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GROWTH AND DEVELOPMENT CHARACTERISTICS OF PLANT INDIVIDUALS FROM TWO *LYCIUM BARBARUM* L. VARIETIES

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Abstract

This study is the result of the interpretation and synthesis of the observations, measurements and calculations performed with regard to the biological characteristics of growth and development dynamics of the vegetative and reproductive organs of Lycium barbarum L. plants. Two varieties of this species were studied. Research has been conducted between the years 2010 and 2012. Some of the biological characteristics, that have been measured or observed, were: plant height, number and length of shoots, number of leaves, flowering and fructifying dates, fruit yield, soluble dry substance in fruit (SU%) and fruit weight. Also, the volume and shape of the two years old goji shrubs were determined. The plants' shapes were either truncated cones or inverted (reversed) truncated cones. Our work highlights some of the differences between the two studied Lycium barbarum L. varieties. These differences refer to adaptability potentials as well as biological characteristics. The significance of our contribution is that it presents the growth dynamics and development stages of two varieties belonging to the Lycium barbarum L. species, making comparisons between the two varieties' characteristics and showing how the second year's measurements compare to those of the first year from planting.

Key words: *biological characteristics, fructification, growth dynamics, Lycium barbarum L. (Goji), varieties.*

INTRODUCTION

Lycium barbarum L. is a deciduous shrub belonging to the Solanaceae family and which is native to Asia and S-E Europe. Its fruit are also known as Goji berries and they have been used for a long time in Traditional Chinese Medicine together with other parts of the plant (Institute of Chinese Materia Medica, 1997).

In recent years, the species' popularity has grown, especially in western countries, as its fruit is being used as a functional food or as a major component for many different categories of healthcare products.

This is mostly due to marketing claims, although scientific research, which is increasingly focusing on goji berries' health promoting properties, has shown that the fruit's nutritional value and sanogene potential are impressing (Amagase et al., 2011).

Thus, these exotic berries are highly valued for their: antiageing properties, antidiabetic effects, antioxidant activity, cardiovascular benefits, for promoting eye health and for strengthening the immune system (Mencinicopschi, 2010).

Though numerous studies on the plants' biological characteristics exist in China, where this species is considered a national treasure, this type of research hasn't been conducted at the same scale in western countries.

Moreover, the majority of studies which have been carried out lately are increasingly focusing on the positive health effects of the berries active components (LBP) and less on the biological characteristic of the plants.

In Romania, *L. barbarum* has only been regarded as a potentially invasive species (Anastasiu, 2005), and the possibility of introducing these plants towards cultivation hasn't been studied yet.

This is why this study aims to present the biological characteristics of growth and development dynamics of the vegetative and reproductive organs of *Lycium barbarum* L. plants, grown in Northern Bucharest region.

MATERIALS AND METHODS

In order to study the growth and development characteristics of plant individuals from the *Lycium barbarum* L. species, the following

indicators were used: plant height, number and length of shoots, number of leaves, flowering and fructifying dates, fruit yield, soluble dry substance in fruit (SU%) and fruit weight. Also, the volume and shape of the two years old goji shrubs were determined.

These indicators were determined for two phenotypes (V_1 and V_2), which were planted in a non-random block experiment with 6 repetitions (3 for V_1 and 3 for V_2), on the research field within the Campus of the University of Agronomic Sciences and Veterinary Medicine of Bucharest.

The volume of the plants was determined by using the mathematical formula for the truncated cone shape which bared the most similarity with the plants' architecture.

The plants were regularly measured and the fructification stages were closely observed. The fruit were measured, weighed and tested. Both sensorial and chemical properties were analyzed.

Some of the instruments that were used are: WAA analytical balance/scales, portable refractometer and binocular eyeglass.

The collected data have been statistically processed and interpreted using Microsoft Office Excel™ 2007, according to Pena A. (Pena, 1986) and Cociu V., Oprea S. (Cociu et al., 1989) research methods, in order to illustrate the Goji plants' growing and development dynamics.

The period analyzed in this study was 2010 - 2012, with 2010 being the year in which the shrubs were planted and 2011-2012 being the interval in which the plants' growth dynamics has been studied.

