RESEARCH ON GROWTH, YIELD AND QUALITY CHARACTERISTICS OF IMPORTED ASPARAGUS VARIETIES ADAPTED TO THE RED RIVER DELTA, VIETNAM

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ABSTRACT

Asparagus (*Asparagus officinalis* L.) is known as a valuable vegetable due to its richness in anti-cancer and antioxidant compounds, vitamins, minerals, and high economic efficiency. Asparagus is being expanded in production in Vietnam. Breeding asparagus varieties has not been carried out in Vietnam, so asparagus varieties grown in Vietnam are all imported varieties. The study aimed to choose the best varieties among 12 asparagus varieties imported from the US and Netherlands for production in the Red River Delta, Vietnam. The yield of spears was assessed in the spring and autumn season 2022 using the second-year asparagus in the field of the Field Crops Research Institute, Hai Duong province, Vietnam. The results indicated that Atlas F1 was the variety with the most advantages in both seasons, with a low infection rate of stemblight, large diameter of spears, high dry weight of spears, high yield and yield component, and moderate vitamin C content. In addition, Purple passion was also a special variety with high stability due to its low infection rate, high dry weight, high vitamin C content in both seasons, high sugar accumulation rate in roots, root CHO, and total sugar content in the autumn season 2022, although the yield productivity and yield component were low. The results also showed a positive and significant correlation between asparagus yield productivity and root Brix in both seasons of 2022. The results suggest that the root Brix of asparagus could be the target trait for choosing varieties for production.

Keywords: *Asparagus officinalis, asparagus varieties, root Brix, root CHO, quality, yield.*

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1. INTRODUCTION

Asparagus (*Asparagus officinalis* L.) belongs to the family *Asparagaceae* and is a dioecious perennial crop. Asparagus is a premium vegetable with edible shoots called spears [1]. Asparagus has been grown in 45 countries around the world, on five continents: Europe, America, Asia, Africa, and Australia. The average worldwide yield in 2021 was 5.33 tons/ha. The total area for harvest in 2021 worldwide is 1.60 million hectares, with China taking the leading position at 1.44 million hectares [2].

Asparagus products are rich in anticancer and antioxidant compounds such as rutin, saponins, polyphenols, polysaccharides, and polyamines, which are considered high-value products [3]. Asparagus is rich in vitamins, minerals, and folate salts: potassium (202 g/100 g fresh), folate (52 mg/100 g fresh), vitamin A (38 mg/100 g fresh), C 95.6 mg/100 g fresh), K (41.6 mg/100 g fresh), phosphorus (52 mg/100 g fresh), calcium (24 mg/100 g fresh), magnesium (14 mg/100 g fresh), and very little sodium (2 mg/100 g fresh) [4].

In Vietnam, the first asparagus was planted in 1960. Until 2005, asparagus was widely grown in Ninh Thuan, Binh Thuan, Ba Ria - Vung Tau, Dong Nai, Cu Chi, Binh Phuoc, Vinh Long, and An Giang [5]. Recently, asparagus has been grown in the North: Hai Duong, Ha Noi, Hai Phong, Bac Ninh, and Phu Tho. Asparagus can bring a high income to

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growers. In Ninh Thuan province, farmers earn 150-300 million VND/ha/year from asparagus. Prices range from 30,000 VND to 90,000 VND per kg depending on the season. This crop has been considered a high-value crop [5].

In the production of asparagus, the first strategy is to choose a source of asparagus varieties adapted to the growing regions. Additionally, the cultivation must remain productive for a few years to recover the initial investment and make a profit [6]. However, the morphological characteristics and yield of asparagus depend on the characteristics of different varieties, techniques, and growing conditions [7]. Asparagus breeding has not been done in Vietnam, so seeds are imported mainly from the US and the Netherlands [8]. In recent years, some heat-resistant asparagus varieties imported from the Netherlands and the US have been tested in some regions [8], [9]. However, choosing a suitable variety of asparagus for the Red River Delta-the center of Vietnam's socio-economic development, is essential. Therefore, this study aims to select the promising varieties imported from the US and Netherlands for asparagus production in the Red River Delta in Vietnam.

