi, Vietnam in field experiment include 15 crosses, 6 parent lines and Fancy 111 (check varity), designated RCBD with three replications, plot area is 14m^2.

Data collection

Data were recorded for whole ear yield, marketable husked yield, ear diameter, ear length, plant height, ear height, days to tasseling and days to silking. Days to 50% tasseling and silking were recorded from total number of plants in each plot. After pollination, plant height and ear height were recorded from 10 randomly chosen plants in each plot. Harvesting time was determined at 20 days after pollination (R4 growth stage). All ears from the center two rows or 40 plants were harvested and weighed. Ear diameter, ear length and marketable husked yield were recorded from good 10 representative ears in each plot.

Antioxidant analysis

Screening of total anthocyanin content in this study was conducted measurement of total anthocyanins by the pH method according to Ronald E Wrolstada et al.[6] Anthocyanins reversibly change color with pH, which limits their effective use as food colorants for many applications, but also provides an easy and convenient method for measuring total pigment concentration Giusti & Wrolstad.[7] Samples were diluted with aqueous pH 1.0 and 4.5 buffers and absorbance measurements were taken at the wavelength of maximum absorbance of the pH 1.0 solution. The difference in absorbance between the two buffer solutions is due to the monomeric anthocyanin pigments. Calculation for determining total monomeric anthocyanin as follows:

$$\text{Total Anthocyanins (mg/g)} = \frac{AxMWxDFx10^3}{\varepsilon x1}$$

$$A = \left(A_{\max} - A_{700nm}\right) pH_{1.0} - \left(A_{\max} - A_{700nm}\right) pH_{4.5}$$

MW: Molecular Weight

DF: Dilution Factor

$\varepsilon =$ *molar extinction coefficient*, $L\ x\ mol^{-1} x\ cm^{-1}$

L: path length (1cm)

Pericarp thickness and sugar content were measured by micrometer Brix meter (°Bx), respectively. Tenderness and taste were evaluated by eating testing and recording score rank 1 to 9. Selection of the elite

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lines for continuous study used the selection based on distances from ideotype according to Claudio Guilherme Portela de Carvalho et al.[8] calculated by formula as follows:

$$IDI = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(y_{ij} - Vo_j)^2}$$

Where: IDI is the index based on the distance from ideotype, n is the number of traits included in the index, and aj is the relative importance for the jth trait. The ideotype was defined as the accession, not necessarily evaluated, presenting a mean phenotypic value for each trait equal to the respective VOj. The diallel cross analysis designated as model IV according to Griffing.[9] with the following model:

$$Y_{ijk} = \mu + g_i + g_j + S_{ij} + C_{ijk}$$

Where:

Y_{ijk}, phenotypic value observed for the cross with

parents i and j in block k

μ, effect common to all the observations

g_i, effect of the general combining ability of parent i

S_{ij}, effect of the specific combining ability of the cross (i, j)

C_{ijk}, random environmental effect corresponding to the observation (i, j, k).

Data analysis

Analysis of variance was performed for each character and combined analysis of variance, and the ratio of error variance Gomez and Gomez.[10] Significant differences among lines were assessed by least significant difference (LSD) at 0.05 probability level, and all analyses were carried out on IRRISTAT software ver. 5.0; selection index analysis used DTSL software, Nguyen Dinh Hien (1995)

Results and discussion

Some characteristics of the growth and development among 45 purple waxy lines measured (Table 1) revealed that growth duration from sowing to harvest was ranged 95 to 104 days, there were 2 lines have growth duration are shorter F46 (check) at significant level (P<0.05), days to tasseling of the purple waxy lines ranged from 66 to 70 days and day to silking from 67 to 71 days equivalent to check varieties and belong to early and medium maturity groups. There were not significant differences between genotype domestic and exotic germplasm on these characteristics. Such growth duration suitable for fresh waxy production in Northern of Vietnam, special in winter season of the Red River Delta with the cropping alternation are rice – rice – winter crop. The purple waxy corn lines had better aspect Anthesis-silking-interval (ASI) trait shorter, because ASI involving adapted to a biotic stress condition and yield lines, most lines have Anthesis-silking-interval ranged from 0 to 3 days, three lines with larger ASI were T17, T39 and T42 (4 days) (Table 1).

