

Determination of Some Morphological Features of Spinach Populations

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Makale Bilgileri

ABSTRACT

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Spinach (*Spinacia oleracea* L.) is one of the most important winter vegetables used for its edible green leaves. Due to the increase in demand in most parts of the world, significant changes have occurred in production amounts in the last ten years. Based on use, spinach leaves are broadly divided into three types: (i) savoy type (used for fresh market), (ii) processing type (smooth leaf type with flat, unwrinkled and spade-shaped leaves), and (iii) flavor and delicate. Due to its structure, it is baby spinach that is preferably used in salads. There is a need for sufficient biological, taxonomic, genetic and agronomic knowledge about spinach populations in order to investigate spinach populations, develop new varieties and be successful in their studies. In this study, 157 spinach genotypes belonging to the S2 grade, which consists of domestic and commercial varieties, were evaluated to determine their diversity by using agro-morphological characteristics in order to determine their performance as a winter vegetable in our country. The studied genotypes are an important resource for the establishment of the world's core spinach collection. As a result, spinach genotypes, which were agro-morphologically characterized according to IPGRI criteria, showed high morphological diversity. It is thought that the results of the present study will support the conservation and use of local species in spinach cultivation programs.

Ispanak Populasyonlarının Bazı Morfolojik Özelliklerinin Belirlenmesi

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Ispanak (*Spinacia oleracea* L.), yenilebilir yeşil yapraklar için kullanılan en önemli kışlık sebzelerden biri olmakla birlikte dünyanın çoğu bölgesinde talep artışına bağlı olarak son on yılda üretim miktarlarında önemli değişiklikler meydana gelmiştir. Kullanıma bağlı olarak, ıspanak yaprakları genel olarak üç tipe ayrılır: (i) savoy tipi (taze pazar amaçlı kullanılır), (ii) işleme tipi (düz, kırışksız ve kürek şeklindeki yaprakları olan pürüzsüz yaprak tipi), ve (iii) tadı ve narin yapısı nedeniyle tercihen salatalarda kullanılan bebek ıspanaktır. Ispanak populasyonlarının araştırılması yeni çeşitlerin geliştirilmesi ve çalışmalarının başarıya ulaşabilmesi için ıspanak populasyonları hakkında yeterli biyolojik, taksonomik, genetik ve agronomik bilgi birikimine gereksinim vardır. Bu araştırma ülkemiz koşullarında kışlık sebze olarak performanslarının belirlenmesi için yerli ve ticari çeşitlerden oluşan S2 kademesine ait 157 ıspanak genotipi agro-morfolojik özellikler kullanılarak çeşitliliklerini belirlemek için değerlendirilmiştir. Çalışılan genotipler, dünyadaki çekirdek ıspanak koleksiyonunun oluşturulması için önemli bir kaynaktır. Sonuç olarak IPGRI kriterlerine göre agro-morfolojik karakterizasyonu yapılan ıspanak genotiplerinin yüksek oranda morfolojik çeşitlilik gösterdiği göstermiştir. Mevcut araştırmanın sonuçları, ıspanak yetiştirme programlarında yerel türlerin korunması ve kullanılması görevlerini destekleyeceği düşünülmektedir.

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1. Introduction

Spinach (*Spinacia oleracea* L.) is an edible flowering plant from the Amaranthaceae family (Chenopodioideae subfamily), which is native to central and southwestern Asia and may survive over winter in temperate regions. Among leafy vegetables, spinach is characterized by having higher concentrations of vitamins A, B, E, and K, as well as calcium, magnesium, phosphorus, iron, and potassium (Kawashima and Soares, 2003; Mohebodini *et al.*, 2017; Olaoye, 2021). In addition, it is known that vitamin C contains high amounts of oxalic acid, which is a secondary metabolite (Morelock and Correll, 2008). Depending on the use, spinach leaves are broadly divided into three types: (i) savoy type (used for fresh market purposes), (ii) processing type (smooth leaf type with flat, unwrinkled, and spade-shaped leaves), and (iii) baby spinach, which is preferably used in salads due to its taste and delicate structure (Avşar, 2011; Decoteau, 2000). Morphological characteristics of spinach such as color, leaf size, and smoothness of leaves are important for industrial targets.

New varieties are required due to growing conditions, consumer demands, and disease resistance in spinach. However, these requirements are being developed by multinational companies. With regard to the country's interests, it is a necessity to develop spinach varieties suitable for domestic producer and consumer demands. However, in order to use the genetic potential of different germplasmas, it is necessary to know their genetic variations (Morelock and Correll, 2008; Sabaghnia *et al.*, 2015).