2. MATERIALS AND METHODS

2.1. Materials

Twelve varieties of F1 asparagus were imported from the US and Netherlands, which are listed in table 1.

Table 1. List of asparagus varieties participating in the experiment

No	Varieties	Origin	No	Varieties	Origin
1	K767	Netherlands	7	UC157	USA
2	Starlim	Netherlands	8	Grande	USA
3	Lunalim	Netherlands	9	WB212	USA
4	Apollo	USA	10	WB230	USA
5	Atlas	USA	11	WB231	USA
6	Delux	USA	12	Purple passion	USA

2.2. Methods

2.2.1. Experiment design

The experiment was arranged in a completely randomized block design (RCBD), with 12 varieties and 3 replicates in the open field at Field Crops Research Institute, Hai Duong province, Vietnam, with the attitudes of 20°53' N and 106°17' E. The experimental plot size is 25 m^2plot^{-1}, planting 2 $rows^{-1}$, planting distance 0.75 m x 0.4 m. The experiment was planted on March 27, 2020. Seedlings were planted when 3 stems per plant were 3 months old. The second-year asparagus was evaluated in this study. The experiment was evaluated in two seasons (spring season 2022 and autumn season 2022) of the second asparagus year. Soil was sampled in the second year of asparagus to analyze its chemical properties (Table 2).

Table 2. Soil chemical properties - sampling at the second-year asparagus

pH	OC	N	P_2O_5	K_2O	N	P_2O_5	K_2O	Ca	Mg	Fe
	%				mg/100 g			mg/100 g		
7.69	1.54	0.12	0.32	2.07	5.2	33.1	21.4	274.7	22.2	18.5
Rating hierarchy/Threshold										
High	>2,0	>0,2	>0,1	>2,0	>6	>10	>20	>160	>36	-
Low	<0.9	<0,1	<0,06	<1,0	4-6	<5	<10	<40	<12	-
Moderate	1,0-1,9	0,1-0,2	0,06-0,10	1,0-2,0	<4	5.0-10.0	10-20	80-160	12-36	-

Note: Fertilizer for the second-year asparagus: Organic fertilizer: 40 tons/ha; NPK: 150 kg N: 150 kg P_2O_5: 150 kg K_2O ha; MgO: 30 kg/ha.

2.2.2. Asparagus growth, yield measurements

Growth characteristics: Diameter dynamics of harvested spears were measured from emergence to harvest height (spear length greater than 27 cm). The size of the sample was 10 plants per replicate per variety. The chlorophyll content of a fully expanded

leaf was measured by the method of Wintermans and De Mots A (1965) [10]. Carbohydrate content (CHO) in the root was measured using the Wilson *et al.* (2008) [11] method via root Brix: Dug 50 cm depth, took 3 roots/cluster, then cut 15 cm roots in the middle. Root extract was measured Brix with a Brix meter.

Water loss was determined on a fresh weight basis. For each treatment, ten spears per replication were harvested separately, and the fresh weights were recorded immediately. The spears were kept in normal room conditions (26°C ± 1°C temperature, 75% ± 3% relative humidity) for 6 hours. After 6 hours, the spears were weighed for calculate spear moisture loss. Then, these spears were dried in the oven at 80°C for many hours until a constant weight was reached and the dry weights were recorded.

The spear moisture content (SMC) and spear moisture loss of the treatments were calculated separately using the following formulas and expressed as percentages (%):

$$\text{Spear moisture content (\%) (SMC)} = \left[\frac{\text{Fresh weight of spear} - \text{Dry weight of spear}}{\text{Fresh weight of spear}} x\ 100\right]$$

Water loss = 100% - SMC

Stem blight *Phomopsis asparagi* infection was surveyed in May and autumn season 2022, from the end of the rainy season: *Phomosisasparagi* infection rate was measured based on the number of infected plants in a total of 20 plants of each replication per variety with the following formula:

Disease rate = number of infected stems/total number of stems in the cluster

Asparagus yield of the second asparagus year in the spring and autumn seasons, 2022: each season harvested for 30 days. The length of the harvested spear was 27-30 cm.

