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Agro-biological Characteristics and Biochemical Parameters of Purple Waxy Corn [*Zea mays* (L.) var *certaina*] in Son La Province, Vietnam

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ABSTRACT

Background: Local purple waxy corns, biocompound activity and nutrition content good for health, are growing from different districts and altitude of sea level in Sõn La province with various characters. It is essential for evaluation of agro-biological characteristics and nutritional composition of local purple waxy corns was to find out which is the best and suitable for rejuvenlination, market and production in Son La province.

Methods: Field experiment was conducted following scientific principle of agricultural research and designed with random completed block design (RCBD) with three replications, a 20 m^2 block area. Observations and quality analysis of main traits of 12 purple local waxy corns were analyzed in summer season of 2022.

Result: Results showed various data of agro-biological characters, yield and biochemical kernel characters of twelve local purple waxy corns. SM8 local purple waxy corn variety showed the best agro-biological characters such as soluble protein 6.25 mg/g, total phenol 4.12 mg/g, chlorophyll stable index 89.5%, yield about 3.96 tons/ha, quality grain with starch content 68.63%, protein content 8.53% and anthocyanin content 315.03 mg/100 g. This variety can be a good option for the farmers to produce a variety with higher yield and good agro-biological characteristics.

Key words: Agro-biological characters, Biochemical parameters, Purple waxy corn.

INTRODUCTION

Corn (*Zea mays* L.) is one of the most important cereal crops in the world and it has been cultivated for thousands of years for its nutritional and economic values. This cereal was grown across the whole American continent and Mexico. Presently, corn is one of the three most important agricultural plant species in the world, alongside wheat and rice. As an annual plant, it is mostly grown for grain which is used for the production of food, flour, animal feed and ethanol (Serna-Saldivar, 2010).

In Vietnam, corn appeared quite soon afterwards 16th century by Phung Khac Khoan who brought it from China. Corn is grown in different regions and local varieties with unique characteristics are still grown in some areas. One of these local varieties is the purple corn [*Zea mays* (L.) var *ceratina*], which is cultivated in the Son La mountain province of North Vietnam. Purple waxy corn has high anthocyanin contents located in the pericarp layers which are powerful antioxidants that have been linked to a reduced risk of chronic diseases such as cancer, cardiovascular diseases and diabetes. Stickiness in sticky corn is due to its amylopectin content in its endosperm. The endosperm is also enriched with various types of antioxidants, bioactive compounds and amylopectin that are good for the human health (Lertrat and Thongnarin, 2008; Kesornkeaw *et al*., 2009; Harakotr *et al*., 2014). Moreover, purple corn is also rich in dietary fiber, vitamins and minerals, which are essential for human health (Tian *et al*., 2018).

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There are various special cultivars that contain colored pigments and give rise to numerous varieties of black and purple waxy corn. The ethnic farmers in Vietnam have planted purple waxy corn for vegetable as a cash crop. The purple corn is known for its distinctive color and flavor and it is a staple food for many local communities. The Son La province of North Vietnam has some characters due to they are grown at high altitude, cool climate and in diverse flora and fauna. These factors create a unique environment for the cultivation of crops such as purple corn. Son la province includes 12 ethnic farmer groups which are growing local purple waxy corns for staple food and main income source in different pedologic areas. These are reasons leading to local purple waxy corns have many different characters, yield and quality. Despite the importance of purple corn in the

local diet, there are limited researches on its agro-biological characteristics and nutritional composition.

Therefore, this study aims to investigate main agro-biological, physiological characteristics and biochemical quality of local purple corn collected for selecting a variety adapt in Son La ecology and also help to improve income of ethnic group of farmers by growing good variety of purple waxy corns in the Son La province, Vietnam. Moreover, the findings of this study would contribute to enhance the local knowledge of the agro-biological characteristics and nutritional composition of purple corn in the Son La province, Vietnam. Good characteristics varieties can be useful for improving the cultivation practices of purple waxy corn, as well as promoting its consumption for potential health benefits.

MATERIALS AND METHODS

Plant materials

12 cultivars of open-pollinated purple waxy corn were collected from different regions of Son La province (Table 1).

Field experiment

The experiment was conducted in randomized complete block design with three replications; a block is 20 m^2 in the summer season during 2022 at the Tay Bac University, Son La province, Vietnam. The plot size was five-row plot with seven meters in length and spacing of 0.70 × 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. These cultivars were planted under rained condition in Son La and insect pests, diseases and weed were appropriately managed to obtain optimum growth and yield of crop in the tested seasons.