RESULTS AND DISCUSSIONS

Plant height. The average height of the potted plants, at the date of their planting (19.11.2010), varied between 17.86 cm and 44.25 cm. The V1 phenotype had taller plants than V2. For V1, the average height was 41.13 cm, while for V2 the average value was 19.25 cm.

The next year (2011) (Table 1), average plant heights varied between 35.68 cm and 72 cm. The variability coefficient was very high, meaning that the plants had very different growth rates and adaptability potentials. While the tallest plants were those in V_2's 3rd and 1st repetitions, with maximum averages of 107 cm and 99 cm, the average heights of plants as a whole (per year/variety) were rather close: 51.70 cm for V_1 and 52.43 cm for V_2. Besides having the tallest plants, V_2 also had the highest variability coefficient for this indicator.

By looking at the way the plant heights have evolved, we can see that, at first, the growth rate of the V_2 plants was a little slower than that of the V_1 plants, but by the end of November, V_2 caught up and even surpassed V_1. In the end, during 2011, V_2 had a higher growth rate than V_1.

Table 1. Average heights of *Lycium barbarum* plants, the first year from planting

2011		Average plant height (cm)				Variability coefficient of plant height (s%)			
		May	Jul-Aug	Nov	Average	May	Jul-Aug	Nov	Average
V_1	1st repetition	41.50	55.64	52.93	50.02	20.22	27.28	27.02	24.84
	2nd repetition	45.71	66.00	61.14	57.62	33.60	36.89	34.76	35.08
	3rd repetition	38.50	54.75	49.13	47.46	12.46	31.54	48.33	30.78
Average		41.90	58.80	54.40	51.70	22.09	31.90	36.71	30.23
V_2	1st repetition	23.00	94.00	99.00	72.00	104.53	-	-	-
	2nd repetition	12.29	22.50	72.25	35.68	64.56	154.72	105.21	108.16
	3rd repetition	15.83	26.00	107.00	49.61	72.83	137.66	-	105.24
Average		17.04	47.50	92.75	52.43	80.64	146.19	105.21	106.70

In 2012, which is the second year from planting (Table 2), the average plant height varied between 85.14 cm and 180 cm.

The variability coefficient was even higher than in 2011 due to the loss of some of the plants from the second variety. Again, the variability coefficient for V_2 was higher than that for V_1.

This time, the average heights of plants as a whole (per variety) had more distinct values: 107.77 cm for V_1 and 177.50 cm for V_2.

Thus, V_2 plants have grown higher than those of V_1 in the second year as well as in the first year from planting.

Table 2. Average heights of *Lycium barbarum* plants, the second year from planting

2012 (Nov)		Average plant height (cm)	Variability coefficient of plant height (s%)
V_1	1st repetition	85.14	67.64
	2nd repetition	125.43	38.31
	3rd repetition	112.75	46.18
Average		107.77	50.71
V_2	1st repetition	-	-
	2nd repetition	180.00	70.71
	3rd repetition	175.00	-
Average		177.50	70.71

So, V_1 plants went from an average of 41.13 cm to 51.70 cm to 107.77 cm. This shows that the growth rate of these plants was slower in the first year than in the second. V_1's growth rate, over these two years, was also slower than that of V_2's which started with an average height of 19.25 cm, followed by 52.43 cm and reached 177.50 cm by the end of 2012.

These results clearly show that V_2 plants tend to have a slow start when developing, but they compensate by having a more luxuriant growth later on.

As a conclusion, both varieties of *Lycium barbarum* L. had a positive growth trend. The plants of V_1 were shorter and had a slower growth rate than those of V_2.

Also, the first variety showed a lower variability than that of the second, meaning that the average values are more relevant in its case. For V_2, the values reflect the fact that its individuals were more different from one another and had more variable growth rates.

Number of shoots. The dynamics of this characteristic has been studied for every variety, repetition and plant in the research field during the first year from planting. Three major stages were observed in 2011. May represented the growth debut, June-August represented the months with an intensive growth rate and November marked the end of the growth period (Table 3).

