Determination of Natural Distribution Areas and Some Agro-Morphological Characteristics with Sexual Dimorphism of Wild Asparagus (*Asparagus Officinalis* L.) in Iğdır Plain-Turkey

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Abstract

Globally, interest in wild plants has been on the rise in recent years. The potential of wild plants to be used in breeding for sustainable agriculture and people's preference for consumption attract research attentions. The study was aimed to investigate the natural distribution of *Asparagus officinalis* L. taxon, along the Iğdır plain, one of the largest micro-climate regions of Turkey and consumed by the people of the region. The research was also motivated to evaluate wild Asparagus species using some agro-morphological characteristics with sexual dimorphism, for a two years study period. It has been identified that asparagus spreads along the Aras river forming the border of Armenia at altitudes of 800–1076 masl in the region and most densely populated in Karakoyunlu district. The result of the present investigation revealed a wide range of variations for agro-morphological characteristics like days to fruit ripening (76–91 d), edible spear length (168.21-315.34 mm), diameter (6.30-10.86 mm), fresh weight (5.27–19.52 g), dry weight (0.38–1.55 g), number of spear (8–26 plant^{-1}), number of fruit (61-2467 spear^{-1}), fruit weight (8.0-258.3 g spear^{-1}), male plant length (1116.9-2.163.7 mm), female plant length (1219.4-2110.2 mm), male pedicle length (3.72–4.17 mm) and female pedicle length (3.21–3.54 mm) were observed, which can be useful for breeding purposes. Cluster constellation analysis was conducted to investigate the genetic diversity of 31 asparagus genotypes. According to the agro-morphological properties, asparagus were divided into 2 main groups and 4 sub-groups (A; A1, A2 and B; B1, B2). Aralık district samples were mostly collected in the B1 (pink), Karakoyunlu district in the B2 (blue), Tuzluca district in the Al (red) and A2 (green), and Iğdır district mostly in the B2 (blue) cluster. As a result, Karakoyunlu were found superior with the highest asparagus density and edible spear yield as compared to other districts. In order protect the habitat of wild asparagus from excessive consumption and losses due to climate changes, seeds should be collected from these areas to be used for cultivation and breeding purposes. In addition, it is advisable to keep seeds in gene banks for sustainable agriculture and protection of genetic diversity.

Introduction

The genus Asparagus, a member of the *Asparagaceae* family, originates from the Mediterranean region and spreads in Southern Europe, Anatolia, Asia, Africa and Europe (Davis 2001; Eşiyok 2012). There are approximately 300 asparagus species distributed in the arid and semi-arid regions of these regions (Mabberley, 2008; Kubota et al. 2012). The existence of wild asparagus species is known in a large part of Turkey (Eren, 2014).

Acosta-Naranjo et al. (2020) hypothesized a symbiotic and biocultural relationship between asparagus and humans through some attractive mechanisms. The part of asparagus which is consumed as a vegetable is its spear. According to an information from the region where it is grown regarding varieties and cultivation method; the spears, which can be green, white and purple in color, can be consumed fresh as well as canned or frozen food. The green asparagus is specially a good source of phytochemicals as it contains flavonoids, vitamins, sterols, saponins, oligosaccharides, carotenoids, amino acids and fiber (Fuentes-Alventosa et al. 2009; Garcìa-Herrera et al. 2013; Slatnar et al. 2018; Chitrakar et al. 2019). Wild asparagus spears harvested in Europe are sold at very affordable prices in local and small markets in many parts of Turkey, especially in the Aegean and Marmara regions. They are collected from wild habitats in March-April, and they find buyers in local markets at very good prices upon the intense demands of consumers (Alan, 2016). In 2020, the world production amount of asparagus was 9.43 million tons, and in Turkey it was 1,079 tons, an increase of about 10 times compared to the previous year (FAO 2022). This does not include wild species collected and sold in markets. According to the world vegetable statistics, asparagus is one of the least cultivated vegetables, but its production tends to increase sharply day to day. Among the reasons for this increasing interest are the development of new varieties that adapt to different ecologies and the increasing interest of consumers in wild plants.