Table 1 Characteristics of the growth duration of purple waxy corn lines in spring season at VNUA, Hanoi

Line	Growth duration (day)	Day to tasseling	Day to silking	ASI (day)	Line	Growth duration (day)	Day to tasseling	Day to silking	ASI (day)
NT1	98	68	70	2	NT24	100	69	70	1
NT2	100	69	70	1	NT25	101	70	70	0
NT3	95*	66	68	2	NT26	100	69	70	1
NT4	96	67	68	1	NT27	98	68	69	1
NT5	98	67	70	3	NT28	96	67	68	1
NT6	98	68	69	1	NT29	98	68	69	1
NT7	102	70	71	1	NT30	98	67	70	3
NT8	100	69	70	1	NT31	97	67	69	2
NT9	99	68	70	2	NT32	97	67	69	2
NT10	98	67	70	3	NT33	98	67	70	3
NT11	100	70	69	-1	NT34	104	72	71	-1
NT12	96	67	68	1	NT35	102	70	71	1
NT13	100	68	71	3	NT36	103	70	72	2
NT14	100	69	70	1	NT37	104	72	71	-1
NT15	104	72	71	-1	NT38	103	71	71	0
NT16	103	71	71	0	NT39	99	67	71	4
NT17	99	67	71	4	NT40	95*	67	67	0
NT18	100	70	69	-1	NT41	101	70	70	0
NT19	103	71	71	0	NT42	99	67	71	4

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Table Continued....

Line	Growth duration (day)	Day to tasseling	Day to silking	ASI (day)	Line	Growth duration (day)	Day to tasseling	Day to silking	ASI (day)
NT20	101	70	70	0	NT43	102	70	71	1
NT21	102	70	71	1	NT44	98	68	69	1
NT22	102	70	71	1	NT45	97	67	69	2
NT23	103	70	72	2	F46	98	66	68	2
cv%	5.4	3.5	2.5	9.4		5.4	3.5	2.5	9.4
$LSD_{0.5}$	2.6	2.5	1.7	1.4		2.6	2.5	1.7	1.4

*Significant at the 0.05 probability level

The lines have ASI shorter could be effectively utilized for developing maize hybrid suitable for drought/rain fed conditions Shadakshari & G Shanthakumar.[11] and also applying for purple waxy corn breeding. The total leaves per plant ranged 16 to 17 leaves; there were 15 lines have higher number of leaves than check variety at significant level and other lines have not significant difference (Table 2). Plant and ear height are the most important selection criteria in most maize breeding programs. Especially, ear and plant height are importance when it comes to lodging, high ear position is generally like to become more susceptible to lodging Ji et al.[12] Plant height of the lines in this experiment ranged 85.3 cm (NT16) to 160 cm (NT43), among 46 studied lines, 30 have plant height shorter than that of check variety at significance level, and most lines ranged 110 to 130 cm. Ratio of plant height to ear height appeared was 50% below is ration appropriately for inbred line according to Hee Chung Ji et al.[13] There were 8 lines including NT4, NT19, NT30, NT31, NT32, NT35, NT40 and NT44 with ratio of plant height to ear height appeared above 50% and higher than check F46 could be unsuitable maize breeding for lodging tolerance. There were 7 lines have ear height higher check line that were NT4, NT19, NT35, NT37, NT40 and NT44 and another lines were lower check at significant difference level.

Analysis of variance indicated significant difference for number ear per plant (EP), number of kernel row per ear (RE), 1000-kernel weight (KW), grain yield (GY) and Marketable husked yield (MHY) among the inbred lines. The inbred means calculated for each trait indicated considerable diversity among the set of inbred lines in this study (Table 3). Number of ear per plant ranged from 0.9 (NT27, NT33 and NT43 lines) to 1.3 (NT2, NT23 and NT37 lines) ear per plant, ear length ranged from 10.7cm (NT9) to 16.3 cm (NT13), there were 3 lines have EL longer than that of check variety at significant level, which were NT12, NT13 and NT19, the ear diameter of the 46 lines was belong medium size ranged from 3.53 cm to 4.82 cm, there were 4 lines have ear diameter larger than check at significant level that were NT19, NT21, NT38 and NT39 compared check F46 was 4.2cm. The number of kernel row per ear was large variance from 10.0 to 19.2, it is with similar number of kernel per row ranged from 14.4 to 28.0 kernels /row, respectively (Table 3). Most lines have 1000-grain weight lighter than check accepted lines NT12 (317g) and NT31 (288g) higher than check variety F46 at significance level of 5%.