Quality traits of spears: Brix of spears was measured using the Brix meter (Milwaukee MA882); Nitrate content in spears (NO_3^- content) was measured using the SoeksNuc 091-01 machine; Vitamin C content (mg $100g^{-1}$), Fiber content (%) [12] and Total sugar content (%) in spear were measured as per protocols described previously [12-14].

Data analysis

Analysis of variance (ANOVA) was performed using Minitab 16 software, and the significance of mean values was analyzed by Tukey's test.

3. RESULTS

3.1. Climate condition of the experimental site

The climate in Hai Duong province has been considered representative of the climate of the Red River Delta, Vietnam, and subtropical regions (Figure 1). The spring season started from January to March with low temperatures and rainfall. Next was summer (April to July) and autumn season (August to September), in which August was the heaviest rain and a favorable condition for stem blight disease to thrive. December-winter months dropped sharply in temperature and rainfall in a year.

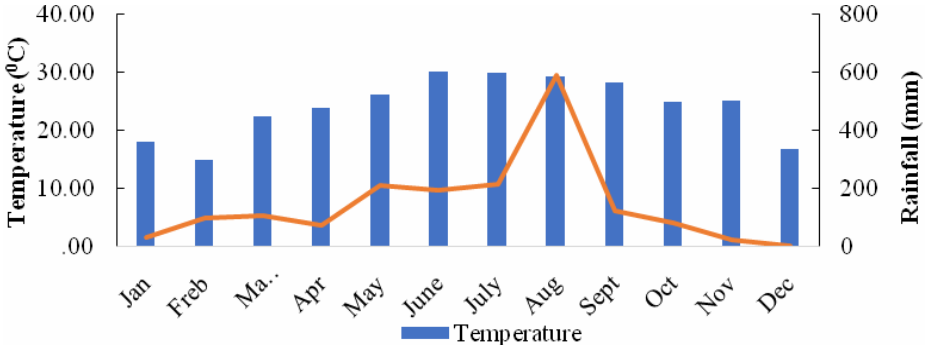

Figure 1. Mean monthly climate data of Hai Duong province in 2022

Source: Hai Duong hydrometeorological station 2022.

3.2. Growth characteristics of spears of imported asparagus varieties

The diameters of spear bases measured at peak harvest reflect the spear thickness of each variety. The diameter of spears increased gradually from day 1 to day 3, and 4, some varieties reached the harvested diameter on day 4. The diameter of spears in the spring season of 2022 tended to be higher than in the autumn crop season of 2022 (Figure 2).

In the spring season of 2022, on day 1 and day 2, the difference in diameter of spears was not statistically significant, but from day 3 to day 4, different varieties gave significantly different diameters of spears. The highest and most significant difference in the diameter of spears was Atlas and K767 varieties. Varieties with spear diameters ranged from 0.55 to 0.94 cm (Figure 2).

In the autumn season of 2022, the varieties with a high spear diameter and significantly different from the remaining varieties on day 3 were Grande, Atlas, Purple passion, UC157, and K767. The spear diameter of asparagus varieties ranged from 0.66 - 0.85 cm (Figure 2).

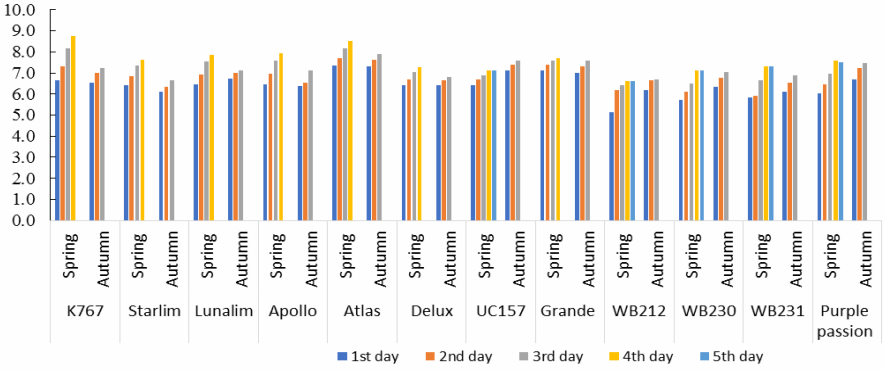

Figure 2. Diameter dynamics of harvested spears of imported asparagus varieties in the spring and autumn seasons of 2022