The evaluation of genetic diversity acts as a starting point for the establishment of “a core collection.” Here, the whole variability in the collection is represented in a small subset of accessions (Sabaghnia *et al.*, 2015). Spinach genotypes present interesting adapted traits, so the knowledge of diversity among spinach genotypes is critical in breeding programs and for the conservation of genetic resources (Liu *et al.*, 2019; Sabaghnia *et al.*, 2015). This study was based on a doctoral thesis carried out at Selcuk University, the Institute of Science and Technology, the Department of Horticulture. In this context, the study presents the agro-morphological characteristics of 157 S2-level spinach germplasm collections of the gene pool created.

2. Material and Methods

This study was carried out in the research and application greenhouse of Selcuk University, the Faculty of Agriculture in the 2018 spring semester. In the study, using IPGRI (International Plant Genetic Resources Institute) parameters, green color density in the leaf blade, swelling in the leaf blade, lobed in the leaf blade, attachment on the petiole, petiole length, leaf blade position, leaf blade shape, leaf blade edge, leaf blade apex shape, longitudinal shape of the leaf blade, number of leaves and agro-morphological observations such as leaf fragility were investigated (Table 1).

Results and Discussion

Agro-morphological studies are known to be the simplest and easiest way of taxonomic description of plants (Smith *et al.*, 1991). They have also been reported to be a basic requirement for the effective use of plant material by plant breeders (Barro-Kondombo *et al.*, 2010). Within the scope of the study, 157 genotypes belonging to the S2 level were subjected to agro-morphological observation. The distribution ratios of the criteria belonging to the morphological characteristics are given as percent (%) in all genotypes.

Table 1. *Agro-morphological Observations of the S2 Level*

Genotype no (S2)	A	B	C	D	E	F	G	H	I	J	K	L	
1	1k-1	Mid	Absent/ Very little	Absent/ Very little	Semi-erect	Tall	Semi-erect	Triangular	Curved	Pointy	Flat	Mid	Low
2	1k-3	Mid	Little	Little	Semi-erect	Tall	Semi-erect	Triangular	Curved	Pointy	Flat	Mid	Low
3	2k-1	Little	Mid	Mid	Semi-erect	Tall	Semi-erect	Triangular	Curved	Chump	Convex	Mid	Mid
4	2k-2	Mid	Mid	Mid	Semi-erect	Mid	Horizontal	Ovate	Smooth	Circular	Flat	Mid	High
5	3k-1	Mid	Little	Little	Semi-erect	Mid	Erect	Mid Elliptical	Curved	Chump	Flat	Mid	Low
6	3k-2	Little	Absent/ Very little	Absent/ Very little	Erect	Short	Erect	Mid Elliptical	Smooth	Chump	Flat	Low	Low
7	5k-1	Little	Little	Mid	Semi-erect	Mid	Horizontal	Triangular	Curved	Pointy	Convex	Mid	Mid
8	5k-4	Mid	Little	Little	Semi-erect	Mid	Semi-erect	Ovate	Smooth	Circular	Flat	Mid	High
9	5k-5	Mid	Little	Absent/ Very little	Semi-erect	Mid	Semi-erect	Ovate	Smooth	Circular	Convex	Mid	Mid
10	6k-1	Mid	Little	Absent/ Very little	Semi-erect	Short	Horizontal	Ovate	Smooth	Circular	Convex	Mid	Low
11	6k-3	Mid	Little	Absent/ Very little	Semi-erect	Short	Semi-erect	Ovate	Smooth	Chump	Flat	Low	Mid
12	7k-2	Mid	Little	Absent/ Very little	Semi-erect	Short	Semi-erect	Ovate	Smooth	Pointy	Flat	Mid	High
13	10a-4	Dark	Little	Absent/ Very little	Horizontal	Short	Semi-erect	Mid elliptical	Smooth	Circular	Flat	Mid	High
14	10a-5	Mid	Little	Little	Semi-erect	Mid	Semi-erect	Mid elliptical	Smooth	Chump	Convex	Little	Mid
15	10b-4	Mid	Little	Absent/ Very little	Semi-erect	Mid	Semi-erect	Mid elliptical	Smooth	Chump	Convex	Little	Mid
16	10b-5	Mid	Little	Absent/ Very little	Semi-erect	Mid	Semi-erect	Mid elliptical	Smooth	Chump	Convex	Little	Mid
17	15k-1	Mid	Absent/ Very little	Little	Semi-erect	Mid	Horizontal	Mid elliptical	Smooth	Chump	Convex	Little	Mid

