



# Determining the Morphologic, Yield and Phytochemical Properties of 'Damaye' and 'Nq-7' Goji Berry Varieties Under Semi-Arid Climate Conditions

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## Abstract

This study has been conducted during the 2015–2016 period in Aksaray, with semi-arid climate conditions, with the purpose of defining the morphologic, yield and phytochemical parameters of 'Damaye' and 'NQ-7' Goji Berry varieties. The trial was conducted with 'Damaye' and 'NQ-7' varieties in randomized blocks experimental design, with three repetitions and 10 plants in each repetition, tubed saplings in every 3 m × 2 m intervals, during the years 2015 and 2016. Morphologic and yield parameters such as plant stem diameter, plant crown height, plant shoot size, plant size, yield per plant, yield per decare, yield efficiency, 100 grain weight and phytochemical parameters such as antioxidant ratio, total phenolic matter quantity, C vitamin quantity, glyucose quantity, fructose quantity and sucrose quantity were examined. In the study, year × variety interaction was found to be statistically meaningful at a rate of 5% in plant stem diameter, plant crown width, plant crown height, plant size, yield per plant, yield per decare parameters; while year was found to be statistically meaningful at a rate of 5% in plant crown width, plant shoot size and yield efficiency parameters. And in terms of phytochemical properties, the difference between varieties were found to be statistically insignificant. In 2015, the average plant stem diameter (4.01 mm), plant crown height (71.12 cm), plant size (84.27 cm), yield per plant (0.22 kg/tree) and yield per decare (47.71 kg/decare) values of 'Damaye' variety were observed to be higher than the 'NQ-7' variety. In 2016, the average plant stem diameter (15.12 mm) and plant size (167.50 mm) values were higher in 'Damaye' variety, while the average yield per plant (2.12 kg/tree) and average yield per decare (468.29 kg/decare) values were higher in 'NQ-7' variety. As for plant corolla height, both 'NQ-7' (114.73 cm) and 'Damaye' (105.06 cm) varieties were ranked first and statistically placed within the same group. In conclusion, in 2015 'Damaye' variety displayed a better performance in terms of morphologic and yield parameters, while in 2016, 'NQ-7' variety displayed a better performance. But in both years, yield efficiency and yield per decare values were higher in 'NQ-7' variety when compared to the 'Damaye' variety.

**Keywords** *Lycium barbarum* · Morphologic characteristics · Yield · Phytochemical properties

## Untersuchung von Morphologie, Ertrageigenschaften und sekundären Pflanzeninhaltsstoffen bei den unter semi-ariden Klimabedingungen angebauten Goji-Beerensorten 'Damaye' and 'Nq-7'

**Schlüsselwörter** *Lycium barbarum* · Morphologische Merkmale · Ertrag · Sekundäre Pflanzeninhaltsstoffe

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## Introduction

Goji berry is being widely grown as a medical aromatic plant, mostly in South-western parts of China, but also in Southeast Asian countries, and many European countries. Goji berry is botanically a member of the *Solanaceae* family, and the most common types are *Lycium barbarum* L. and *L. sinensis* L.. For many years, fruits of goji berry plant have been used to make fruit juice, and its leaves have been used by people as healthy food. Goji berry is be-

ing widely produced for commercial purposes in Xinjiang, Shaanxi, Gansu and Hebei regions of China, Central Mongolia, Japan, Korea and Taiwan and many European countries. According to 2016 data, 95,000 tons of goji berry were produced in an area of 82,000 hectares in China (Kulczyński and Michałowska 2016).

It is known that there are many wild goji berry varieties in moderate climate regions of the world. Some of these varieties are found in Mediterranean basin while some are found in Southwest and Central Asia. Goji berry plant is also being used as border plant in North America and Australia (Hänsel et al. 1993). *L. chinense* is widely spread in East Asia and is particularly grown in South China, Korea and Japan (Qian et al. 2004). Goji berry products are also consumed in China and some European countries in the form of powder and tablet (Bensky et al. 2004).

In a study conducted in Switzerland, Potterat (2010) reported a high nutritional value and antioxidant capacity of goji berry fruit. In addition, he was also reported that the growers were generally drying the fruits, harvested during August–October period, while those harvested in the month of May are consumed as fresh fruit and their fresh leaves are consumed as vegetables while the dried leaves are made diet tea. In a study conducted in Romania, Istrati et al. (2013) were observed that in the jam and marmalade of goji berry fruit, the total phenol contents ranged between  $351 \pm 7.25$  mg GAE/100 g and flavonoids ranged between  $53.06 \pm 1.23$  mg QE/100 g and that goji berry jam contained antioxidant activity of 60.98%, while this figure in the marmalade was 41.96%.