3.3. Physiological characteristics of spears of imported asparagus varieties

The root Brix was measured before harvest. The root Brix of varieties in the spring season of 2022 was higher than that in autumn 2022; in both seasons, the Atlas variety still achieved a high root Brix and was significantly different from the other varieties. In the spring season, root Brix was highest in the Atlas variety and was not significantly different from UC157, Grande, K767, Delux, and lowest in the WB212, WB 230, and Apollo varieties. In the autumn season of 2022, root Brix was highest in Purple passion and was not significantly different from Atlas, Grande, and lowest in Lunalim (Table 3).

Table 3. Root Brix, root carbohydrate, and chlorophyll content of imported asparagus varieties

Variety	Root Brix (%)		CHO (mgg^{-1})		Chlorophyll in Autumn 2022		
	Spring 2022	Autumn 2022	Spring 2022	Autumn 2022	Chl. a	Chl. b	Chl. a+b
K767	18.88abc	15.0bc	441.3abc	377.4ab	28.9ab	63.7ab	92.3ab
Starlim	16,33def	14.5bc	387.5def	349.6bc	28.9a	63.0ab	91.5ab
Lunalim	17.75bcde	11.1d	419.6bcde	298.2d	29.8a	59.7ab	89.2ab
Apollo	14.77f	15.2b	354.5f	364.3abc	28.5ab	63.9ab	92.1ab
Atlas	20.77a	15.6ab	481.1a	385.4a	28.8ab	63.0ab	91.5ab
Delux	18.33abcd	15.0bc	440.3abcd	360.1abc	29.2ab	62.6ab	91.5ab
UC157	19.23ab	15.0bc	448.7ab	360.1abc	29.3ab	62.5ab	91.5ab
Grande	18.92ab	15.6ab	469.4ab	372.8ab	28.8ab	63.4ab	91.91ab
WB212	14.83f	14.0c	355.9f	339.0c	29.0ab	62.9ab	91.6ab
WB230	14.83f	14.5bc	355.9f	348.1bc	29.5ab	59.7ab	88.9b
WB231	15.07ef	14.5bc	360.8ef	3448.1bc	29.4ab	59.6b	88.7b
Purple Passion	16.37cdef	16.4a	388.2cdef	384.0a	28.5b	65.3a	93.4a

Note: Mean values with different alphabet letters are significantly different at 0.05 probability and vice-versa.

CHO content in the root was also higher in the spring season than in the autumn season of 2022 because the root Brix in the spring season was higher than in the autumn season. In both seasons, the Atlas variety had the highest CHO content. In the spring season of 2022, the Atlas variety had the highest CHO, followed by UC157, Grande, and K767. In the autumn season of 2022, the Atlas variety also had the highest CHO, followed by Purple assion and Grande.

Chlorophyll a + b in the autumn season of 2022 was highest in the Purple passion variety and lowest in the WB231 variety. However, all varieties had no significant difference in the amount of chlorophyll a + b in leaves except for two varieties WB230, which was significantly lower than the remaining varieties (Table 3).

The Spear moisture content of spears did not differ between varieties in both seasons (spring and autumn), ranging from 92.23-95.35% in spring 2022 and 90.3-92.1% in autumn season 2022. Spear moisture content in the spring season of 2022 tended to be higher than in the autumn season. However, the spears moisture loss after 6 hours of the autumn season 2022 tended to be higher than that of the spring season (Table 4).