Asparagus is a mild and cool season plant, which can be successfully grown in sandy-loam soils. The plant is among the vegetables that are relatively cold, drought and salt tolerant (Wilcox-Lee 1987; Sterrett et al. 1990; Wilson et al. 1996). In this respect, it is economically possible to grow in areas with low annual precipitation and slightly salty areas. These features of the plant are an important advantage in terms of plant growth. The global climate change problem that the world is facing increases the importance of these heat and drought resistant plants for Turkey and many other European countries. Hence, the collection of asparagus plant genetic resources naturally found in Iğdır flora, and the agro-morphological characterization are of paramount significance in terms of evaluating these species as a breeding material because wild genotypes can enable a species to be produced in very large areas in breeding programs.

Iğdır province, which is located in the Eastern Anatolia geographical region, has a microclimate feature and shows different ecological characteristics. In other words, it has softer seasonal transitions rather than a dense continental climate like other areas in the region. This ecological difference increases the number of species and varieties that are cultivated or spread naturally in the plain. Asparagus is among the species that can adapt to the ecology of Iğdır areas.

This study was carried out to investigate the natural distribution of wild asparagus (*A. officinalis* L.) grown in the Iğdır plain and reveal some agro-morphological characteristics of the plant. The result obtained from the present investigation can greatly contribute to the protection of the natural flora by revealing the herbal characteristics of asparagus in the region for the first time. It also helped to collect preliminary data on the asparagus starting materials that can be used in future breeding programs.

Material And Method

Material

In order to mark and measure asparagus samples, it has been observed whether asparagus is found in 97 locations, every 4 km, in 4 cities, including the center and districts of Iğdır (Aralık, Karakoyunlu, Tuzluca), where the plant grows naturally. The latitude, longitude and altitude of the locations where asparagus was found were recorded.

In Iğdır climate, the months with frost and the possibility of frost are January, February and December. There is a dry period starting from the end of May and continuing until the beginning of November (Fig. 1)

Method

Determination of natural distribution areas and plant material

The examination of the plant samples and the marking of the sampling sites began in early March, when the air temperature started to rise above 0 degrees and above-ground spears began to emerge (Fig. 1). Asparagus plants were found in 31 of the 97 locations surveyed (Fig. 2). Measurements were made by measuring at least 5 different plant spears and their harmonic averages in each location. For each sampling location, 5000 m^2 area was scanned and the density of asparagus was determined by calculating the number of plants in 100 m^2 area. In the Geostatistical Analyst module of the Arc-GIS 10.2 package program, point data were added and analyzed according to the coordinates, and distribution raster maps were created. Fieldwork was carried out daily for the first month for plant and spear measurements, and three times a week after the spear emergence stopped. The collected plant materials were stored according to their drying characteristics; it was dried in accordance with the recommended technique and then taken into storage.

The Turkish name of the plant is “Kuşkonmaz”. The taxonomic classification was verified by the taxonomist, Prof. Dr. Ahmet Zafer TEL based on Davis v8 (1965–1985) with a voucher specimen (voucher code: INWM0000087), which is protected in the Iğdır National Wild Life Museum.

Morphological characterization

Agro-morphological analysis was carried out separately on the spears of the aerial parts of the plant, and the female and male adult plant parts. Marking was made when the spear tips emerged from the soil surface. The first date when the emergence started and the last date when the emergence stopped were determined. Calculations were started at the same time the next day on the spear tips determined to appear on the soil surface. The start date of flowering was noted for each location separately, and the day after anthesis was calculated as the fruit ripening period. The examined morphological parameters are given in Table 1.

Table 1
List of morphological characters with abbreviations recorded for 31 location of asparagus

Character	Abbreviation
First day spear length (mm)	FDSL
First day spear diameter (mm)	FDSD
Edible spear length (mm)	ESL
Edible spear diameter (mm)	ESD
Edible spear fresh weight (g)	ESFW
Edible spear dry weight (g)	ESDW
Mean spear number per plant (adet)	SNPP
Number of fruits per spear (adet)	NFS
Fruit weight in Spear (g)	FWS
Fruit diameter (mm)	FD
Number of seeds per spear (adet)	NSS
1000 seed weight (adet)	TSW
Plant lenght (mm)	PL
Plant diameter (mm)	PD
Plant fresh weight (g)	PFW
Plant dry weight (g)	PDW
Branch lenght (mm)	BL
Number of branches in spear (adet)	NBS
Number of cladods in branch (adet)	NCB
Cladod length	CL
Pedicle length (mm)	PedL
Petal length (mm)	PetalL