In a study conducted in Romania; it was observed that *L. barbarum* leaves contained  $43.73 \pm 1.43$  mg/g flavonoid while *L. chinense* leaves contained  $61.65 \pm 0.95$  mg/g flavonoid. Quality and quantity analyses of phenolic compounds were defined by HPLC—UV—MS method. Being dominant in both analysis types, flavonoid was found to be routine and in highest quantity in *L. chinense*. *L. chinense*'s fruits were proved to have twice as much chlorogenic acid than *L. barbarum*. Gentisic and caffeic acids were observed only in *L. barbarum*, while caempherol were observing only in *L. chinense*. According to antimicrobial test results, both Gram (+) and Gram (–) opposite *L. chinense* extract was found to be more active than *L. barbarum* extract. In conclusion, it was reported that as well as relevant antioxidant and antimicrobial activities, these varieties are valuable flavonoid resources (Mocan et al. 2014). In a study conducted with 'JB 1' and 'JB 2' goji berry varieties in Bulgaria, it has been reported the varieties reach a height of 40 cm within a year and in 'JB 1' variety the yield per tree was 0.56 kg/tree (Dzhugalov et al. 2015).

In a study was conducted in Çumra district of Konya, defining physico-chemical properties and fatty acid composition in goji berry fruits; 3.44 mg GAE/100 ml total phe-

nol, 8.9% crude protein and 487.29 g/100 ml total sugar amount have been measured in goji berry fruits (Endes et al. 2015). In China, the chemical properties and bioactivities of polysaccharides in goji berry were examined with different methods, *L. barbarum*'s polysaccharides, the effect on LBP yields and bioactivity properties in different environments such as ultrasonic water, warm water were observed. It was concluded that heat and ultrasound were two important factors effecting LBP's extraction yield, chemical properties and bioactivities (Yang et al. 2015).

Oğuz and Erdoğan (2016) were conducted a study in Adıyaman's Tut district to determine both the morphologic development of 'Damaye' and 'NQ-1' Goji berry varieties and also the phytochemical change ratios in the physical quality criteria of their fruits and reported that in 2012 the sapling size (71.35 cm), sucker size (7.91 cm), yield (0.33 kg/tree) parameters have been higher in 'Damaye' variety while in 2013 the sapling size (67.02 cm), sucker size (7.91 cm), yield (0.33 kg/tree) values were higher in 'NQ-1' variety. In both years, ascorbic acid values (10.78–12.29 mg/100 g) were observed to be high in 'NQ-1' variety. While values related to properties such as fruit size (15.78 mm), fruit weight (4.13 g), protein ratio, (11.68%), raw fat ratio (8.12%),  $\beta$ -carotene (8.83  $\mu$ g/l), phenolic compounds (351.35 mg GAE/100 g) and flavonoids (51.09 mgQE/g) were higher in 'NQ-1' variety, properties such as stem diameter (6.55 mm) and WSDM (27.49%) were found to be higher in 'Damaye' variety.

This study has been conducted with the purpose of determining the morphologic, yield and phytochemical properties of 'Damaye' and 'NQ-7' Goji Berry varieties, being produced under semi-arid climate conditions in the Central Anatolian Region.

## Material and Method

### Material

This study was conducted in 2015 and 2016 in the province of Aksaray in Central Anatolian Region in a plantation owned by a private company and containing one-year-old tube saplings of 'Damaye' and 'NQ-7' goji berry varieties. From the goji berry varieties involved in the trial, 'Damaye' variety is a *L. barbarum* L. hybrid, self-yielding, with fruits a bit bigger than 'NQ1' and in oval shape, fresh fruit diameter of 2.75–3.80 cm and the fresh fruit yield per decare is around 300 kg/decare. 'NQ-7' variety is a hybrid of Ningxiya variety, it's fruits are a bit bigger than those of 'NQ-7' and in oval shape, self-yielding, was a fresh fruit diameter of 1.25–2.80 cm and the fresh fruit yield per decare is 275 kg/decare (Lu et al. 2014).