The variance of ear traits was similar to the report on agronomic traits of Arido-American maize accessions in Ohio University Si Hwan Ryu.[4] In general, grain yield of the 46 lines was low from 1.6 t/ha (NT34) to 3.7 t/ha (NT12), among them identified 11 lines were NT3, NT4, NT12, NT17, NT19, NT31, NT38, NT39, NT40, NT42 and NT43 have grain yield higher F46 check line at significance level, these lines were appropriately in hybrid waxy corn breeding and hybrid seed production. Another lines have grain yield were equivalent and lower compared to check F46 line 2.6 t/ha, respectively (Table 3). Marketable husked yield (MHY) is an important target in fresh waxy corn breeding; in this study identified 11 lines were NT3, NT4, NT12, NT17, NT19, NT31, NT38, NT39, and NT40. NT42 and NT43 have fresh ear yield with husk higher than F46 check line (4.9 t/ha). NT3 had the highest marketable husked yield of 6.4 t/ ha and followed NT31 and NT42 by 6.1 t/ ha respectively. Beside the anthocyanin content, major components related to fresh waxy corn qualities are tenderness, pericarp thickness, taste and sugar content. Quantities for these lines and total anthocyanins content were presented in Table 4. Anthocyanin content of these lines were very good because of primary screen for this trait, result measured anthocyanin by the pH method showed very variable ranged from 1.3 mg/L (NT4) to highest content was 490.2 mg/L (NT25). Si Hwan Ryu (2010) reported that very variance of total anthocyanin content between purple corn germplasm accessions ranged 0.8 - 111.7 mg/100g. There were 14 lines have anthocyanin content were above 100 mg/L included NT6 (260.1), NT8 (162.1), NT9 (103.4), NT16 (144.6), NT19 (119.4), NT20 (103.6), NT21 (211.1), NT25 (490.2), NT32 (167.9), NT34 (287.7), NT35 (118.3), NT36 (129.0), NT38 (110.6) and NT41 (205.6). Pericarp thickness was measured by Micrometer with 10 grains of each line was showed average ranged from 55.2 to 122.4 µm. Pericarp thickness trait was responsible for tenderness and ear trait was responsible for consumer preference, pericarp thinner more tenderness Eunsoo Choe et al.[14] In this study identified 8 lines that have PER $\leq$ 60 µm were NT13, NT22, NT23, NT32, NT36, NT39, NT42 and NT45 equivalent F46 check line (64.4 µm). It was appropriated in waxy corn breeding for tenderness eating quality.

Table 2 Major agronomic characteristics among colored waxy corn lines in Spring season at Gia Lam, Hanoi

Line	No. of leaf	Plant height (cm)	Ear height (cm)	Line	No. of leaf	Plant height (cm)	Ear height (cm)
NT1	16.6	123.5*	57.6	NT24	16.7	109.4*	46.3
NT2	17.2*	144	68	NT25	16.7	131.3*	58.7
NT3	16.9*	141.9	62.2	NT26	16.6	112.2*	51.8
NT4	16.9*	137.2	77.2*	NT27	15.6	105.5*	42.6

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Table Continued....