Table 3. Average number of shoots of *Lycium barbarum* plants, the first year from planting

2011		Average number of shoots				Variability coefficient of number of shoots (s%)			
		May	Jul-Aug	Nov	Average	May	Jul-Aug	Nov	Average
V_1	1st repetition	7.71	9.14	13.43	10.10	49.48	46.16	44.65	46.76
	2nd repetition	5.86	15.43	25.29	15.52	47.71	120.50	81.01	83.07
	3rd repetition	5.50	18.00	22.25	15.25	70.42	92.63	71.48	78.17
Average		6.36	14.19	20.32	13.62	55.87	86.43	65.71	69.34
V_2	1st repetition	6.00	11.00	18.00	11.67	-	-	-	-
	2nd repetition	1.67	7.50	17.50	8.89	34.64	103.71	125.26	87.87
	3rd repetition	2.67	72.00	81.00	51.89	78.06	-	-	78.06
Average		3.44	30.17	38.83	24.15	56.35	103.71	125.26	82.97

The average number of shoots varied between 9 and 52, with V_2 having both the lowest and the highest values per repetition (i.e. V_2 2nd repetition had the lowest value, whilst its 3rd repetition had the highest number of shoots).

V_1 had a lower variability for this indicator, and its average number of shoots at the end of the year 2011 was of almost 14 (13.62). For V_2, the average number of shoots for the first year from planting was 24 (24.15). For both varieties, the number of shoots has had a positive trend throughout the year.

So, it is clear that whilst V_1 has had less variation in its number of shoots per plant, V_2 plants have had a more dynamic rate of growing new shoots, especially in its 3rd repetition.

In 2012 (Table 4), the average number of shoots belonging to the growth debut stage (May), was higher than that of 2011 for both V_1 and V_2. The average number for V_1 was 21 shoots, which is 3.71 times more than in the same period of the first year. What's more, the average value for the 2nd repetition of V_1 was higher in May 2012 (28 shoots), than in November 2011 (25 shoots), when it was the maximum average value of V_1 that year.

For V_2, the average values in May 2012 (4.79 shoots) surpassed those of the same period in 2011 (3.44 shoots), but they were far less than those of the maximum value of that year (81 shoots, in the 3rd repetition).

Table 4. Average number of shoots of *Lycium barbarum* plants, the second year from planting

2012 (May)		Average number of shoots	Variability coefficient of number of shoots (s%)
V_1	1st repetition	12.57	90.21
	2nd repetition	28.00	78.41
	3rd repetition	23.75	70.32
Average		21.44	79.65
V_2	1st repetition	1.67	173.21
	2nd repetition	7.71	183.59
	3rd repetition	5.00	255.86
Average		4.79	204.22

Similar to the previous year, the variability coefficient for the number of shoots in V_2 plants was higher than that of the V_1 plants. This was mainly because of the loss of several V_2 plants, but it also reflects the different growth and development rates the plants have.

So, as a conclusion, V_2 plants had a higher number of shoots than V_1 in 2011, but lower values for this indicator in the growth debut period (May) of both 2011 and 2012.

This shows its tendency to enter the growth debut period later than V_1. Nevertheless, once the second variety reaches its intensive growth period, it quickly beats V_1's development rate.

It's also worth mentioning the fact that both varieties have developed anticipated shoots in the second year from planting (2012).

Length of shoots. Same as for the previous indicator, the dynamics of this characteristic has been studied for every variety, repetition and plant in the research field during the first year from planting. The same three major stages were observed: the growth debut was in May, June-August represented the months with an intensive growth rate and November marked the end of the growth period.

In 2011, the average shoot length spanned between 11.84 cm and 29.57 cm. Again, the second variety presented both the top and the bottom values per repetition, though not in the same repetitions as those of the previous indicator.

The average shoot length per year was 14.14 cm for V_1 and 19.57 cm for V_2, so the second variety's faster growth rate is also illustrated by this 2011 indicator (Table 5).

The variability coefficient of the shoots' length was, again, higher for the second variety with a peak of 65.40 % for its 3rd repetition. V_1 also had the most variability of this indicator in its 3rd repetition (42.68 %).