Parameter observations

Days to anthesis (DTA) and days to silking (DTS) were number of days from sowing until 50% of the selected plants. Anthesis to silking interval (ASI) was calculated by DTS-DTA. For ear length, the distance from the base to the apex was measured in centimeters. The diameter of the ear was determined in centimeters using a vernier caliper, measuring the middle section of the upper ear. The weight of 1000 randomly selected grains was determined to quantify the weight of 1000 grains.

The yield (tons/ha) was calculated by the formula (Rabanal-Atalaya *et al*., 2022):

$$GY = FW \times \left(\frac{10}{EPA} \times \frac{100 - \%M}{86} \right) \times S$$

Where,

GY= Grain yield corrected to 14% moisture in tons per hectare.

FW= Field weight of the harvested grain.

%M= Moisture percentage of the grain.

(100-%M)= Coefficient of the percentage of dry matter.

86= Correction coefficient for moisture at 14%.

10/EPA= Correction factor used to convert kilograms per plot to tons per hectare.

S= Percentage of shelling, equivalent to 0.8.

Soluble protein content (Lowry *et al*., 1951), total phenolic content (Malik and Singh, 1980), chlorophyll stable index (Kauland and Deb Roy,1967), dry matter production used hot oven, amylose content (Fitzgerald *et al*., 2009), oil content Sadasivam and Manickam (1991), protein content (Piper, 1966), starch content (Hodge and Hofreiter, 1962) and anthocyanin content (AOAC, 2005) were analyzed for all cultivars.

Data analysis

The data collected from field and laboratory experiments underwent analysis utilizing the appropriate T-test, ANOVA analysis and comparison of means. A significant difference was analyzed at a significance level of ($p \leq 0.05$). The analysis of variance was conducted using PROC ANOVA in SAS v.9.3 (SAS Institute, 2012).

RESULTS AND DISCUSSION

Agro-biological characters of purple waxy corn

Romero-Cortes *et al.* (2022) reported different varieties of purple corn, longer time for panicle flowering ranging from 98.67-118.67 days in Mexico and Medina-Hoyos *et al.* (2020) also reported from 83 to 90 days in Peru. Nankar *et al.* (2016) had studied the DTA of Blue maize landraces from the Southwestern United States, ranges from 52.0 to 57.3 days. The DTA showed various data among the 12 purple local waxy corn varieties (Table 2). Cultivar SM8 and SM4 had the longest DTA values of 78.3 and 77.7 days, respectively, indicating a long duration compared to other varieties while variety SC2 had the shortest DTA value of 69.7 days, suggesting an early anthesis. Romero-Cortes *et al*. (2022) and Medina-Hoyos *et al*. (2020) reported purple maize a longer DTS range of 103.33 to 128.67 days in Mexico and from 96 to 102 days in Peru. The days to silking (DTS) values for different corn varieties were analyzed to understand the timing of silking. Results in experiment recorded the average DTS across all varieties is 85.1, with individual values ranging

Table 1: Samples of purple waxy corn cultivars and collection locations.

Cultivar	Collected locations	
	Latitude and longitude	Altitude of sea level (m)
SC1	20°57′34″N 103°37′41″E	910
SC2	20°57′35″N 103°37′43″E	914
SC3	20°57′31″N 103°37′33″E	872
SC4	20°58′34″N 103°374′49″E	823
SM1	21°06′53″N 103°474′06″E	897
SM2	21°06′22″N 103°47′37″E	1073
SM3	21°06′27″N 103°47′19″E	1076
SM4	21°01′35″N 103°40′09″E	625
SM5	21°01′27″N 103°40′24″E	482
SM6	21°01′27″N 103°40′23″E	497
SM7	21°01′33″N 103°40′15″E	556
SM8	21°01′38″N 103°40′07″E	616

from 80.0 to 87.7 days. SM4 exhibited the highest DTS value of 87.7 days, indicating delayed silking, while SC2 and SC4 had the lowest DTS values of 80.7 and 80.0 days, respectively, suggesting early silking. The average ASI across all varieties was 9.9 days, with values ranging from 8.7 to 11.0 days. The consistent ASI values (10.0 days) for most varieties suggest synchronized flowering. However, SC2 (11.0 days) and SM8 (8.7 days) show variations, possibly due to genetics or environmental factors. The difference of DTA, DTS and ASI data in experiment caused genetic factors and environmental conditions impact to the observed variation.