Table 4. Spear moisture content, spear moisture loss after 6 hours, and dry weight of imported asparagus varieties

Variety	Spear moisture content (%)		Spears moisture loss after 6 hours levels (%)		Dry weight (g/100 g fresh weight)	
	Spring 2022	Autumn 2022	Spring 2022	Autumn 2022	Spring 2022	Autumn 2022
K767	93.56a	90.8a	7.36b	7.9a	6.51cdef	9.2ab
Starlim	94.46a	91.7a	9.7a	7.2a	6.02f	8.0bc
Lunalim	93.31a	91.4a	5.0efg	8.2a	6.40cdef	8.2bc
Apollo	93.77a	92.3a	5.5de	7.7a	6.11ef	7.9bc
Atlas	92.69a	90.3a	5.1efg	8.4a	7.41a	9.8a
Delux	92.87a	90.7a	5.9cd	7.6a	6.90abc	8.1bc
UC157	93.42a	92.1a	6.2c	7.5a	6.78bcd	8.9abc
Grande	94.24a	90.9a	5.0efg	8.2a	6.39cdef	9.1abc
WB212	92.23a	91.6a	5.0fg	6.3a	6.58bcde	8.4abc
WB230	95.35a	90.4a	6.1c	6.8a	6.53bcdef	8.7abc
WB231	93.66a	91.2a	5.3ef	7.5a	6.35dè	7.6c
Purple passion	93.3a	90.7a	4.7g	6.7a	7.1ab	9.0abc

Note: Mean values with different alphabet letters are significantly different at 0.05 probability and vice-versa.

The dry weight of the autumn season was higher than that in the spring season, and the Atlas variety had the highest dry weight in both seasons. The varieties with high dry weight in both crops are Purple passion, Grande, and K767 (Table 4).

3.4. Phormosis asparagi infection rate of some asparagus varieties in the autumn season 2022

Table 5. The situation of Phomopsis disease of asparagus varieties in the autumn season of 2022

Varieties	Infection rate (%)			
	May	August	September	October
K767	26.9	56.9	63.2	64.65
Starlim	34.29	64.29	72.46	67.83
Lunalim	33.44	63.44	66.31	64.56

Apollo	35.17	65.17	71.11	70.0
Atlas	15.56	45.56	49.05	50.5
Delux	31.43	61.43	68.92	66.5
UC157	29.0	59.0	60.8	63.42
Grande	27.94	57.94	65.0	62.4
WB212	33.41	63.4	70.8	63.76
WB230	25.75	53.97	68.7	61.7
WB231	23.98	53.7	64.56	60.49
Purple passion	20.9	50.9	55.2	54.6

All varieties were susceptible to stem blight. In May, 25 months after planting, the disease began to appear at a low rate ranging from 15.6% to 35.17%, the lowest in the Atlas and Purple passion varieties and the highest in Apollo. However, in August and September after the increase in temperature and heavy rains, the disease rate increased sharply. The disease rate reached its highest in September, the highest rate was 72.46% in Starlim, followed by Apollo with 71.11%. The disease rate is lowest in the Atlas variety at 49.0% and in Purple passion at 55.2%. By October, when the temperature decreased, the disease rate tended to decrease slightly.

3.5. Asparagus yield productivity and yield component of imported asparagus varieties

The number of spears in the spring season, of 2022 tended to be higher than that in the autumn season of 2022. In both seasons, the Atlas variety had the highest number of spears and was significantly different from the other varieties (Table 6).

The average weight of spears was the highest in the Grande variety in both seasons, significantly different from the rest of the varieties, followed by the Atlas variety. In spring 2022, the average weight of spears of the varieties Apollo, Lunalim, and WB231 was not different from Atlas and was all high. In the autumn season of 2022, the average weight of spears of the Purple passion, Atlas, and UC157 were not significantly different.