Line	No. of leaf	Plant height (cm)	Ear height (cm)	Line	No. of leaf	Plant height (cm)	Ear height (cm)
NT5	16.7	117.6*	49	NT28	16.7	150.9	66
NT6	16.6	136.5	60.9	NT29	16.2	113.6*	48.6
NT7	16.6	118.3*	47.8	NT30	16.9*	108.9*	59.7
NT8	16.7	118.8*	42.6	NT31	17.0*	108.0*	61.2
NT9	16.4	91.6*	37	NT32	16.6	98.8*	52.2
NT10	16.6	104.5*	41.2	NT33	16.8*	104.7*	43.6
NT11	16.7	91.0*	41.2	NT34	16.9*	134	59.4
NT12	16.6	140.2	65.6	NT35	16.9*	143.4	74.5*
NT13	16.5	127.8*	53	NT36	17.0*	143.3	54.4
NT14	16.6	104.7*	43.4	NT37	17.0*	148.4	71.2*
NT15	16.8*	111.7*	55	NT38	16.5	126.0*	59.8
NT16	16.8*	85.3*	40.1	NT39	16.8*	126.3*	63.2
NT17	16.6	87.3*	40.4	NT40	17.0*	151.8	77.8*
NT18	16.6	113.9*	56.5	NT41	16.5	132.7	52.1
NT19	16.4	142.3	73.4*	NT42	17.1*	139.4	67.4
NT20	16.7	115.9*	50.6	NT43	16.7	160	58.4
NT21	16.6	101.4*	49.3	NT44	16.8	129.6*	70.7*
NT22	16.6	112.5*	49.6	NT45	16.8*	108.1*	42.2
NT23	16.3	104.3*	44.5	F46	16.2	138.5	66.4
cv%	0.8	2.54	1.4		0.8	2.54	1.4
$LSD^{0.0}_{5}$	0.59	7.24	4		0.59	7.24	4

*Significant at the 0.05 probability level

Table 3 Yield and yield components of the purple waxy corn lines in Spring season at Gia Lam, Hanoi

Line	EP	EL	ED	RE	KE	KW	Grain Yield (t/ha)	MHY
		(cm)	(cm)			(g)		(t/ha)
NT1	1	12.4	4.09	14.8	18	159	1.8	2.9
NT2	1.3	12.2	3.58	10.6	22.2	213	2.1	4.1
NT3	1.2	13.7	4.46	15.5	25.5	209	3.5*	6.4*
NT4	1	13.8	4.56	14.3	21.5	247	3.3*	5.8*
NT5	1.2	12.3	4.17	12.8	19.8	219	2.4	4.3
NT6	1	11.9	3.7	11.2	18.8	226	2	3.8
NT7	1	14.1	4	12.7	24	195	2.5	4.8
NT8	1	12	4.06	14.8	23.6	171	2.6	4.6
NT9	1	10.7	4.22	16	23	164	2.6	4.6
NT10	1	12	4.09	13	24	205	2.7	5.2
NT11	1	11.8	4.2	14.7	21.3	197	2.6	4.8
NT12	1	15.6*	4.27	13.3	27.0*	317.0*	3.7*	5.9
NT13	1	16.3*	4.5	14.8	25.6	174	2.8	5.4
NT14	1	12.3	3.53	12	19.6	149	1.5	3.2
NT15	1	11.2	4.06	12.7	20.2	187	2	3.9
NT16	1.1	11.6	4.21	14	22.7	177	2.4	4.3
NT17	1.1	14	4.26	13.2	25.4	217	3.1*	5.5*

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Table Continued..

NT18	1	10	3.93	13.6	17	168	1.7	3.4
Line	EP	EL	ED	RE	KE	KW	Grain Yield (t/ha)	MHY
		(cm)	(cm)			(g)		(t/ha)
NT20	1.1	11.8	4.53	14.7	18.5	199	2.3	4.1
NT21	1	12.1	4.91*	16	21	171	2.5	4.6
NT23	1.3	13.2	3.88	10	28	188	2.3	4
NT24	1	13.5	4.11	12	19.6	232	2.3	4.2
NT25	1	11.2	4.05	15.3	16	176	1.8	3.5
NT26	1	12.5	4.39	12.8	20.4	243	2.7	4.8
NT27	0.9	12.3	4.13	13.5	21.9	176	2.2	4.3
NT28	1.1	13.7	4.34	13.6	20.4	216	2.6	4.7
NT29	1.2	11.9	4.36	15	19.3	219	2.7	4.8
NT30	1.3	12.1	4.31	15.6	20.8	142	2	3.8
NT31	1	10.9	4.48	16.7*	18.7	288.0*	3.2*	6.1*
NT32	1	11.2	4.44	19.2*	23.4	179	2.7	5.2
NT33	0.9	11	4.39	16.8*	14.4	187	1.9	3.7
NT34	1.1	11.6	4.08	14.4	20	133	1.6	3.5
NT35	1	11.8	4.12	13.2	24.2	193	2.6	4.8
NT36	1	13.3	3.98	12.4	22.4	161	1.9	3.6
NT37	1.3	13.6	4.58	16	25.4	152	2.6	4.8
NT38	1.1	13.4	4.82*	15.6	24	194	3.1*	5.5*
NT39	1	11	4.62	17.6*	20.4	191	2.9	5.3
NT40	1	13.2	4.45	15.3	21	227	3.1*	5.6*
NT41	1.1	11.5	4.02	13.6	18.2	152	1.6	3.6
NT42	1	11.4	4.19	14.8	26	195	3.2*	6.1*
NT43	0.9	14	4.54	14	23.8	251	3.0*	5.5*
NT44	1	11.5	4.09	14.2	23.2	171	2.4	4.3
NT45	1	12.7	4.05	13.2	19.4	208	2.3	4.1
F46	1	14.3	4.2	14.5	23.2	250	2.6	4.9
cv%	8.7	10.82	8.5	11.7	14.4	8.63	7.04	6.45
$LSD_{0.5}$	0.28	1.32	0.38	1.67	3.14	3.64	0.29	0.58