FDSL and FDSD were measured 24 hours marking of the plant. It was measured from the soil surface to the spear tip, and just above the stem using a horizontal axis digital calliper. In the study, one edible spear was harvested from each plant. The spears were cut from the soil level with a long-handled special knife with a 2.5 cm wide rim, so as not to damage the plant or other spears. ESL and ESD were measured taking into account the distance between soil surface and spear tip. ESFW was determined by measuring the harvested edible shoots without losing moisture. ESDW was determined by keeping the shoot

at room temperature for 24 hours and then keeping it in an oven at 80°C for 24 hours. SNPP was determined as the total number of spears developed from a single claw. NFS was calculated by counting the average of fruits harvested from three different spears. FWS was calculated by weighing the fruits harvested from three different spears on precision scales and averaging them. FD was calculated by measuring the mid-axis of 20 ripe fruit with a digital calliper and averaging them. NSS was calculated by counting the seeds extracted from the fruits harvested from three different spears and taking the mean value. TSW, the seeds harvested from each plant were weighed as 3*100 pieces and their weight was calculated according to the ratio of 1000 pieces after taking the average. PL was measured separately in male and female plants. In terms of plant height, spears that have completed their developmental stages were considered. It was determined by measuring the part from the soil surface to the tip of the plant with a ruler. The plant length measurement time was determined as the time when the fruits of the female plants reached the harvest maturity. PD was calculated by measuring the stem of the plant just above the soil level using a digital calliper. PFW was wrapped in wet paper so that the plants would not lose moisture and immediately weighed on a precision scale. In PDW, the plants whose wet weight was calculated were kept at room temperature for 24 hours and then kept at 80°C for 24 hours and weighed. NBS was determined by counting the branches from the mature spear. BL was calculated by measuring 10 branches from the bottom and 10 branches from the top and averaging them. NCB was calculated by counting the cladodes of the plant on the lower 10 branches and the upper 10 branches, and the average was taken. CL was measured on the branch, 10 from the bottom and 10 from the top, and was calculated by taking their averages. PedL was calculated by measuring and averaging 10 flower stems separately in female and male plants with digital calliper. PetalL was calculated by measuring and averaging 10 petals separately in male and female plants with digital callipers.

Statistical analysis

In this study, statistical analyses were conducted using SPSS v.26. Duncan's multiple range test was used to determine significant differences between locations at $p < 0.05$. Cluster constellation plot and Heatmap analysis were performed using JMP 14.3 statistical software and ClustVis, respectively.

Results

Natural distribution areas

The names of the locations where the measurements were made including latitude, longitude and altitude informations are given in Table 2. The examples are marked in 4 districts, corresponding to areas between 39° 47' 19" and 40° 07' 14" N latitudes and 43° 27' 40" and 44° 41' 24" E longitudes.

Table 2. Latitude, longitude and altitude of the areas where asparagus samples were detected (East to West)

Acronym	Location name	Latitude	Longitude	Altitude (m)
		Aralık		
1	Tigem	39° 47' 19" N	44° 41' 24" E	810
2	Gödekli	39° 49' 16" N	44° 36' 30" E	812
3	Aralık	39° 53' 03" N	44° 32' 55" E	818
4	Aşağı çiftlik	39° 51' 35" N	44° 35' 17" E	821
5	Yukarı çiftlik	39° 52' 17" N	44° 33' 41" E	815
6	Tazeköy	39° 55' 14" N	44° 31' 05" E	821
7	Hacıağa	39° 55' 34" N	44° 29' 27" E	822
8	Saraçlı	39° 54' 29" N	44° 28' 06" E	817
9	Ramazankent	39° 57' 40" N	44° 29' 03" E	826
		Karakoyunlu		
10	Kerimbeyli	39° 59' 45" N	44° 24' 55" E	830
11	Bekirhanlı	40° 01' 45" N	44° 20' 10" E	835
12	Koçkıran	40° 02' 31" N	44° 17' 17" E	833
13	Aşağı Alican	40° 01' 59" N	44° 12' 50" E	837
14	Orta Alican	40° 01' 44" N	44° 11' 09" E	843
15	Yukarı Alican	40° 01' 39" N	44° 09' 59" E	842
16	Mürşitali	40° 02' 82" N	44° 12' 62" E	849
		Iğdır		
17	Kadıkışlak	40° 01' 48" N	44° 04' 30" E	853
18	Tuam	39° 55' 42" N	44° 05' 44" E	852
19	Ağaver	40° 01' 09" N	44° 00' 32" E	864
20	Yüzbaşılar	40° 01' 12" N	44° 03' 06" E	858
21	Kazancı	40° 00' 46" N	44° 01' 08" E	866
22	Hakmehmet	40° 01' 04" N	43° 58' 37" E	876
23	Bayraktutan	40° 00' 55" N	43° 55' 04" E	889
24	Çalpala	40° 02 13" N	43° 51' 32" E	901
		Tuzluca		
25	Sürmeli	40° 04' 08" N	43° 46' 57" E	924
26	Turabi	40° 04' 32" N	43° 46' 17" E	922
27	Tuzluca	40° 06' 30" N	43° 39' 34" E	963
28	Aşağı Çıyrıklı	40° 07' 26" N	43° 36' 56" E	989
29	Yukarı Çıyrıklı	40° 07' 14" N	43° 35' 09" E	996
30	Ağabey	40° 06' 51" N	43° 31' 50" E	1012
31	Gaziler	40° 06' 15" N	43° 27' 40" E	1076