Table 6. Asparagus yield and yield component of imported asparagus varieties

Variety	Number of spears cluster^{-1}		Average weight of spears (g spear^{-1})		Individual yield (g plant^{-1})		Yield productivity (quintal ha^{-1})	
	Spring 2022	Autumn 2022	Spring 2022	Autumn 2022	Spring 2022	Autumn 2022	Spring 2022	Autumn 2022
K767	7.5b	4.9bc	18.5de	9.6cde	137.1c	47.0bc	32.4bc	7.0cd
Starlim	6.8bcd	4.7bc	13.3h	8.8ef	90.6e	41.2c	27.1de	6.2d
Lunalim	6.8bcd	4.4bc	19.8bcd	9.2def	134.2c	40.5c	29.2cd	6.7cd
Apollo	6.5cde	4.2bc	20.2bc	8.8ef	133.9c	36.6c	29.4cd	7.0cd
Atlas	8.6a	6.4a	21.0b	10.9b	180.3a	69.5a	37,5a	9.8a
Delux	6.7bcde	4.2bc	15.9g	8.6f	106.3de	36.1c	28.5de	6.4d
UC157	7.2bc	5.5ab	18.6de	9.8bc	131.4c	53.9b	34.2ab	7.0cd
Grande	7.0bcd	5.4ab	22.4a	12.4a	157.9b	67.3a	34.0ab	8.7b
WB212	5.7ef	4.1c	19.2cde	9.3def	109.9d	37.9c	24.4e	6.4d
WB230	6.1def	4.8bc	18.2ef	9.2def	111.6d	44.2bc	26.3de	6.9cd
WB231	6.8bcd	5.1abc	19.7bcd	9.5def	133.1c	48.3bc	26.2de	7.1cd
Purple passion	5.3f	4.2bc	17.0fg	10.5bc	89.7e	43.7bc	25.2e	7.6c

Note: Mean values with different alphabet letters are significantly different at 0.05 probability and vice-versa.

The individual yield of the spring season of 2022 tended to be higher than that of the autumn season of 2022. In both seasons, the individual yield of the Atlas variety had the highest value, which was significantly different from the other varieties, followed by the Grande variety.

The yield productivity of the spring season of 2022 was higher than that of the autumn season of 2022. The yield productivity of the Atlas variety had the highest value in both seasons and was significantly different from the other varieties; the lowest ones were the WB212 and Starlim varieties. In the spring season of 2022, the yield productivity of UC157 and Grande was not significantly different from that of the Atlas variety. In the autumn season of 2022, the yield productivity of Atlas reached the highest value, followed by Grande, Purple Passion, UC157, and K767 (Table 6).

3.6. Quality characteristics of imported asparagus varieties

The Brix of spears of imported asparagus varieties was measured in the autumn season of 2022; only UC157 and WB231 varieties had the highest Brix of spears, followed by K767, Atlas, and Purple Passion (Table 7).

The vitamin C content of asparagus varieties fluctuated significantly in both seasons. In both seasons, vitamin C content was highest in the Purple passion variety, followed by the Atlas variety. In the spring season of 2022, the vitamin C content of asparagus varieties ranged from 9.49 to 19.25 mg $100g^{-1}$. In the autumn season of 2022, vitamin C content fluctuated more than in the spring season from 8.3 to 20.5 mg $100g^{-1}$ (Table 7).

Table 7. Quality characteristics of imported asparagus varieties

Variety	Brix of spear	Vitamin C content (mg $100g^{-1}$)		Total sugar content (%)		Fiber content (%)
	Autumn 2022	Spring 2022	Autumn 2022	Spring 2022	Autumn 2022	Autumn 2022
K767	6.7b	11.05h	9.66f	1.96a	1.99de	2.14e
Starlim	5.5e	11.64g	14.94b	1.80b	2.09bcde	2.4a
Lunalim	6.3c	9.74i	10.6e	1.60g	1.85e	2.1f
Apollo	6.3c	15.71cd	12.65cd	1.64ef	2.21bcd	2.3c
Atlas	6.5bc	16.32b	14.9b	1.64ef	2.37b	1.59i
Delux	5.9d	14.79e	12.4d	1.67de	1.99de	2.34b
UC157	7.4a	9.49j	14.89b	1.60g	2.04cde	2.35b
Grande	6.3c	12.08f	8.3g	1.66h	2.30bcd	2.11f
WB212	5.5e	15.87c	13.4c	1.75c	2.31bcd	1.94h
WB230	7.3a	9.97i	15.3b	1.68d	2.35bc	2.3c
WB231	6.1cd	15.56d	10.1ef	1.48i	1.99de	2.02g
Purple passion	6.4bc	19.25a	20.5a	1.67de	3.15a	2.16d