## Method

### Experimental Site and Experimental Design

Aksaray province is located in the middle of Central Anatolia, between 33–35° east meridians, 38–39° north parallels. In Aksaray province, continental climate (arid and warm in summers, rainy and cold in winters) reigns. In the province, the annual average temperature is 11.8°C, the coldest month is January (average 0.8°C), warmest month is July (average 22.7°C) and the lowest measured temperature is –21.9°C. Amount of snowfall is lower when compared to other provinces. The annual precipitation average of Aksaray is between 340–348 mm and the province has a semi-arid climate. The province is not rich in terms of flora. Forests can be seen in mountainous areas. Obruk and Kızılırmak plateaus are mostly bare except for steppe plants. Provincial lands are under the dominance of harsh continental climate unique to Central Anatolia (Anonymous 2011). The trial was conducted with 'Damaye' and 'NQ-7' varieties in randomized blocks experimental design, with three repetition and 10 plants in each repetition, tubed saplings in every 3 m × 2 m intervals, during the years 2015 and 2016.

### Morphologic Properties

Starting from the second half of July in 2015 and 2016, measurements were made in the 60 saplings in each parcel by taking the below specified properties into account.

*Plant stem diameter:* was calculated by measuring the saplings with a digital caliper of 0.01 mm sensitivity.

*Plant corolla width:* Diameter of the plant crown circle was measured in cm with a steel meter.

*Plant corolla height:* It was measured in cm with a steel meter, taking into account the height between the tip of the first main branches and the tip of the shoot.

*Plant shoot size:* Goji berry plant's annual shoot size was measured with a steel meter and given in cm.

*Plant size:* The height between the point of contact of the plant stem to the soil and the tip of the shoot was measured with a steel meter and given in cm.

### Yield Parameters

*Yield per plant:* Throughout a season, goji berry plants in each parcel were harvested every fortnight during the production seasons of 2015 and 2016, and all fresh fruits were weighed in a 0.01 g sensitive scale and defined in kg/plant.

*Yield per decare:* Yield values acquired per plant were converted into decares and defined as kg/decare.

100 grain weight: 100 fresh fruit samples were collected from each parcel and weighed in a 0.01 g sensitive scale and defined in kg/plant.

*Yield efficiency:* were calculated by using the following formulae: Tree trunk radius =  $2 \times \pi \times r / 2$ ; tree trunk radius =  $2 \times \pi \times r$ ; tree trunk area =  $\pi \times r^2$ ; tree yield efficiency =  $\text{kg/m}^2 [\pi \times r^2 / 2]$  (Hampson et al. 1998; Oğuz and Erdoğan 2016).

### Phytochemical Properties

*Antioxidant ratio (%):* was defined in accordance with the method recommended by Klimczak et al. (2007).

*Total phenolic matter amount (mg GAE/100 mL):* was defined in accordance with the method recommended by Abdulkasim et al. (2007).

*Ascorbic acid (Vitamin C) amount (mg/L):* was defined in accordance with the method recommended by Cemeroglu (2010).

*Sugar (Glucose, Fructose, Sucrose) amount (g/100 mL):* was determined in accordance with the modified method of Bartolome et al. (1995).

### Data Analysis

Data collected on different parameters were analysed statistically by using JMP statistical software program (5.0.1, SAS Institute, Cary, NC) for analysis of variance and means were compared using Fisher's protected least significance difference (LSD) test at 5% probability level (Steel et al. 1997).

## Result and Discussion

The variance analysis table for the fruit properties studied in 'Damaye' and 'NQ-7' varieties was given in Table 1. Examining Table 1, year × variety interaction in plant stem diameter, plant corolla width, plant corolla height, plant size, yield per plant, yield per decare parameters was found to be statistically significant at a rate of 5%. And in plant corolla width, plant shoot size and yield efficiency parameters, year has been found to be statistically significant at a rate of 5%. On the other hand, phytochemical properties of the varieties were found to be statistically insignificant.

The average values related to the plant stem diameter, plant corolla height, plant size, yield per plant and yield per decare properties of 'Damaye' and 'NQ-7' goji berry plant for the years 2015 and 2016 were given in Table 2. Looking at the 2015 data, the varieties were found to be statistically significant in a rate of 5% for properties such as plant stem diameter, plant corolla height, plant size, yield per plant and yield per decare. While 'Damaye' variety was ranked first

**Table 1** Variance analysis of some morphologic, yield and phytochemical properties of ‘Damaye’ and ‘NQ-7’ Goji berry varieties