Physiological traits of purple waxy corns

Soluble protein in leaves is one of the important aspects to identify yield potential of crops. Reckova *et al*. (2019) analyzed soluble protein of maize leaves under different copper treatments given data 2.03 to 8.25 mg/g. Results in experiment recorded SC4 variety the lowest soluble protein about 3.56 mg/g while SM8 variety has showed the highest soluble protein content about 6.25 mg/g and followed by second highest soluble protein content (5.92 mg/g) by SC3 variety as shown in Table 2.

Total phenolic content of all the tested cultivars was ranged from 2.34 mg/g to 4.12 mg/g. The results showed that the SM8 cultivar was recorded with the highest total phenolic content as compared to the other cultivars (Table 2). Eleftherianos *et al*. (2006) measured total phenolic content with different abiotic stresses. Chlorophyll stability index is one of characters express heat, drought and salinity tolerances of crops. Purple local waxy corn cultivars in Son la showed high chlorophyll stable index value over 80%, however, SM8 cultivar was given 89.5% the highest chlorophyll stability index among 12 cultivars. Sampathkumar *et al*. (2013) also reported high chlorophyll stability index of maize leaves assistant to water deficit of crop.

Corn ear and yield characters of purple waxy corn

The data represents the measurements of corn length and diameter for different varieties. The average corn length was 9.60 cm, ranging from 7.86 cm to 12.02 cm, while the average corn diameter was 2.56 cm, ranging from 2.38 cm to 2.69 cm. Cultivars SM4 and SM7 exhibited the longest corn length (12.02 cm and 11.12 cm, respectively), whereas variety SC2 had the shortest corn length (7.86 cm). In terms of corn diameter, variety SM2 had the largest diameter (2.69 cm), while varieties SC2 and SC4 had the smallest diameters (2.38 cm and 2.47 cm, respectively) (Table 3). These varieties in experiment exhibited shorter ear length and smaller ear diameter but they gave 2-4 number of ears per plant within field observation. According to the research by Romero-Cortes *et al*. (2022) on purple maize varieties in Mexico, with ear diameter ranging from 2.9 to 3.79 cm and ear length ranging from 8.43 to 18.95 cm. These findings indicate significant variations in corn length and diameter among the examined varieties. These differences may have implications for yield and quality. Further investigation and experimentation are warranted to fully comprehend these variations and their potential impact on corn production. This suggests the potential for selecting corn cultivars based on desired ear characteristics.

Significant variations were also observed in the weight of 1000 grains among different corn cultivars of Son La province. SM8 showed the highest weight (1000 grains) about 178.03 g while SM2 and SC2 had the lowest values (133.97 g). Nankar *et al*. (2016) studied on blue maize varieties in New Mexico, USA, the weight of 1000 grains ranged from 217.3 to 318.6 g, depending on the specific

Table 2: Agro-biological and physiological traits of purple waxy corn in the Son La province, Vietnam (2022).

Cultivar	DTA	DTS	ASI	Soluble protein in leaves (mg/g)	Total phenol in leaves (mg/g)	Chlorophyll stable index (%) in leaves
SC1	74.3^{cd}	83.3^{c}	9.0^{a}	3.98^{d}	2.59^{c}	83.4^{d}
SC2	69.7^{f}	80.7^{d}	11.0^{a}	4.12^{c}	2.34^{d}	84.6^{c}
SC3	75.7^{bc}	85.3^{bc}	9.7^{a}	5.92^{ab}	3.86^{ab}	87.8^{b}
SC4	70.7^{ef}	80.0^{d}	9.3^{a}	3.56^{e}	2.53^{d}	85.1^{c}
SM1	73.0^{ed}	83.3^{c}	10.3^{a}	3.76^{d}	2.46^{d}	83.8^{cd}
SM2	76.7^{abc}	86.7^{ab}	10.0^{a}	4.55^{c}	2.71^{c}	84.7^{c}
SM3	75.7^{bc}	86.3^{ab}	10.7^{a}	3.91^{d}	2.63^{c}	85.3^{c}
SM4	77.7^{ab}	87.7^{a}	10.0^{a}	5.88^{b}	3.69^{b}	88.2^{ab}
SM5	77.3^{ab}	87.3^{ab}	10.0^{a}	4.13^{c}	2.56^{d}	83.9^{cd}
SM6	76.3^{abc}	86.3^{ab}	10.0^{a}	4.22^{c}	2.58^{d}	84.3^{c}
SM7	77.0^{ab}	87.7^{a}	10.7^{a}	4.44^{c}	2.81^{c}	84.4^{c}
SM8	78.3^{a}	87.0^{ab}	8.7^{a}	6.25^{a}	4.12^{a}	89.5^{a}
Mean	75.2	85.1	9.9	4.56	2.91	85.42
Range	69.7-78.3	80.0-87.7	8.7-11.0	3.56-6.25	2.34-4.12	83.4-89.5
LSD (≤0.05)	2.5	2.3	3.3	0.36	0.34	1.76