The altitudes of the locations where the samples were marked were measured between 810–1076 m. It was observed that the altitude increased from Aralık district to Tuzluca district (East to West).

As a result of the observations made in the field for two years, the plant densities were converted into numerical values based on the number of plants in the 100 m^2 area. These data were then mapped using remote sensing and geographic information systems (GIS) (Fig. 3 and see also Supplementary Fig. 2). Therefore, the priority regions are identified for scientific and conservation studies that can be done in the future.

Morphological characterization

In the locations where asparagus were found, it was revealed that the spear emergence began on April 4 in the first year. In general, the spear emergence dates from east to west began lately. On average, it was determined that the emergence period of the spears varied between 10–20 days. It has been observed that the flowering date begins at a later date from east to west, similar to the beginning of spear emergence. The fruit ripening period varies between 76–87 days in the first year depending on altitude and temperature (Table 3).

As a result of morphological observations made on asparagus samples obtained from the Iğdır plain, it was identified that the plants have a green small rhizome stem, the cladode appearance is smooth, the petal color is yellow, the flower structure is tubular, the fruit color is red, and the fruit shape is spherical (Fig. 4). The genus Asparagus showed reproductive behavior that include monoic, dioecious, hermaphroditic, andromonoic and in some cases supermale plants (Kanno and Yokoyama 2011). It was revealed that all asparagus examined in Iğdır and its surroundings have dioecious reproductive behavior. Apart from that, it was observed that the seeds were black in color, oval and had seed coat dormancy.

Table 3. First and last emergence dates of spears, flowering date and fruit ripening times

Code	First-Last spears emergence date		Flowering date		Fruit ripening time	
	Years		Years		Years	
	2020	2021	2020	2021	2020	2021
1	05.04-27.04	09.04-01.05	08.05	16.05	80	83
2	04.04-19.04	10.04-02.05	07.05	15.05	80	81
3	06.04-22.04	12.04-04.05	09.05	16.05	82	84
4	08.04-24.04	12.04-02.05	11.05	17.05	83	85
5	09.04-23.04	13.04-05.05	12.05	17.05	83	85
6	09.04-02.05	12.04-07.05	12.05	18.05	82	86
7	07.04-23.04	12.04-06.05	13.05	17.05	82	86
8	06.04-17.04	11.04-07.05	15.05	16.05	77	80
9	11.04-28.04	14.04-08.05	13.05	19.05	81	84
10	09.04-03.05	14.04-09.05	10.05	19.05	80	86
11	09.04-02.05	15.04-08.05	09.05	20.05	82	85
12	09.04-02.05	15.04-10.05	09.05	20.05	80	85
13	10.04-01.05	15.04-09.05	08.05	19.05	81	86
14	11.04-29.04	16.04-08.05	08.05	19.05	81	86
15	11.04-25.04	16.04-07.05	10.05	19.05	82	87
16	12.04-29.04	17.04-07.05	11.05	21.05	80	86
17	14.04-06.05	18.04-09.05	14.05	23.05	80	86
18	10.04-30.04	14.04-07.05	26.05	29.05	76	83
19	14.04-24.05	18.04-08.05	14.05	20.05	80	87
20	18.04-25.04	21.04-07.05	19.05	23.05	84	88
21	18.04-25.04	22.04-09.05	19.05	23.05	84	88
22	14.04-26.04	19.04-08.05	17.05	22.05	81	85
23	19.04-22.04	22.04-10.05	19.05	22.05	83	89
24	13.04-23.04	18.04-09.05	18.05	24.05	82	89
25	15.04-05.05	20.04-13.05	25.05	30.05	87	93
26	16.04-06.05	22.04-11.05	25.05	29.05	83	90
27	19.04-06.05	24.04-14.05	27.05	30.05	85	91
28	20.04-08.05	25.04-15.05	24.05	30.05	84	90
29	20.04-08.05	25.04-14.05	24.05	29.05	84	90
30	20.04-10.05	27.04-16.05	24.05	31.05	84	91
31	20.04-11.05	27.04-18.05	26.05	31.05	85	91