18	16k-3	Mid	Absent/ Very little	Little	Horizontal	Mid	Semi-erect	Mid elliptical	Smooth	Chump	Convex	Little	Mid
19	19a-5	Mid	Absent/ Very little	Absent/ Very little	Semi-erect	Mid	Horizontal	Mid elliptical	Smooth	Circular	Flat	Little	Mid
20	19b-5	Mid	Absent/ Very little	Little	Semi-erect	Mid	Horizontal	Ovate	Smooth	Circular	Convex	Mid	Mid
21	19c-2	Mid	Absent/ Very little	Absent/ Very little	Semi-erect	Mid	Horizontal	Ovate	Smooth	Circular	Convex	Mid	Mid
22	19c-3	Mid	Absent/ Very little	Absent/ Very little	Semi-erect	Mid	Horizontal	Mid elliptical	Smooth	Circular	Convex	Mid	Mid
23	19k-4	Mid	Absent/ Very little	Absent/ Very little	Semi-erect	Mid	Horizontal	Mid elliptical	Smooth	Circular	Convex	Mid	Mid
24	23k-2	Mid	Absent/ Very little	Absent/ Very little	Semi-erect	Mid	Horizontal	Mid elliptical	Smooth	Pointy	Flat	Mid	Mid
25	23k-3	Mid	Absent/ Very little	Absent/ Very little	Semi-erect	Mid	Horizontal	Mid elliptical	Smooth	Pointy	Flat	Mid	Mid
26	24k-1	Mid	Absent/ Very little	Absent/ Very little	Erect	Tall	Erect	Triangular	Ripple	Chump	Flat	Mid	Mid
27	24k-2	Mid	Absent/ Very little	Absent/ Very little	Erect	Tall	Erect	Broad	Ripple	Chump	Flat	Mid	High
28	24k-5	Little	Absent/ Very little	Little	Erect	Tall	Erect	Mid elliptical	Smooth	Chump	Flat	Mid	Mid
29	31a-1	Mid	Absent/ Very little	Absent/ Very little	Erect	Tall	Semi-erect	Ovate	Smooth	Circular	Flat	Mid	High
30	31b-3	Mid	Absent/ Very little	Absent/ Very little	Erect	Tall	Semi-erect	Ovate	Smooth	Circular	Flat	Mid	High
31	31c-1	Mid	Absent/ Very little	Absent/ Very little	Erect	Tall	Semi-erect	Ovate	Smooth	Circular	Flat	Mid	High
32	31d-4	Mid	Mid	Absent/ Very little	Semi-erect	Mid	Semi-erect	Ovate	Ripple	Chump	Flat	Mid	Mid
33	31d-5	Mid	Mid	Absent/ Very little	Semi-erect	Mid	Semi pendulous	Ovate	Ripple	Chump	Flat	Mid	Mid
34	31k-2	Little	Absent/ Very little	Absent/ Very little	Erect	Mid	Semi-erect	Mid Elliptical	Smooth	Circular	Flat	Mid	High
35	32a-5	Mid	Little	Absent/ Very little	Horizontal	Mid	Semi pendulous	Triangular	Smooth	Chump	Flat	Mid	Low