In 2012, the average shoot length varied between 4 cm and 19.79 cm. As in the previous year, both of the values belonged to V2's repetitions. The average shoot length in May was 7.40 cm for V_1 and 11.33 cm for V_2 meaning that, once again, the second variety had a more vigorous growth, despite the values being smaller than those of May 2011.

Table 5. Average shoot length of *Lycium barbarum* plants, the first year from planting

2011		Average shoot length (cm)				Variability coefficient of shoot length (s%)			
		May	Jul-Aug	Nov	Average	May	Jul-Aug	Nov	Average
V_1	1st repetition	13.16	15.80	11.39	13.45	40.66	42.51	35.45	39.54
	2nd repetition	17.56	16.64	11.91	15.37	29.20	42.60	23.77	31.86
	3rd repetition	11.40	16.40	13.00	13.60	40.80	69.75	17.50	42.68
Average		14.04	16.28	12.10	14.14	36.89	51.62	25.57	38.03
V_2	1st repetition	22.00	21.70	45.00	29.57	-	-	-	-
	2nd repetition	19.17	12.80	19.95	17.31	76.69	24.31	42.18	47.73
	3rd repetition	9.43	10.70	15.40	11.84	65.40	-	-	65.40
Average		16.87	15.07	26.78	19.57	71.05	24.31	42.18	56.56

So, the 2011 and the 2012 values have shown that the *Lycium* plants' shoots have been growing in both these years. The plants have grown at different rates, especially those in the second variety. Also, it's interesting to point out the fact that the second year, both varieties had a slower growth rate in their growing debut phase (Table 6).

Table 6. Average shoot length of *Lycium barbarum* plants, the second year from planting

2012 (May)		Average shoot length (cm)	Variability coefficient of shoot length (s%)
V_1	1st repetition	5.20	104.07
	2nd repetition	9.04	51.20
	3rd repetition	7.98	47.75
Average		7.40	67.67
V_2	1st repetition	4.00	-
	2nd repetition	10.18	102.92
	3rd repetition	19.79	-
Average		11.33	102.92

Number of leaves. In May 2011, the average number of leaves on the goji shrubs varied between 44 and 260. The minimum value belonged to the 2nd repetition of V_2 and the maximum one was also found in the 2nd repetition, but that of the first variety. The average number of leaves per variety was nearly 227 for V_1 and almost 96 for V_2.

As opposed to the other indicators, the average number of leaves per plant was higher in 2011 for the first variety. The variability coefficient, though, was still higher for the second variety of goji shrubs (Table 7).

Table 7. Average number of leaves on *Lycium barbarum* plants, the first year from planting

2011 (May)		Average no. of leaves	Variability coefficient of no. of leaves (s%)
V_1	1st repetition	217.43	43.95
	2nd repetition	259.86	38.34
	3rd repetition	202.25	48.34
Average		226.51	43.54
V_2	1st repetition	198.00	-
	2nd repetition	44.00	47.62
	3rd repetition	45.50	135.21
Average		95.83	91.41

In the second year from planting, the average number of leaves varied between 147 and 1,589. Both the maximum and the minimum values belonged to the second variety. The variability coefficient was, as in the previous year, higher for V_2 than for V_1.

The average number of leaves per variety was 1,073 for V_1 and 860 for V_2. Although the first variety had the higher value for this indicator in both years, the difference between V_1's and V2's values was smaller in 2012 than in 2011 (Table 8).

Table 8. Average number of leaves on *Lycium barbarum* plants, the second year from planting

2012 (May)		Average no. of leaves (cm)	Variability coefficient of no. of leaves (s%)
V_1	1st repetition	534.43	59.39
	2nd repetition	1,299.57	55.64
	3rd repetition	1,385.50	78.90
Average		1,073.17	64.64
V_2	1st repetition	147.00	-
	2nd repetition	1,589.00	122.46
	3rd repetition	844.00	-
Average		860.00	122.46

By comparing the two years, we can conclude that V_1 plants had more leaves than those from the second variety. Still, the difference between the values of V_1 and V_2 was smaller in 2012 than in 2011, meaning that V_2 plants have increased their development rate in the second year. Also, both varieties had significantly more leaves in 2012 than in 2011, thus reflecting they have undergone a growth stage.