Note: Mean values with different alphabet letters are significantly different at 0.05 probability and vice-versa.

The NO_3^- content threshold for asparagus is 200 mg kg^{-1} (WHO standard), in the autumn season of 2022, all varieties of asparagus had NO_3^- content below the permissible threshold and were safe for human consumption.

The total sugar content of the autumn season of 2022 tended to be higher than that of the Spring season of 2022. In the Spring season 2022, the K767 variety had the highest total sugar content, followed by Starlim, and was significantly different from the other varieties. In the autumn season of 2022, the Purple passion variety had the highest total sugar content and was significantly different from the other varieties, followed by Atlas, WB230, WB212, Grande, Apollo, and Starlim (Table 7).

The fiber content of the asparagus varieties in the autumn season of 2022 ranged from 1.59 to 2.4%. The Atlas variety had the lowest fiber content and was significantly different from the other varieties.

3.7. Relationship between Asparagus yield productivity and root Brix

The relationship between asparagus yield productivity and root Brix were positive and significant in both the spring and autumn seasons 2022 (Figure 3).

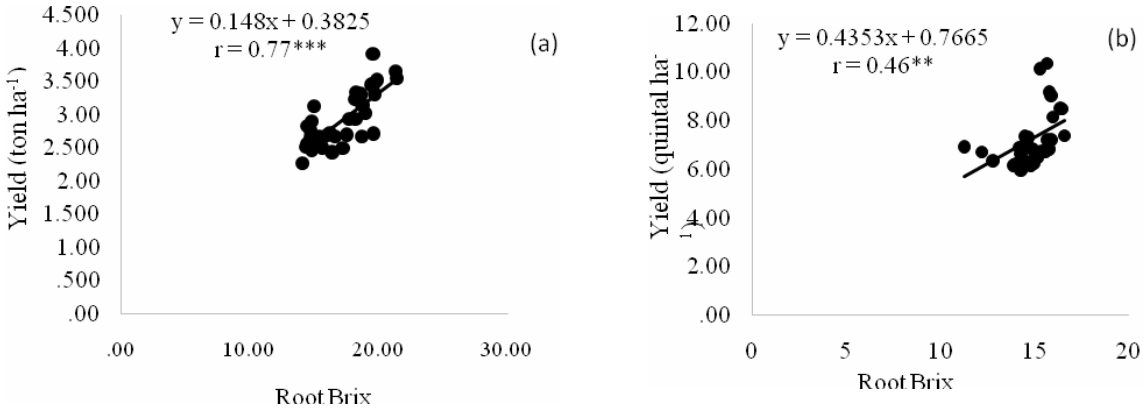

Figure 3. The relationship between Asparagus yield productivity and root Brix in the spring season 2022 (a) and autumn season 2022 (b). **, *, significant at (P)< 0.01 and (P)<0.001, respectively**

4. DISCUSSION

The Northern of Vietnam belongs to the tropical and subtropical regions, reported the high temperature and humidity, and adaptability of asparagus varieties can provide a good yield. However, stem blight has been a constraint to extending asparagus growing areas in the Red River Delta in Vietnam as well as other regions in Vietnam and other Asian and Pacific countries such as Japan, China, Myanmar, Australia, and New Zealand [15]. Until now, no resistant asparagus variety has been developed. There were no effective chemical synthetics to control disease [16]. Therefore, it is necessary to have integrated management the asparagus under the field to control the disease, such as plant density, nutrition management, and increase biodiversity, especially growing under plastic tunnels or mulch to reduce the possibility of *Phomopsis asparagi* spores reaching the foliage. In this study, Atlas could be a good variety to resist *Phomopsis asparagi* infection because of its lower infection rate (Table 5).