36	32b-2	Mid	Little	Absent/ Very little	Erect	Mid	Semi-pendulous	Triangular	Smooth	Chump	Flat	Mid	Low
37	32b-3	Mid	Little	Absent/ Very little	Erect	Tall	Semi-erect	Broad Ovate	Ripple	Pointy	Convex	Mid	High
38	32b-4	Dark	Mid	Absent/ Very little	Horizontal	Tall	Horizontal	Ovate	Curved	Chump	Convex	Mid	High
39	32c-2	Mid	Absent/ Very little	Absent/ Very little	Horizontal	Mid	Horizontal	Broad ovate	Curved	Chump	Convex	Mid	Mid
40	32d-4	Mid	Absent/ Very little	Absent/ Very little	Horizontal	Mid	Horizontal	Ovate	Curved	Chump	Convex	Mid	High
41	32k-3	Mid	Little	Absent/ Very little	Semi-erect	Tall	Semi-erect	Triangular	Curved	Pointy	Flat	Mid	Mid
42	33c-4	Mid	Little	Absent/ Very little	Semi-erect	Mid	Semi-erect	Ovate	Smooth	Chump	Flat	Mid	Mid
43	33k-5	Dark	Mid	Little	Semi-erect	Tall	Semi-erect	Ovate	Curved	Chump	Flat	Mid	High
44	36k-2	Mid	Mid	Mid	Semi-erect	Mid	Erect	Triangular	Curved	Chump	Flat	Mid	High
45	38-1*2	Mid	Mid	Mid	Horizontal	Short	Semi-erect	Ovate	Ripple	Chump	Convex	High	Low
46	38k-1	Very little	Mid	Mid	Horizontal	Short	Semi-erect	Ovate	Ripple	Chump	Convex	High	Low
47	38k-5	Mid	Mid	Absent/ Very little	Horizontal	Short	Semi-erect	Ovate	Ripple	Chump	Convex	High	High
48	39a-1	Mid	Absent/ Very little	Absent/ Very little	Horizontal	Short	Semi-erect	Ovate	Smooth	Chump	Convex	High	High
49	39a-4	Mid	Absent/ Very little	Absent/ Very little	Horizontal	Short	Semi-erect	Ovate	Ripple	Chump	Convex	High	High
50	39k-2	Very little	Absent/ Very little	Absent/ Very little	Semi-erect	Mid	Semi-erect	Ovate	Smooth	Chump	Flat	Mid	Mid
51	39k-3	Mid	Absent/ Very little	Absent/ Very little	Semi-erect	Tall	Semi-erect	Ovate	Smooth	Chump	Convex	Mid	High
52	40-1*1	Mid	Little	Little	Erect	Tall	Erect	Ovate	Smooth	Chump	Flat	Mid	High
53	40-1*2	Little	Mid	Mid	Semi-erect	Tall	Semi-erect	Triangular	Curved	Chump	Flat	Mid	Mid
54	40k-1	Mid	Mid	Absent/ Very little	Semi-erect	Tall	Semi-erect	Triangular	Ripple	Chump	Convex	Mid	Mid
55	40k-4	Mid	Mid	Absent/ Very little	Semi-erect	Tall	Semi-erect	Triangular	Smooth	Chump	Convex	Mid	Mid

56	42b-1	Mid	Absent/ Very little	Absent/ Very little	Horizontal	Short	Horizontal	Triangular	Smooth	Chump	Flat	Mid	Mid
57	42c-1	Mid	Little	Absent/ Very little	Horizontal	Short	Horizontal	Mid Elliptical	Smooth	Chump	Flat	Low	Mid
58	42d-3	Mid	Mid	Little	Semi-erect	Mid	Horizontal	Triangular	Smooth	Chump	Flat	Mid	Mid
59	44k-2	Mid	Mid	Little	Semi-erect	Mid	Horizontal	Triangular	Smooth	Chump	Flat	Mid	Mid
60	46k-1	Mid	Absent/ Very little	Absent/ Very little	Erect	Mid	Erect	Triangular	Curved	Pointy	Convex	Low	High
61	47c-5	Mid	Mid	Absent/ Very little	Erect	Mid	Erect	Triangular	Ripple	Chump	Convex	Mid	High
62	47d-2	Mid	Mid	Absent/ Very little	Semi-erect	Mid	Erect	Ovate	Curved	Circular	Convex	High	Low
63	47k-2	Mid	Absent/ Very little	Absent/ Very little	Erect	Mid	Erect	Triangular	Curved	Pointy	Convex	Low	High
64	48a-2	Mid	Absent/ Very little	Absent/ Very little	Erect	Mid	Erect	Triangular	Curved	Pointy	Convex	Low	High
65	48b-2	Mid	Little	Little	Erect	Tall	Erect	Triangular	Ripple	Pointy	Convex	Mid	Low
66	48c-4	Mid	Absent/ Very little	Absent/ Very little	Horizontal	Tall	Semi-erect	Triangular	Ripple	Pointy	Convex	Mid	Low
67	48c-5	Mid	Absent/ Very little	Absent/ Very little	Horizontal	Tall	Erect	Triangular	Ripple	Pointy	Convex	Mid	Low
68	48d-5	Mid	Absent/ Very little	Absent/ Very little	Erect	Tall	Semi-erect	Triangular	Ripple	Chump	Convex	Mid	High
69	48e-1	Mid	Absent/ Very little	Absent/ Very little	Erect	Tall	Erect	Ovate	Ripple	Chump	Flat	Mid	High
70	48f-1	Mid	Mid	Little	Erect	Tall	Erect	Triangular	Curved	Chump	Convex	Mid	Mid
71	48f-5	Mid	Mid	Little	Erect	Tall	Erect	Triangular	Ripple	Chump	Convex	Mid	Mid
72	48k-4	Mid	Mid	Little	Erect	Tall	Erect	Triangular	Ripple	Chump	Convex	Mid	Mid
73	49a-4	Mid	Mid	Little	Horizontal	Tall	Horizontal	Broad ovate	Curved	Chump	Convex	Low	Low
74	49b-3	Dark	Little	Absent/ very little	Semi-erect	Tall	Semi-pendulous	Ovate	Ripple	Circular	Convex	Mid	High
75	49c-3	Mid	Absent/ Very little	Absent/ Very little	Erect	Mid	Semi-erect	Ovate	Ripple	Circular	Flat	Mid	Mid
76	49k-2	Little	Little	Little	Erect	Tall	Erect	Triangular	Ripple	Chump	Flat	Low	Low