Variation coefficient	DF	PSD (mm)	PCW (cm)	PCH (cm)	PSS (cm)	PS (cm)	YPP (kg/tree)
REPETITION	2	0.40ns	19.43 ns	69.30ns	10.42ns	17.33 ns	0.01 ns
YEAR	1	288.92 <sup>a</sup>	10,725.43 <sup>a</sup>	6595.27ns	535.60ns	18,375.36 ns	6.29ns
VARIETY	1	13.50 <sup>a</sup>	1415.99 <sup>a</sup>	32.30ns	508.81 <sup>a</sup>	1940.59 <sup>a</sup>	0.78 <sup>a</sup>
YEAR X VARIETY	1	4.50 <sup>a</sup>	126.60ns	502.95 <sup>a</sup>	17.64ns	73.99 <sup>a</sup>	0.62 <sup>a</sup>
ERROR	6	1.476	212.35	375.17	105.58	61.27	0.01
TOTAL	11	308.80	12,499.81	7575.01	1178.07	20,468.56	7.72
Variation coefficient	DF	YPD (kg/decare)	YE (kg/m <sup>2</sup> )	100GW (kg/tree)			
REPETITION	2	130.46 ns	0.64 ns	1.38 ns			
YEAR	1	311,283.17 ns	6.95 ns	1.38 ns			
VARIETY	1	39,601.18 <sup>a</sup>	26.56 <sup>a</sup>	0.0006ns			
YEAR X VARIETY	1	29,083.33 <sup>a</sup>	0.12 ns	0.0006ns			
ERROR	6	559.13	0.90	3.66			
TOTAL	11	380,657.27	35.20	100.61			
Variation coefficient	SD	AR (%)	TPMA (mg-GAE/100mL)	CVA (mg/L)	GA (g/100mL)	FA (g/100mL)	SA (g/100mL)
REPETITION	2	17.99ns	23.56ns	1.78 ns	0.17 ns	0.03 ns	0.005 ns
YEAR	1	70.96 ns	265.43 ns	0.004 ns	0.060 ns	0.03 ns	0.260 ns
VARIETY	1	0.0007 ns	0.09 ns	0.002 ns	0.0002 ns	0.00005 ns	0.0000009 ns
YEAR X VARIETY	1	0.0007 ns	0.098 ns	0.002 ns	0.0002 ns	0.00005 ns	0.0000009 ns
ERROR	6	15.92	44.69	2.94	0.120	0.023	0.004
TOTAL	11	104.88	333.89	4.74	0.352	0.087	0.270

Df degrees of freedom, ns not significant, PSD Plant stem diameter, PCW Plant crown width, PCH Plant crown height, PSS Plant shoot size, PS Plant size, YPP Yield per plant, YPD Yield per decare, YE Yield efficiency, 100GW Grain weight, AR Antioxidant ratio, TPMA Total phenolic matter amount, CVA Vitamin C amount, GA Glucose amount, FA Fructose amount, SA Sucrose amount

<sup>a</sup>Different letters between genotypes denote significant differences at 5% probability level

**Table 2** Some average morphologic and yield property values of ‘Damaye’ and ‘NQ-7’ Goji Berry varieties

VARIETIES	2015					2016				
	PSD (mm)	PCH (cm)	BB (mm)	BBV (Kg/tree)	DV (Kg/dekar)	PSD (mm)	PCH (cm)	BB (mm)	BBV (Kg/tree)	DV (Kg/dekar)
‘Damaye’	4.089 a	71.12 a	84.27 a	0.22 a	47.71 a	15.12 a	105.06 a	167.50 a	1.15 b	254.94 b
‘NQ-7’	3.19 b	54.89 b	63.80 b	0.16 a	31.28 b	11.78 b	114.73 a	137.10 b	2.12 a	468.29 a
LSD	0.197 <sup>a</sup>	4.545 <sup>a</sup>	7.448 <sup>a</sup>	0.087 <sup>a</sup>	3.497 <sup>a</sup>	2.523 <sup>a</sup>	42.350ns	14.023 <sup>a</sup>	0.223 <sup>a</sup>	49.093 <sup>a</sup>

PSD Plant stem diameter, PCH Plant crown height, BB Plant size, BBV Yield per plant, DV Yield per decare

<sup>a</sup>Different letters between genotypes denote significant differences at 5% probability level

in 2015 for plant stem diameter (4.089 mm), plant corolla height (71.12 cm), plant size (84.27 cm) and yield per decare (47.71 kg/decare) parameters, both ‘Damaye’ (0.22 kg/tree) and ‘NQ-7’ (0.16 kg/tree) varieties were ranked first and within the same group in terms of yield per plant value. In 2016, ‘Damaye’ variety was ranked first for the plant stem diameter (15.12 mm) and plant size (167.50 mm) parameters, while ‘NQ-7’ variety was ranked first in terms of yield per plant (2.12 kg/tree) and yield per decare (468.29 kg/decare) properties. As for plant corolla height, both ‘NQ-7’ (114.73 cm) and ‘Damaye’ (105.06 cm) varieties were ranked first and statistically placed within the same group (Table 2). Looking at both years of the study, ‘Damaye’ variety was more prominent than ‘NQ-7’ variety in all mor-

phologic properties other than yield per plant and yield per decare values. Our findings had similarities to those findings by Oğuz and Erdoğan (2016), in their study conducted in Adıyaman to determine the performances of ‘NQ-1’ and ‘Damaye’ varieties.