Note: DTA- Days to 50% anthesis; DTS- Days to 50% silking; ASI- Anthesis to silking interval; PH- Plant height; EH- Ear height. Values followed by the same letter in a column do not differ significantly (p≤0.05).

variety. Purple Kculli Corn was studied in Mexico and the weight of 1000 grains varied from 238.5 to 456.2 g depending on different fertilizer conditions (Romero-Cortes *et al*., 2022). Notably, other varieties of purple corn in Peru recorded weights ranging from 495.8 to 569.1 gram of 1000 grains. These findings highlight the significant variations in grain weight among different purple corn varieties, emphasizing the influence of genetics and environmental factors on grain development. The yield of purple waxy corn cultivars varied significantly difference. SM8 cultivar showed the highest yield (3.96 tons/ha) and SC2 the lowest 2.26 tons/ha compare to other cultivars (Table 3). Rabanal-Atalaya *et al*. (2022) conducted a study on several purple maize varieties in Peru, which revealed that the yield of purple maize ranged from 0.9 to 4.4 tons/ha, depending on the specific variety and cultivation region. Purple Kculli Corn was studied under different fertilizer conditions, the yields ranging from 1.02 to 6.19 tons/ha (Romero-Cortes *et al*., 2022). The observed results of yield among various purple corn cultivars may be due to the purple waxy corns studied in this study were from different selected positions influenced by environment and cultivated practices. These variations in yield highlight the crucial role of selecting appropriate varieties and employing efficient management strategies to optimize productivity. Varieties such as SM8 exhibited higher yields, suggesting their potential for enhanced productivity.

Biochemical quality of purple waxy corn kernel

The aim of analysis of quality characters is to get the best variety which supports the market and consumption also develops for rejuvenlination and production. The results of analysis grain quality characters of purple local waxy corns in Son La province is given in Table 4. Oil content and dry matter content recorded no significant difference among all twelve purple local waxy varieties studied. Although, they are impacted by genetic, macronutrients and environment. Starch content is one of important quality of grain. Hiilya (2006) reported that the starch content of different maize varieties varied from 43.2% to 84.75% depend on cultivars. SC1 and SM8 varieties were given the highest starch content at 68.14 and 68.63 %, respectively compared to other varieties at significant difference at LSD (≤0.05) =1.58 (%). Amylose content is a character of sticky quality of grain maize for cooking. Local purple waxy corn varieties of Son La province were showed amylose content from 6.13 to 7.40 % with SM3 and SM6 respectively. Similarly, Pandey and Nigam (2000) have given the results of amylose content varied from 3 to 30% of starch content alinear molecule of α-1,4-linked glucan.

Protein content is an important character of maize grain which gives its value of marketable and consumption. Local purple waxy corns of Son La province were given different results of protein content. SM8 recorded the highest protein content at 8.53% the second highest protein content is SM1 variety at 8.42% and the lowest protein content is SM5 variety with significant different at LSD (≤0.05). Similarly, Olowookere *et al*. (2017) has given protein content of maize grain from 5.8-13.5% depends on cultivars and environment. Anthocyanins are important bioactive substances and good for human health, found in purple corns (*Zea mays* L.) Anthocyanins are natural pigments, have strong antioxidant potential and the ability to scavenge oxygen free radicals (Tian *et al*., 2018). Local purple waxy corns in Son La province were given various results of anthocyanins in kernel. SM8 variety recorded the highest anthocyanin content about 315.03 mg/100 g and followed by SM5 variety with second highest content about 313.52 mg/100 g. The SM1 variety showed lowest anthocyanin content about 225.53 mg/100 g at a significant difference LSD (≤0.05). These results were indicated that SM8 variety recorded with the highest quality characteristics: high starch content, protein content and anthocyanin content.

Table 3: Mean values of corn ear and yield characters of purple waxy corn in Son La province, Vietnam (2022).