In the first day of spear length measurements, which was one of the morphological observations made on plant samples, it was determined that the spear length changed between 24.57–49.25 mm in the first year and between 24.37–48.68 mm in the second year. According to the average of two years, the highest spear length on the first day was calculated in location 10, and the lowest in location 4. In one-day spears for which the spear emergence length was calculated, spear diameters were measured between 4.82–9.64 mm in the first year and between 5.89–9.55 mm in the second year. Similar to FDSL, the highest FDSD was determined in locaiton 10 and the lowest in location 4, based on the average data of both years. Considering the locations, the highest FDSL and FDSD were calculated from Karakoyunlu district (Table 4).

Table 4 FDSL, FDSD, ESL, ESD, ESFW, ESDW in asparagus spears by location

Code	FDSL (mm)		FDSD (mm)		ESL (mm)		ESD (mm)		ESFW (g)		ESDW (g)	
	Years		Years		Years		Years		Years		Years	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
1	45.07b	42.83bc	9.02cd	9.08b	232.02i	234.51fg	9.61bc	9.51c	11.52f	11.61hi	0.91e	0.94hi
2	44.02bc	43.95b	8.89d	9.03b	225.09j	228.08g-i	9.68bc	9.65c	11.47f	11.52i	0.85f-h	0.87k
3	30.09lm	38.43e-g	6.22p	8.24d	199.75pr	195.79op	6.30r	6.43n	5.27s	5.33u	0.50n	0.52u
4	25.34op	24.66m	4.82r	6.04lm	222.00k	229.51g-i	8.60e	8.71e	13.09c	12.77f	0.98d	0.98fg
5	26.11o	28.11l	5.06r	5.89m	264.40f	266.72c	8.99d	8.82e	12.00e	12.17g	1.06c	1.06e
6	37.43h	35.59hi	8.70e	8.60c	197.50r	218.21j-l	7.25kl	7.28k	5.96r	6.05st	0.63k	0.64pr
7	38.50gh	40.13d-e	8.01gh	7.63ef	204.21op	213.94k-m	6.91mn	6.97l	7.38mn	7.37p	0.59l	0.60s
8	29.71m	29.63kl	6.51n	6.44k	189.94s	191.19pr	7.18k-m	7.23k	6.12r	6.22s	0.54m	0.55t
9	43.16cd	33.85ij	7.21k	7.39gh	210.07mn	208.39mn	7.77hi	7.74j	7.20n	7.28p	0.63k	0.62rs
10	49.25a	48.68a	9.48b	9.51a	220.62k	233.05f-h	10.86a	10.34a	15.06b	16.08b	1.18b	1.30b
11	39.90g	41.05c-e	7.94h	8.17d	208.51no	214.31k-m	9.73bc	9.61c	12.74d	12.72f	0.99d	0.99f
12	40.29fg	44.80b	9.15c	9.55a	227.21j	234.47fg	9.59c	10.19a	12.57d	14.13d	1.06c	1.15d
13	32.36j	35.49hi	8.51f	8.53c	202.43op	212.84lm	8.99d	9.14d	10.44h	10.53k	0.86fg	0.93ij
14	35.08i	34.89i	9.64a	8.61c	315.34a	283.88a	10.73a	10.26a	19.52a	19.47a	1.55a	1.52a
15	26.42o	31.45jk	7.53ij	8.21d	270.25e	277.86sb	7.57ij	8.42f	9.35i	10.52k	0.88f	0.90jk