77	50a-1	Dark	Little	Absent/ Very little	Semi-erect	Tall	Semi-pendulous	Ovate	Ripple	Circular	Convex	Mid	High
78	50b-5	Mid	Absent/ Very little	Little	Erect	Tall	Erect	Broad Ovate	Curved	Circular	Flat	Mid	Low
79	50c-5	Little	Absent/ Very little	Absent/ Very little	Erect	Tall	Erect	Ovate	Ripple	Circular	Convex	Mid	High
80	50k-1	Mid	Little	Absent/ Very little	Erect	Mid	Semi-erect	Mid elliptical	Ripple	Chump	Flat	Mid	Low
81	50k-2	Mid	Absent/ Very little	Little	Erect	Tall	Erect	Broad Ovate	Curved	Circular	Flat	Mid	Low
82	50k-3	Little	Little	Little	Erect	Tall	Erect	Triangular	Ripple	Chump	Flat	Low	Low
83	51a-1	Mid	Absent/ Very little	Little	Erect	Tall	Erect	Broad ovate	Curved	Circular	Flat	Mid	Low
84	51a-3	Little	Absent/ Very little	Absent/ Very little	Erect	Tall	Erect	Ovate	Ripple	Circular	Flat	Mid	Low
85	51b-2	Little	Absent/ Very little	Absent/ Very little	Erect	Tall	Erect	Triangular	Curved	Pointy	Convex	Mid	Mid
86	51c-5	Mid	MIDDLE	Little	Erect	Tall	Erect	Ovate	Ripple	Pointy	Convex	High	Low
87	51d-5	Mid	Absent/ Very little	Little	Erect	Tall	Semi-erect	Triangular	Curved	Pointy	Convex	Mid	High
88	51k-4	Mid	Little	Absent/ Very little	Erect	Mid	Semi-erect	Mid elliptical	Ripple	Chump	Flat	Mid	Low
89	52a-5	Mid	Absent/ Very little	Little	Erect	Tall	Semi-erect	Triangular	Curved	Pointy	Convex	Mid	High
90	52b-3	Little	Mid	Absent/ Very little	Semi-erect	Mid	Semi-erect	Triangular	Ripple	Chump	Flat	Low	Low
91	52b-5	Little	Absent/ Very little	Mid	Semi-erect	Tall	Erect	Triangular	Curved	Chump	Flat	High	Low
92	52c-2	Mid	Mid	Little	Erect	Tall	Semi-erect	Triangular	Curved	Pointy	Convex	High	Low
93	52c-5	Mid	Absent/ Very little	Little	Erect	Tall	Semi-erect	Triangular	Curved	Pointy	Convex	Mid	High
94	52k-5	Mid	Absent/ Very little	Little	Erect	Tall	Semi-erect	Triangular	Curved	Pointy	Convex	Mid	High
95	53a-4	Mid	Mid	Little	Semi-erect	Tall	Horizontal	Triangular	Curved	Chump	Convex	Mid	High
96	53a-5	Mid	Little	Little	Semi-erect	Tall	Semi-erect	Triangular	Curved	Pointy	Convex	Mid	Low