In Table 3, average values related to the plant corolla width, plant shoot size and yield efficiency parameters of ‘Damaye’ and ‘NQ-7’ varieties were given. In terms of plant corolla width, plant shoot size and yield efficiency properties, the varieties were found to be statistically significant at a rate of 5%. In ‘Damaye’ variety, plant corolla width (101.62 cm), plant shoot size (75.64 cm) were found to be higher than ‘NQ-7’ variety (79.89 cm; 62.62 cm), while in ‘NQ-7’ variety, yield efficiency (4.98 kg/m<sup>2</sup>) was

**Table 3** Average plant corolla width, plant shoot size and yield efficiency values of 'Damaye' and 'NQ-7' Goji berry varieties

VARIETIES	PCW (cm)	PSS (cm)	YE (Kg/m <sup>2</sup> )
'Damaye'	101.62 a	75.64 a	2.01 b
'NQ 7'	79.89 b	62.62 b	4.98 a
LSD	8.405 <sup>a</sup>	5.926 <sup>a</sup>	0.547 <sup>a</sup>

PCW Plant crown width, PSS Plant shoot size, VE Yield efficiency

<sup>a</sup>Different letters between genotypes denote significant differences at 5% probability level

found to be higher than 'Damaye' variety (2.01 kg/m<sup>2</sup>). Mencinicopschi and Bălan (2013), in their study conducted in Romania with 'V<sub>1</sub>' and 'V<sub>2</sub>' goji berry varieties, reported the plant size of 'V<sub>1</sub>' variety as 52 cm in 2011 and 108 cm in 2012, the plant sizes of the varieties grew an average of 1.23 m/year over the two years, and in 2012, the plant size of 'V<sub>1</sub>' variety reached 108 cm and plant size of 'V<sub>2</sub>' variety reached 178 cm. In our study, as was the case in 'Damaye' and 'NQ-7' varieties, 'V<sub>1</sub>' and 'V<sub>2</sub>' varieties went through a more rapid growth during the second year. Similarly, in a study conducted in Bulgaria with 'JB 1' and 'JB 2' Goji berry varieties, it was reported that the varieties reached a height of 40 cm in a year and for the 'JB 1' variety the yield per tree was reported as 0.56 kg/tree (Dzhugalov et al. 2015).

Considering the two-year morphologic, yield and phytochemical properties of 'Damaye' 'NQ-7' and Goji Berry varieties during the study; 'Damaye' variety was displayed a better performance than 'NQ-7' variety in 2015, in terms of plant stem diameter, plant corolla height, plant size, yield per plant, yield per decare. However, in 2016 'NQ-7' variety was better than 'Damaye' variety both in yield per plant and yield per decare parameters. In general, it was observed that NQ genotypes displayed a slower growth than 'Damaye' variety in the first year and had a lower yield. This can be associated with the variety properties (Anonymous 2016; Oğuz and Erdoğan 2016). In the study, plant corolla width and plant shoot size values were found to be higher in 'Damaye' variety when compared to the 'NQ-7' variety. And in terms of yield efficiency, 'NQ-7' variety displayed a better performance than 'Damaye' variety. In terms of phytochemical parameters, no statistical differences were observed between the two goji berry varieties in the study.

In conclusion, the study conducted under the semi-arid climate conditions of Central Anatolian Region with 'Damaye' and 'NQ-7' Goji Berry varieties in the years 2015 and 2016, 'Damaye' variety had a better performance during the first year in terms of morphologic and yield parameters, while 'NQ-7' variety was better during the second year. As for the yield efficiency and yield per decare parameters, 'NQ-7' variety was observed to have a better performance than 'Damaye' variety. The differ-

ence in phytochemical properties between the varieties was insignificant. However, more comprehensive studies with more varieties and indifferent locations are required to have a more conclusive finding about the adaptation or performances of the varieties. In addition, the findings of this study should shed a light to future studies on the subject.

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