Flowering dates. In 2011, on V_1 individuals, flower buds first appeared at the middle of June. Towards the end of the same month, flowering also occurred on the shrubs. V_2 plants flowered in august, and had far less flowers than those of V_1.

Both phenotypes flowered until late November. The average number of flowers per shoot was between 5 and 40, with the minimum value belonging to V_2 and the maximum value belonging to V_1.

In 2012, the first floral buds appeared at the beginning of May on a V_2 plant. A few days later, they were also seen on V_1 plants. After a few more days, the first flowers also appeared. The average number of flowers and buds, per branch, was 5 to 50, with a maximum of 70. Again, V_1 plants were the ones to bare the most flowers.

Fructifying dates. In 2011, the first fruit appeared at the end of June on V_1 individuals. Production peaked in August and September and fructification continued until the end of November, for both phenotypes. V_2 shrubs had fewer but bigger fruit. For this variety, fructification started later and was less frequent.

In 2012, fructifying started towards the middle of May, which was earlier than the first year. At that time, the first fruit appeared on a V_2 plant, although they had not ripened yet.

Not all plants fructified during the first or the second year, but it is important to point out that the *Lycium* shrubs which bore fruit did so in less than a year's time from their planting. This reveals a precocity trait in the new species' fructifying habits in Romania's pedo-climatic conditions.

Fruit yield. The total fruit yield for 2011 was 1,343.16 g. For 2012 the total fruit yield reached 6,512.13 g. So, the second year's fruit yield was almost 5 times bigger than that of the first year's yield.

The average fruit yield per plant varied between 2.68 g and 128.68 g, the first year from planting. V_1 plants yielded the most fruit. The average fruit yield per variety was 88.33 g for V_1 and 2.68 g for V_2. Also, all the repetitions of this variety had fructifying plants, while in V_2 only the plants from the 2nd repetition bore fruit (Table 9).

The next year, the average fruit yield per plant varied between 23.24 g and 589.28 g. The maximum value was that of V_1's second repetition, while the minimum value belonged to V_2's 3rd repetition. The average fruit per repetition was 317.74 g for V_1 and 50.77 g for V_2 (Table 10).

So, V_1 was - for a second time - the more productive of the two Lycium varieties. Still, in 2012, V_2 had fruit bearing plants in two of its 3 repetitions, which is more than the previous year. Also, the average yield per plant was significantly higher in the second year for both varieties.

In 2012, the average values varied between 0.25 g and 0.34 g for V_1. The average fruit weight for V_1, the second year, was 0.31 g (Table 12). Also, the average fruit weight for V_2 was 0.40 g.

Table 9. Average fruit yield of *Lycium barbarum* plants, the first year from planting

2011		Average fruit yield (g)	Variability coefficient of fruit yield (s%)
V_1	1st repetition	15.41	110.31
	2nd repetition	128.68	79.90
	3rd repetition	120.90	56.95
Average		88.33	82.39
V_2	1st repetition	-	-
	2nd repetition	2.68	-
	3rd repetition	-	-
Average		2.68	-

Table 10. Average fruit yield of *Lycium barbarum* plants, the second year from planting

2012		Average fruit yield (g)	Variability coefficient of fruit yield (s%)
V_1	1st repetition	77.97	140.83
	2nd repetition	589.98	73.84
	3rd repetition	285.28	105.69
Average		317.74	106.79
V_2	1st repetition	-	-
	2nd repetition	78.30	-
	3rd repetition	23.24	-
Average		50.77	-

Fruit weight. The average weight for the V_1 fruit was mostly the same in 2011 and 2012. The first year, average values varied between 0.26 g and 0.39 g. The average fruit weight for 2011 was 0.35 g (Table 11).

Table 11. Average fruit weight of *Lycium barbarum* plants, the first year from planting

2011		Average fruit weight (g)	Variability coefficient of fruit weight (s%)
V_1	1st repetition	0.26	44.74
	2nd repetition	0.41	31.78
	3rd repetition	0.39	19.00
Average		0.35	31.84

Table 12. Average fruit weight of *Lycium barbarum* plants, the second year from planting

2012		Average fruit weight (g)	Variability coefficient of fruit weight (s%)
V_1	1st repetition	0.25	18.76
	2nd repetition	0.33	10.91
	3rd repetition	0.34	16.46
Average		0.31	15.38

Though the average fruit weight values for 2011 were bigger than those of the second year, in 2012 the coefficient of variability of these values was smaller. This means that the *Lycium* shrubs have started to produce more regular sized fruit which are in conformity with the specie's fructification characteristics.