97	53b-3	Mid	Mid	Mid	Semi-erect	Tall	Horizontal	Triangular	Curved	Chump	Convex	Mid	Mid
98	53c-4	Mid	Absent/ Very little	Little	Erect	Tall	Semi-erect	Triangular	Curved	Pointy	Convex	Mid	High
99	53c-5	Mid	Very dense	Little	Erect	Mid	Semi-erect	Triangular	Ripple	Pointy	Convex	Mid	Mid
100	53d-4	Mid	Mid	Mid	Horizontal	Mid	Horizontal	Ovate	Smooth	Circular	Convex	Mid	Low
101	53k-1	Mid	Mid	Mid	Horizontal	Mid	Horizontal	Ovate	Smooth	Circular	Convex	Mid	Low
102	54a-4	Mid	Mid	Mid	Horizontal	Mid	Horizontal	Ovate	Smooth	Circular	Convex	Mid	Low
103	54b-3	Mid	Absent/ Very little	Absent/ Very little	Semi-erect	Tall	Horizontal	Ovate	Smooth	Circular	Convex	Mid	Mid
104	54b-5	Mid	Absent/ Very little	Mid	Semi-erect	Tall	Semi-erect	Triangular	Ripple	Chump	Convex	Mid	High
105	54c-3	Mid	Mid	Mid	Erect	Tall	Erect	Mid Elliptical	Ripple	Chump	Convex	Mid	Mid
106	54c-4	Mid	Little	Absent/ Very little	Semi-erect	Tall	Horizontal	Ovate	Smooth	Chump	Flat	Mid	Low
107	54k-3	Little	Absent/ Very little	Absent/ Very little	Semi-erect	Tall	Semi-erect	Mid Elliptical	Smooth	Chump	Convex	Mid	High
108	54k-4	Mid	Absent/ Very little	Absent/ Very little	Horizontal	Tall	Semi-erect	Triangular	Ripple	Pointy	Convex	Mid	Low
109	55a-3	Mid	Absent/ Very little	Absent/ Very little	Horizontal	Tall	Erect	Triangular	Ripple	Pointy	Convex	Mid	Low
110	55b-5	Mid	Absent/ Very little	Absent/ Very little	Erect	Tall	Semi-erect	Triangular	Ripple	Chump	Convex	Mid	High
111	55k-4	Mid	Mid	Little	Erect	Tall	Erect	Triangular	Curved	Chump	Convex	Mid	Mid
112	56a-3	Mid	Mid	Little	Erect	Tall	Erect	Triangular	Ripple	Chump	Convex	Mid	Mid
113	56a-4	Mid	Mid	Little	Erect	Tall	Erect	Triangular	Ripple	Chump	Convex	Mid	Mid
114	56b-5	Mid	Mid	Little	Horizontal	Tall	Horizontal	Broad Ovate	Curved	Chump	Convex	Low	Low
115	56c-1	Dark	Little	Absent/ Very little	Semi-erect	Tall	Semi-pendulous	Ovate	Ripple	Circular	Convex	Mid	High
116	56c-5	Mid	Absent/ Very little	Absent/ Very little	Erect	Mid	Semi-erect	Ovate	Ripple	Circular	Flat	Mid	Mid
117	56d-5	Little	Little	Little	Erect	Tall	Erect	Triangular	Ripple	Chump	Flat	Low	Low
118	56k-5	Dark	Little	Absent/ Very little	Semi-erect	Tall	Semi-pendulous	Ovate	Ripple	Circular	Convex	Mid	High

119	57a-3	Mid	Absent/ Very little	Little	Erect	Tall	Erect	Broad Ovate	Curved	Circular	Flat	Mid	Low
120	57b-1	Mid	Very dense	Little	Semi-erect	Mid	Semi-erect	Triangular	Curved	Pointy	Convex	Mid	Mid
121	57k-2	Dark	Mid	Absent/ Very little	Erect	Tall	Semi-erect	Mid Elliptical	Ripple	Chump	Convex	Mid	High
122	57k-4	Mid	Mid	Little	Erect	Tall	Erect	Triangular	Ripple	Chump	Convex	Mid	Mid
123	58a-2	Mid	Mid	Mid	Horizontal	Mid	Horizontal	Ovate	Smooth	Circular	Convex	Mid	Low
124	58b-4	Mid	Absent/ Very little	Absent/ Very little	Semi-erect	Tall	Horizontal	Ovate	Smooth	Circular	Convex	Mid	Mid
125	58b-5	Mid	Absent/ Very little	Mid	Semi-erect	Tall	Semi-erect	Triangular	Ripple	Chump	Convex	Mid	High
126	58c-5	Dark	Mid	Absent/ Very little	Horizontal	Tall	Horizontal	Ovate	Ripple	Circular	Convex	Mid	Mid
127	59a-2	Dark	Absent/ Very little	Little	Erect	Tall	Erect	Mid Elliptical	Ripple	Chump	Convex	Mid	High
128	59b-5	Dark	Absent/ Very little	Absent/ Very little	Semi-erect	Tall	Semi-erect	Triangular	Ripple	Pointy	Convex	Mid	High
129	59c-4	Mid	Little	Little	Erect	Tall	Erect	Triangular	Ripple	Chump	Flat	Mid	High
130	59k-4	Dark	Very dense	Mid	Semi-erect	Mid	Horizontal	Ovate	Ripple	Circular	Convex	Mid	Mid
131	60a-4	Mid	Absent/ Very little	Absent/ Very little	Horizontal	Mid	Horizontal	Ovate	Ripple	Circular	Convex	Mid	Mid
132	60b-3	Dark	Very dense	Little	Erect	Mid	Semi-erect	Triangular	Ripple	Pointy	Convex	Mid	Mid
133	60c-5	Dark	Very dense	Mid	Semi-erect	Mid	Semi-pendulous	Ovate	Ripple	Chump	Convex	Mid	High
134	60d-4	Mid	Little	Little	Semi-erect	Mid	Erect	Mid Elliptical	Curved	Chump	Flat	Mid	Low
135	60d-5	Little	Absent/ Very little	Absent/ Very little	Erect	Short	Erect	Mid Elliptical	Smooth	Chump	Flat	Low	Low
136	60k-4	Dark	Very dense	Mid	Semi-erect	Mid	Horizontal	Ovate	Ripple	Circular	Convex	Mid	Low
137	61a-2	Mid	Absent/ Very little	Little	Erect	Tall	Erect	Broad Ovate	Curved	Circular	Flat	Mid	Low
138	61a-3	Little	Absent/ Very little	Absent/ Very little	Erect	Tall	Erect	Ovate	Ripple	Circular	Flat	Mid	Low
139	61b-1	Little	Absent/ Very little	Absent/ Very little	Erect	Tall	Erect	Triangular	Curved	Pointy	Convex	Mid	Mid