Cultivar	Corn length (cm)	Corn diameter (cm)	P 1000 grain (g)	Yield (Tons/ha)
SC1	8.86	2.63^{ab}	158.20^{cd}	2.65^{e}
SC2	7.86^{d}	2.38^{c}	144.03^{f}	2.26^{f}
SC3	9.06^{c}	2.51^{abcde}	156.80^{cde}	2.34^{f}
SC4	8.46^{cd}	2.47^{cde}	151.93^{e}	2.56^{e}
SM1	8.64^{cd}	2.63^{ab}	155.60^{cde}	2.68^{e}
SM2	8.70^{cd}	2.69^{a}	133.97^{g}	2.34^{f}
SM3	8.72^{cd}	2.55^{abcd}	143.43^{f}	2.65^{e}
SM4	12.02^{a}	2.55^{abcd}	153.97^{de}	3.56^{b}
SM5	10.58^{b}	2.67^{a}	167.13^{b}	3.27^{c}
SM6	10.76^{b}	2.41^{de}	160.13^{c}	2.63^{e}
SM7	11.12^{ab}	2.61^{abc}	160.63^{bc}	3.08^{d}
SM8	10.46^{b}	2.65^{ab}	178.03^{a}	3.96^{a}
Mean	9.60	2.56	155.40	2.83
Range	7.86-12.02	2.38-2.69	133.97-178.03	2.26-3.96
LSD (≤0.05)	1.07	0.15	5.47	0.19

Note: Values followed by the same letter in a column do not differ significantly (p≤0.05).

Table 4: Kernel biochemical quality of purple waxy corn in the Son La province, Vietnam (2022).

Cultivar	Starch content (%)	Protein content (%)	Oil content (%)	Dry matter content (%)	Amylose content (%)	Anthocyanin content (mg/100 g)
SC1	68.14^{a}	7.57^{a}	6.23^{a}	89.75^{a}	7.30^{a}	244.02^{c}
SC2	63.18^{c}	6.92^{d}	6.10^{a}	88.92^{a}	7.20^{a}	249.70^{c}
SC3	60.76^{d}	8.07^{a}	6.16^{a}	89.31^{a}	7.03^{a}	243.53^{c}
SC4	62.56^{c}	8.35^{a}	6.11^{a}	89.26^{a}	6.40^{b}	259.36^{b}
SM1	61.92^{d}	8.42^{a}	6.09^{a}	88.88^{a}	7.06^{a}	225.53^{d}
SM2	67.36^{a}	7.35^{b}	6.19^{a}	88.95^{a}	6.55^{b}	249.18^{c}
SM3	66.36^{b}	7.86^{a}	6.15^{a}	89.55^{a}	6.13^{b}	229.02^{d}
SM4	67.76^{a}	7.46^{a}	6.14^{a}	89.68^{a}	7.07^{a}	262.02^{b}
SM5	62.39^{cd}	6.76^{d}	6.18^{a}	89.61^{a}	7.10^{a}	313.52^{a}
SM6	65.36^{b}	7.63^{a}	6.25^{a}	88.99^{a}	7.40^{a}	228.85^{d}
SM7	65.92^{b}	7.32^{c}	6.17^{a}	89.25^{a}	7.05^{a}	248.02^{c}
SM8	68.63^{a}	8.53^{a}	6.21^{a}	89.84^{a}	6.19^{b}	315.03^{a}
Mean	65.04	7.69	6.17	89.33	6.87	255.65
Range	60.76-68.63	6.76-8.53	6.09-6.25	88.88-89.84	6.13-7.40	225.53-315.03
LSD (≤0.05)	1.58	0.23	0.21	2.25	0.45	5.38

Note: Values followed by the same letter in a column do not differ significantly (p≤0.05).

CONCLUSION

The observations and analysis among 12 purple local waxy corns of Son La province exhibited significant variations in main agro-biological traits including days to anthesis, days to silking, anthesis to silking index, physiological traits involvesoluble protein, total phenol and chlorophyll stable index,corn length and diameter, 1000 grain weight, yield and kernel biochemical qualities. However, SM8 local purple waxy corn variety showed the best characters of physiological (soluble protein 6.25 mg/g, total phenol 4.12 mg/g and chlorophyll stable index 89.5%), yield (potential yield 4.95 tons/ha and yield 3.96 tons/ha), kernel characteristics (starch content 68.63%, protein content 8.53% and anthocyanin content 315.03 mg/100 g). In conclusion, SM8 variety is a good variety for consumption enriched with bioactive compounds and can have potential to generate marketable revenues for farmers and agriculturists, throughout the world.

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Conflict of interest

All authors declare that they have no conflict of interest.

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