*Significant at the 0.05 probability level

EP, number of ear per plant; EL, ear length; ED, ear diameter; RE, number of kernel per row; KE, number of kernel per row; KW, weight of 1000 seeds; MHY, marketable husk yield

Table 4 Quality of the purple waxy lines in Spring season at Gia Lam, Hanoi

Line	Anthocyanin content	Pericarp thickness (µm)	Tenderness (1- 9)	Sugar content	taste (1- 9)
	(mg/L)			(°Bx)	
NT1	35.5*	64.6	2	12.7	2
NT2	31.2*	70.7	3	12.6	3
NT3	56.4*	75.7	3	12.6	3
NT4	1.3ns	77.3	2	12.2	3
NT5	64.5*	97	2	10.7	2
NT6	260.1*	67.5	3	14.3	3
NT7	23.1*	69.4	2	14.7	2
NT8	162.1*	78.6	3	12.7	3

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Table Continued..

Line	Anthocyanin content	Pericarp thickness (µm)	Tenderness (1- 9)	Sugar content	taste (1- 9)
	(mg/L)			(°Bx)	
NT10	15.5*	68.8	3	12.5	3
NT12	43.2*	72	3	10.8	3
NT13	52.1*	56.3*	3	13.3	3
NT14	26.6*	78	3	11.2	3
NT15	59.2*	70.8	3	11.8	3
NT16	144.6*	122.4	3	13	3
NT17	24.2*	96.4	2	11.9	2
NT18	27.9*	85	3	14	3
NT19	119.4*	101.9	2	10.9	3
NT20	103.6*	68.7	3	11.2	3
NT21	211.1*	79.6	3	13.7	3
NT22	57.8*	59.2*	3	13.2	3
NT23	66.8*	58.6*	3	12.5	4
NT24	29.2*	70.8	4	12.8	3
NT25	490.2*	68.6	3	12.9	2
NT26	72.0*	70.8	3	13.1	2
NT27	34.0*	74.2	3	12.6	3
NT28	49.9*	77.3	3	13.2	3
NT29	75.5*	78.1	3	13.4	3
NT30	10.4*	77.6	2	12.8	3
NT31	48.4*	66.5	3	13	3
NT32	167.9*	60.7*	2	12.8	3
NT33	20.1*	88.1	3	13.1	3
NT34	287.7*	86.8	3	12.3	3
NT35	118.3*	78.2	2	12	3
NT36	129.0*	60.2*	2	13	3
NT37	73.3*	66.2	3	13.2	3
NT38	110.6*	74.7	2	12.2	2
NT39	33.3*	61.5*	2	8.8	3
NT40	33.4*	66.1	3	11.7	3
NT41	205.6*	76.1	3	11.7	3
NT42	22.4*	55.2*	4	13.6	3
NT43	75.0*	63.7	2	12.5	2
NT44	39.1*	99.2	3	13.8	3
NT45	39.6*	60.9*	2	13.3	3
F46	10.7	64.4	3	14.8	3
cv%	16.3	5.4		6.6	
LSD.05	9	2.4		1.3	