Dry substance in fruit. The average dry substance in 2011's fruit took values between 14.37 % and 17.03 %. For V_1, the average dry substance within fruit was 15.46 %. The average variability coefficient of these values was of only 5.38 %, meaning that the variability was low (Table 13).

Table 13. Average dry substance of *Lycium barbarum* fruit, the first year from planting

2011		Average fruit D.S. (%)	Variability coefficient of fruit D.S. (s%)
V_1	1st repetition	17.03	5.59
	2nd repetition	15.00	3.56
	3rd repetition	14.37	7.01
Average		15.46	5.38

In 2012, the average values for dry substance in fruit were between 14.69 % and 16.85 %. The average dry substance within V_1's fruit was 15.84 %. For V_2's fruit, this indicator was 17.26 % (Table 14).

The variability coefficient of this indicator was higher in 2012 mostly due to the fact that the plants fructified more frequently and in higher quantities than the previous year.

In conclusion, the values for this indicator were slightly higher in 2012 than in 2011. Also, in comparison with V_1's values, V_2's fruit had a superior dry substance concentration.

Table 14. Average dry substance of *Lycium barbarum* fruit, the second year from planting

2012		Average fruit D.S. (%)	Variability coefficient of fruit D.S. (s%)
V_1	1st repetition	15.98	11.64
	2nd repetition	16.85	6.16
	3rd repetition	14.69	19.69
Average		15.84	12.50

Volume and shape. The shape of the *Lycium* shrubs was determined based on the plants' dimensions and architecture. As a consequence, the plants had either truncated cone or inverted (reversed) truncated cone shapes.

The average volume of the plants varied between 77,216.24 cm^3 and 1,636,777.63 cm^3. The minimum value was that of V_1's 1st repetition and the maximum one was that of V_2's 2nd repetition. The average plant volume per variety was 233,905.36 cm^3 for V_1 and 1,361,867.98 cm^3 for V_2 (Table 15).

So, we can see that V_2's more luxuriant growth is, once more, demonstrated by indicators. Also, the variability coefficient is higher for V_2 than for V_1.

Table 15. Average volume of *Lycium barbarum* plants, the second year from planting

2012		Average plant volume (cm^3)	Variability coefficient of plant volume (s%)
V_1	1st repetition	77,216.24	140.96
	2nd repetition	326,277.55	78.01
	3rd repetition	298,222.29	78.76
Average		233,905.36	99.24
V_2	1st repetition	-	-
	2nd repetition	1,636,777.63	139.98
	3rd repetition	1,086,958.33	-
Average		1,361,867.98	139.98

CONCLUSIONS

In a nutshell, we can see that the various indicators representing the dynamics of plant growth have had a positive trend over the two years from planting. V_2 plants have exhibited a more luxuriant growth, though accompanied by a later debut in their development. On the other hand, V_1 plants have had a more constant growth rate and an earlier debut in their development.

With regard to the fruit yield, V_1 incontestably had the superior values. Nevertheless, what V_2 lacked in quantity, it compensated in quality as the fruit of this variety were both bigger in size and had a higher concentration of dry substance. Also, it's interesting to point out the fact that fruit weights were smaller but less variable in 2012 than in 2011. Moreover, both varieties bore flowers and fruit at earlier dates the second year than the first.

The plants belonging to both studied varieties presented a discontinuous variability of their architectural elements. Still, V_2 repetitions had high variability coefficients for all calculated indicators mostly due to the loss of some of the plants.

To sum it all up, while V_1 individuals showed higher survival rates and higher yields, V_2 individuals presented a more luxuriant growth and a higher fruit quality. Also, judging by their growth dynamics, both varieties are exhibiting the normal behaviour of shrubs in their "beginning of fructifying" growth phase of their ontogenetic cycle.

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