140	61c-5	Mid	Absent/ Very little	Absent/ Very little	Horizontal	Tall	Horizontal	Ovate	Smooth	Circular	Convex	Mid	Mid
141	62a-3	Little	Mid	Little	Semi-erect	Tall	Semi-erect	Triangular	Curved	Chump	Convex	Mid	High
142	63b-4	Mid	Absent/ Very little	Absent/ Very little	Semi-erect	Tall	Horizontal	Ovate	Smooth	Circular	Convex	Mid	Mid
143	63k-2	Mid	Absent/ Very little	Mid	Semi-erect	Tall	Semi-erect	Triangular	Ripple	Chump	Convex	Mid	High
144	64a-2	Mid	Little	Absent/ Very little	Semi-erect	Mid	Semi-erect	Ovate	Smooth	Chump	Flat	Mid	Mid
145	64c-5	Mid	Absent/ Very little	Mid	Semi-erect	Tall	Semi-erect	Triangular	Ripple	Curved	Convex	Mid	High
146	64d-3	Mid	Mid	Little	Semi-erect	Tall	Semi-erect	Broad Elliptical	Curved	Chump	Convex	High	High
147	67a-5	Mid	Absent/ Very little	Absent/ Very little	Erect	Tall	Erect	Triangular	Ripple	Pointy	Flat	Low	High
148	67b-4	Dark	Absent/ Very little	Absent/ Very little	Erect	Tall	Erect	Triangular	Ripple	Chump	Convex	Mid	High
149	67c-1	Mid	Little	Little	Semi-erect	Mid	Erect	Mid Elliptical	Curved	Chump	Flat	Mid	Low
150	67c-4	Little	Absent/ Very little	Absent/ Very little	Erect	Short	Erect	Mid Elliptical	Smooth	Chump	Flat	Low	Low
151	67d-5	Dark	Absent/ Very little	Absent/ Very little	Erect	Tall	Erect	Triangular	Ripple	Pointy	Convex	Mid	High
152	67k-1	Dark	Absent/ Very little	Absent/ Very little	Erect	Tall	Erect	Mid Elliptical	Ripple	Pointy	Convex	Mid	High
153	70k-3	Dark	Mid	Absent/ Very little	Horizontal	Tall	Horizontal	Ovate	Ripple	Circular	Convex	Mid	Mid
154	71a-5	Dark	Mid	Absent/ Very little	Erect	Tall	Semi-erect	Mid Elliptical	Ripple	Chump	Convex	Mid	High
155	71b-2	Dark	Absent/ Very little	Little	Erect	Tall	Erect	Mid Elliptical	Ripple	Chump	Convex	Mid	High
156	71c-2	Dark	Absent/ Very little	Absent/ Very little	Semi-erect	Tall	Semi-erect	Triangular	Ripple	Pointy	Convex	Mid	High
157	71d-4	Mid	Little	Little	Erect	Tall	Erect	Triangular	Ripple	Chump	Flat	Mid	High

A: Green color intensity in the leaf blade; B: Blistering of the leaf blade; C: Lobed leaf blade; D: Petiole attitude; E: Petiole length; F: Leaf blade stance; G: Shape of the leaf blade; H: Edge of the leaf blade; I: Shape of apex in the leaf blade; J: Longitudinal shape of the leaf blade; K: The number of leaves; L: Leaf fragility