Among the varieties evaluated, the Atlas variety had the highest yield productivity and yield components (Table 6) because the Atlas variety had the highest root Brix, highest root CHO (Table 3), and highest dry matter weight (Table 4), the rate of diseases caused by *Phormopsis asparagi* was low (Table 5). The research results of Nguyen *et al.* (2020) [9] also pointed out that Atlas had a high spear yield, the ratio of spear grades 1,2 was over 30%, and the economic variety was suitable for South Central Vietnam. Moreover, the cultivar of Atlas had a high tolerance to soil-borne disease caused by *Fusarium* sp. and leaf rust caused by *Cercospora* sp. Atlas can adapt to the tropical medium environment, which is constrained by high temperature and humidity [17]. Besides, the reasons why the number and weight of asparagus spears yield higher than the others in this study, and that's why Atlas is well adapted to the hot, humid climate of the Red River Delta, Vietnam.

Besides the advantage of the thickness of the spears, purple asparagus has been expected to contain more antioxidant content than green asparagus. Purple passion has been approved since it contains the novel anthocyanin A1 cyanidin 3-[300-(O-b-D-glucopyranosyl) - 600 - (O - a - L - rhamnopyranosyl) - O - b - D - glucopyran - oside] and the anthocyanin A2 cyanidin 3-rutinoside with high antioxidant activities [18]. In addition, the high rutin content, high chl a and b, and total carotenoid content were found in the 'Purple passion' variety [21]. That is the reason why consumers can pay a higher price for the products and can compensate for the low yield of this Purple passion variety.

Asparagus yields are linked to the availability of soluble carbohydrates (CHO) in the storage root system, which is considered a key factor in asparagus productivity. Asparagus yield and plant

growth are highly dependent on the availability of soluble carbohydrates (CHO) in the storage root system [11]. Ultimately, root CHO levels are considered to be a key factor determining asparagus yield performance, which was officially recognized by the AspireNZ decision support system of Wilson *et al.* (2002) [20], which provided growers with an interpretation guide of root CHO content to facilitate better crop management decisions. There is significant variation in asparagus storage root CHO levels between plants depending on the size of the root system [11]. In this study, root Brix was measured before harvesting and decision the time of harvest asparagus and using the root Brix data to convert to root CHO. There was a positive and significant correlation between root Brix and yield productivity of 12 asparagus varieties in both seasons (spring and autumn seasons 2022), this finding agreed with the finding of Maˇskov´a *et al.* (2023) [21] that asparagus yields are linked to the availability of soluble carbohydrates (CHO) in the storage root system via root Brix, which is considered a key factor in asparagus productivity.

5. CONCLUSION

The growth, physiological, yield productivity, and yield components of asparagus varieties in the spring season of 2022 tended to be higher than those of the autumn season of 2022. Sterm blight due to Phormosis asparagi infection is very prevalent in September in the autumn season of 2022. Atlas is the most promising asparagus variety that can be grown commercially because of the advantages of having the largest spear diameter, root Brix, and CHO of the roots, and the highest dry matter weight, yield productivity, and yield components as compared with other varieties. Besides, quality characteristics such as Brix of spears, vitamin C content of spears were high, and fiber content of spears was the lowest. Some promising varieties of asparagus are Grande and Purple Passion which are also promising varieties after Atlas. In addition, the Purple passion variety is special because it has the highest vitamin C content of spears, the highest total sugar content of spears in the autumn season of 2022, and has more anthocyanin content in spears compared to the other varieties. From these results, Purple passion is also a promising variety for commercial production, although the yield is not high.

There was a positive and significant correlation between asparagus yield productivity and root Brix in both seasons in 2022. The results suggeststst that the root Brix of asparagus could be the target trait for choosing varieties for production.

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