*Significant at the 0.05 probability level

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Sweetness was measured by Brix meter showed °Bx ranged from 8.8 (NT39) to 14.7 (NT7) and all purple waxy corn lines have sugar content lower than check line (F46). Tenderness and taste measurement evaluated by eating test recorded in 2-4 score and equivalent check line (Table 4) Base on the phenotyping of 46 purple waxy corn lines, the selection index was used to select out best lines for further study. Analysis performed by considering 12 purple waxy corn traits and intensive selection according to Claudio Guilherme Portela de Carvalho et al.[8] & Lucas Nunes da Luz et al.[15] about 35.5%, this study applied a 40% selection pressure and simultaneously the traits on the components of yield and yield, some qualities trait as tenderness, taste, sugar, special anthocyanin content to choose genotypes that express the highest phenotypic values for the traits targeted to obtain positive genetic gains and the lowest phenotypic values for traits targeted to obtain negative genetic gains.

The IDI value ranged from 7.16 to 9.54, 18 lines were selected from total 46 of purple waxy corn lines in this study (Table 4). The anthocyanin content in highest was 260.10 µg/L, grain yield were ranged from 2.0 – 3.5 t/ha and marketable husk yield from 3.8 to 6.4 t/ha, respectively (Table 5). The best 18 lines were selected from 46 of the purple waxy corn; they were related closer to Ideotype plant model with high anthocyanin content, thinner pericarp, and more tenderness, high grain yield and fresh ear yield. These lines will be used for further self-pollination to develop inbred lines in hybrid variety of the purple waxy corn breeding programs. The Six of purple waxy corn elite lines were selected take into hybridization to specific combining ability in method 4 of Griffin with check variety is Fancy111 that is mega-variety in Vietnam. Analysis SCA was identified the crosses N2 x T141 with fresh cob yield as equivalence to Fancy 111 but Anthocyanin content higher at significant level (112.5 mg/100g) (Table 6) Crosses to name NT141 and submitted to Vietnam Nation Testing System from 2015 to 2017 and NT141 purple waxy corn hybrid was recognized new crop hybrid from Ministry of Agricultural and Rural development of Vietnam February 2018.[16–18]

Table 5 Elite lines were selected by IDI (index based on the distance from ideotype) on the 12 of phenotype traits and 40% selection pressure

No.	Line	IDI	An (mg/L)	PER (µm)	Ten (1-9)	Su (°Bx)	Tas (1-9)	EL (cm)	ED (cm)	RE	KR	KW (g)	GY (t/ha)	MHY (t/ha)
1	NT21	7.16	211.1	79.6	3	13.7	3	12.1	4.91	16	21	171	2.5	4.6
2	NT6	7.58	260.1	67.5	3	14.3	3	11.9	3.7	11.2	18.8	226	2	3.8
3	NT9	7.66	103.4	76.8	4	12.7	4	10.7	4.22	16	23	164	2.6	4.6
4	NT8	7.67	162.1	78.6	3	12.7	3	12	4.06	14.8	23.6	171	2.6	4.6
5	NT3	7.81	56.4	75.7	3	12.6	3	13.7	4.46	15.5	25.5	209	3.5	6.4
6	NT37	7.84	73.3	66.2	3	13.2	3	13.6	4.58	16	25.4	152	2.6	4.8
7	NT29	7.98	75.5	78.1	3	13.4	3	11.9	4.36	15	19.3	219	2.7	4.8
8	NT19	8.2	119.4	101.9	2	10.9	3	14.8	4.62	14.7	27.5	194	3.1	5.6
9	NT13	8.21	52.1	56.3	3	13.3	3	16.3	4.5	14.8	25.6	174	2.8	5.4
10	NT28	8.35	49.9	77.3	3	13.2	3	13.7	4.34	13.6	20.4	216	2.6	4.7
11	NT32	8.71	167.9	60.7	2	12.8	3	11.2	4.44	19.2	23.4	179	2.7	5.2
12	NT44	8.84	39.1	99.2	3	13.8	3	11.5	4.09	14.2	23.2	171	2.4	4.3
13	NT31	8.86	48.4	66.5	3	13	3	10.9	4.48	16.7	18.7	288	3.2	6.1
14	NT42	9.01	22.4	55.2	4	13.6	3	11.4	4.19	14.8	26	195	3.2	6.1
15	NT40	9.06	33.4	66.1	3	11.7	3	13.2	4.45	15.3	21	227	3.1	5.6
16	NT35	9.18	118.3	78.2	2	12	3	11.8	4.12	13.2	24.2	193	2.6	4.8
17	NT12	9.36	43.2	72	3	10.8	3	15.6	4.27	13.3	27	317	3.7	5.9
18	NT38	9.54	110.6	74.7	2	12.2	2	13.4	4.82	15.6	24	194	3.1	5.5