According to the morphological observations regarding the green color density in the leaf blade of the spinach genotypes belonging to the S2 level, 1.2% of the genotypes had very little color, 13.3% had little color, 71.3% had medium color, and 14% had dark color. Leaf color is highly significant in leafy vegetables, as this parameter is a desirable and marketable feature in spinach cultivation (Eftekhari, Hasandokht, FatahiMoghadam, & Kashi, 2010; Sabaghnia et al., 2015). This is because dark green color is considered an important feature for consumers when choosing fresh or frozen spinach (Brandenberger, Wells, & Haigh, 2004). Researchers reported that green color in spinach is usually associated with chlorophyll a and b pigments, which inhibit the appearance of carotenoid pigments (Kidmose, Edelenbos, Christensen, & Hegelund, 2005; Wang, Chen, Stamps, & Li, 2005). Köse (2018), when looking at the green color intensity of the leaf blades of 50 spinach genotypes, determined nine of the genotypes as light, 28 as medium, 12 as dark, and one (Spi 151/93 genotype) as very dark green. Mohebodini et al. (2017) stated that 54 spinach accessions can be helpful for the development of new varieties for use in breeding programs by characterizing their morpho-agronomic properties. When the blistering of the leaf blades is considered, 47.1% have no or very little, 22.9% have little, 26.1% have medium, and 3.8% have very strong blistering. Blistering in the leaf blade is a consumer demand that varies according to the market condition of spinach. The lobedness of the leaf blade among genotypes was also investigated. While 54.7% of them had no or very little lobedness, moderate lobe was observed in 13.3% of them. When we look at petiole attitude, 41.1% of 157 S2-level spinach genotypes were observed to be erect, 41.4% semi-erect, and 17.1% horizontal. Petiole attitude is one of the principles of mechanical harvesting, and genetic improvement of this parameter during the selection of the S2 stage was one of the objectives of this study. In a study on spinach, 91.7% of the leaf lobes were found to be slightly deep and 5.6% to be medium-deep, while the attachment to the petiole was determined as horizontal in 50% and erect in 33.3% of the leaf lobes (Arif, Jatou, Rafique, & Ghafoor, 2013). In the petiole length evaluations, it was determined that 8.9% was short and 91.1% was medium length. It has been stated that petiole length is considered to be a commercial factor for the production of canned spinach, especially in addition to machine harvesting (Sabaghnia et al., 2015). Leaf blade posture is a significant feature of fresh market and cultural processes of spinach. Of 157 spinach genotypes, 32.4% were erect, 39.4% were semi-erect, 22.9% were horizontal, and 5% were semi-pendulous. Spinach is grown primarily for its fresh leaves, and leaf and leaf area determine the yield performance. When the shape of the leaf blades was examined, it was determined that 40% of 157 spinach genotypes were triangular, 33.7% were ovate, 18.4% were mid-elliptic, and 7% were wide elliptic. Furthermore, dry weight is one of the desired properties for spinach processing and packaging, and it has been reported that high dry matter is directly related to the width of leaf structure in spinach (Arshi, 2000; Eftekhari et al., 2010). Another study reported that there was a positive correlation between yield, leaf area, and the number of leaves in spinach (Abolghasemi, Haghghi, Etemadi, Soorni, & Jafari, 2019). The apex shape in the leaf blades varied among genotypes, with 21.6% of them being pointy, 51.5% chump, and 26.7% rounded. As for the form of the leaf blade edge, it was observed that 41.4% were ripple, 31.8% were smooth, and 26.7% were curved. The longitudinal shape of the leaf blades was determined to be flat in 38.2% and convex in 61.7% of the genotypes. The observational value of leaf numbers was determined to be low in 13.3%, mid in 80.2%, and high in 6.3% of the genotypes. Regarding the current study, Abolghasemi et al. (2019) and Asadi and Hasandokht (2007) reported that the longitudinal shape of the leaf blade in spinach is an important part of the yield, together with the leaf width and the number of leaves. Another report on the subject stated that the harvest of marketable spinach plants depends on the size and number of leaves. Also, this is related to the length of the growth period and the effectiveness of the ambient warm conditions (Pandey & Kalloo, 1993). Morphological evaluations of leaf fragility

indicated a low fragility level in 28%, medium in 35.6%, and high in 36.3% of 157 genotypes. Rashid et al. (2020) conducted a field trial to investigate the genetic diversity of spinach germplasm from 30 different countries by using 21 agro-morphological features, six of which are quantitative and 15 of which are qualitative.

4. Conclusions

In this study, differences were observed between genotypes, especially with respect to plant height and leaf characteristics (both quantitative and qualitative). Based on this, it was predicted that it would be beneficial to create a breeding program to increase the leaf yield of 157 spinach genotypes observed in terms of leaf characteristics.

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