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 appropriate 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

**Introduction**

Purple waxy corn (*Zea mays L. ceritina Kulesh.*) is edible with high anthocyanin contents Harakot 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,V | 24  | NT24 | NT11.2.6 | S4 | China      |
| 2   | NT2  | NNT.2    | S3 | China      | 25  | NT25 | NT11.4   | S3 | Lao Cal,V  |
Field experiment

The experiment was conducted in the autumn season 2014 at the CRDI, VNUA. Forty-six purple waxy corn 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 variety), designated RCBD with three replications, plot area is 14m².

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 10 randomly chosen plants in each plot. Harvesting time was determined at 20 days after pollination 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 variety), designated RCBD with three replications, plot area is 14m².

Antioxidant analysis

Screening of total anthocyanin content in this study was conducted measurement of total anthocyanins by the pH method according to Ronald E Wrolstad 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:

\[ \text{Total Anthocyanins (mg/g)} = \frac{AxMWxDFx10^{3}}{\varepsilon x L} \]

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

\[ \varepsilon = \text{molar extinction coefficient}, \ L x \text{mol}^{-1} x \text{cm}^{-1} \]

\[ L: \text{path length (1cm)} \]

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...
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:

\[
IDI = \sqrt{\frac{1}{n} \sum_{j=1}^{n} (y_{ij} - V_{Oj})^2}
\]

Where: IDI is the index based on the distance from ideotype, \(n\) is the number of traits included in the index, and \(a_j\) is the relative importance for the \(j\)th trait. The ideotype was defined as the accession, not necessarily evaluated, presenting a mean phenotypic value for each trait equal to the respective \(V_{Oj}\). 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 \(k\)
- \(\mu\): 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).

| 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         |
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 significant 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 Chuong 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 10.7 cm (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 ≤ 60 μm were NT13, NT22, 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           |

*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 | 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            | LSD  | 0.59        | 7.24             | 4              |

*Significant at the 0.05 probability level

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

| Line  | Anthocyanin content (mg/L) | Pericarp thickness (μm) | Tenderness (1-9) | Sugar content (°Bx) | Taste (1-9) |
|-------|---------------------------|-------------------------|-----------------|--------------------|-------------|
| 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           |

*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 Continued..

| Line  | Anthocyanin content (mg/L) | Pericarp thickness (μm) | Tenderness (1-9) | Sugar content (°Bx) | Taste (1-9) |
|-------|---------------------------|-------------------------|-----------------|---------------------|------------|
| 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
Sweetness was measured by Brix meter showed $\text{Bx}$ 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. & Lucas Nunes da Luz et al. 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 mg/L, grain yield were ranged 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 Fancy 111 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 (g) | KW | 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   | 22.4   | 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 row per; 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    | 13.6ns         | 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                | 216.7ns              | 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                  | 87.0*                | 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                  | 97.5*                | 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                  | 92.5*                | Purple    | 14.0ns         | 29.1*                  | 220.0*               | 0.82*                  |
| N2 x T141   | 1           | 2                  | 112.5*               | Purple    | 15.0ns         | 37.4 ns                | 244.5*               | 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<sub>0.05</sub> | -          | -                  | 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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### Conflict of interest

None.

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