IDI, index based on the distance from ideotype; an, Anthocyanin; PER, pericarp thickness; Ten, tenderness; Su, sugar content; Tas, taste; EL, ear length; ED, ear diameter; RE, number of kernel row per ear; KE, number of kernel per row; KW, weight 1000 kernel; GY, grain yield; MHY, marketable husk yield

Table 6 Combining ability of six elite lines on the some traits and fresh cob yield in Winter season 2015 at Gialam, Hanoi, Vietnam

Crosses	Brix (Score)	Tenderness (Score)	AN content (mg/100g)	Cob color	Kernel row/cob	No. Kernel per row (g)	Weight 1000 kernels	Fresh cob yield (t/ha)
NT19 x NT21	1.1	2.3	87.5*	Purple	14.8ns	31.4 ns	251,5 ns	1.04 ns
NT19 x NT37	1.3	2	85.0*	Purple	13.8ns	36.0 ns	238,5 ns	1.07 ns
NT19 x NT38	1	3	65.0*	Purple	14.6ns	31.7 ns	241,8 ns	1.04 ns

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Table Continued..

Crosses	Brix (Score)	Tenderness (Score)	AN content (mg/100g)	Cob color	Kernel row/cob	No. Kernel per row (g)	Weight 1000 kernels	Fresh cob yield (t/ha)
NT19 x N2	1.5	1	50.0*	Purple	15.2ns	29.7*	233,4 ns	0.95*
NT19 x T141	2	2	82.5*	Purple	14.6ns	27.0*	232,5 ns	0.84*
NT21 x NT37	1	1.3	87.5*	Purple	14.5ns	34.5 ns	216,7*	0.99*
NT21 x NT38	2.5	3	67.5*	Purple	13.5ns	32.1 ns	269,5*	1.03*
NT21 x N2	2	3	87.5*	Purple	14.5ns	28.5*	253,0 *	0.95*
NT21 x T141	1.5	2.1	52.5*	Purple	15.5ns	32.1 ns	218,5*	1.01*
NT37 x NT38	1	2	97.5ns	Purple	14.5ns	32.8 ns	224,5*	0.97*
NT37 x N2	2	2	85.0*	Purple	15.6ns	28.3*	248,0 ns	0.99*
NT37 x T141	1	2	87.5*	Purple	14.5ns	34.5 ns	233,0 ns	1.06 ns
NT38 x N2	1	1	75.0*	Purple	15.1ns	32.5 ns	226,5*	1.01*
NT38 x T141	1	2	92.5ns	Purple	14.0ns	29.1*	222,0*	0.82*
N2 x T141	1	2	112.5*	Purple	15.0ns	37.4 ns	244,5 ns	1.18ns
Fancy111	1	2	100	Purple	14.8	38.1	239,8	1.13
CV%	-	-	5.9	-	5.1	10.6	3,1	5.4
LSD_{005}	-	-	8	-	1.7	7.2	11,2	0.97

Note: AN, Anthocyanin; ns, non-significant; *, significant at $P < 0.05$, respectively

Conclusion

In conclusion, evaluation and selection of purple waxy corn lines in generation from S3 to S6 on the agronomical traits as growth duration, ASI, plant height, ear height, yield and yield components to identify lines suitable for develop inbred line. The eating quality traits as pericarp thickness, tenderness, sugar content, taste and anthocyanins content to select elite line for development hybrid variety. Base on the traits above were selected 18 lines of purple waxy corn from 46 lines studied, these lines have high anthocyanin content and good eating quality, simultaneously, they were have appropriated agronomical characteristics to continuous self-pollination develop inbred lines. This study also contribution provides information on the concentration of anthocyanins in gene pool of purple waxy corn in Viet Nam. Purple waxy corn hybrid NT141 was recognized new crop hybrid from Ministry of Agricultural and Rural development of Vietnam February 2018.

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None.

Conflict of interest

None.

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