16	41.33ef	40.81c-e	7.46j	8.59c	278.99d	270.70bc	7.93gh	8.25fg	11.52f	11.74h	0.92e	0.94hi
17	39.56g	44.48b	6.31op	8.66c	242.96h	251.73d	9.89b	9.97b	12.65d	13.28e	1.04c	1.23c
18	31.42j-l	35.36hi	6.67m	6.76i	260.14g	243.76de	7.00l-n	7.26k	8.69k	8.78n	0.84g-i	0.83l
19	30.19lm	31.70jk	7.65i	7.42gh	306.86b	277.63ab	7.71hi	8.14g	10.75g	11.09j	0.93e	0.95g-i
20	28.22n	29.92kl	6.25p	6.13l	285.31c	247.72de	6.35r	6.37n	8.10l	8.17o	0.81i	0.82l
21	29.54m	30.52kl	6.53n	6.51jk	240.26h	242.11ef	6.78no	6.66m	6.83op	7.20p	0.66k	0.73n
22	35.33i	36.17g-i	7.61ij	7.60ef	235.86i	271.09bc	8.23f	8.36f	9.19ij	8.95mn	0.82hi	0.78m
23	31.55jk	33.68ij	6.42no	7.25h	211.51lm	212.03l-n	6.61op	6.69m	5.86r	5.96t	0.46o	0.53tu
24	24.57p	31.70jk	8.37f	8.21d	214.06l	214.80k-m	8.13fg	8.10gh	9.03j	9.10lm	0.92e	0.92ij
25	30.38k-m	24.37m	6.89l	6.62ij	212.43lm	210.24l-n	7.19k-m	7.20k	6.62p	6.75r	0.44o	0.46v
26	38.04gh	39.71d-f	7.55ij	8.53c	216.86l	224.14h-j	7.81hi	7.96hi	6.94o	7.22p	0.50n	0.66op
27	44.25bc	40.94c-e	7.51ij	7.52fg	168.21u	186.80r	7.66h-j	7.72j	5.94r	6.16st	0.38p	0.45v
28	48.89a	43.34bc	8.13g	8.14d	206.45no	225.43g-j	8.31f	8.37f	9.08ij	9.19l	0.97d	0.97f-h
29	37.42h	41.26cd	7.16k	7.73e	221.53k	222.46i-k	7.39jk	7.92i	7.56m	9.10lm	0.70j	0.94hi
30	37.79h	39.48d-f	8.12g	8.26d	209.84mn	239.67ef	8.60e	8.64e	9.17ij	14.74c	1.01d	1.30b
31	42.11de	37.58f-h	8.50f	8.32d	174.48t	203.68no	8.71e	8.69e	7.57m	8.16o	0.64k	0.69o
Mean	35.91	36.60	7.54	7.84	228.23	231.83	8.20	8.28	9.52	9.98	0.81	0.86

Table 5. SNPP, NFS, FWS, FD, NSS, TSW in asparagus spears by location

Code	SNPP (number/plant)		NFS (g)		FWS (g)		FD (mm)		NSS (number)		TSW (g)	
	Years		Years		Years		Years		Years		Years	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
1	24b	25a	514fg	486fg	67.6e	63.2g	7.9b	7.8bc	1150e	1021fg	14.05l	14.18m
2	18fg	21cd	433h	404h	58.0g	53.7i	7.7c	7.6d	1106e	1036f	16.07k	16.14m
3	12k	12ij	299ij	252l-n	18.9m-o	15.2r	7.1gh	7.1fg	541i	496l	23.59f-h	21.73k
4	12k	13hi	548ef	476g	62.6f	57.6h	7.6cd	7.6d	1466d	1229e	24.37f-h	23.43j
5	11kl	11jk	572e	543e	67.5e	64.1g	7.7c	7.6d	775g	681j	23.14f-h	23.34j
6	17gh	19ef	219k	238m-o	19.7l-n	20.7op	6.9ij	7.0g	1083ef	1235e	17.76jk	17.92l
7	9mn	9lm	61n	123p	8.5p	13.2rs	7.1gh	7.1fg	89n	185s	18.65ij	18.39l
8	8n	9lm	2467a	1747a	258.3a	221.0a	7.4d-f	7.4e	4532a	3342a	36.53de	29.50hi
9	19ef	19ef	405h	368hi	48.1h	44.7k	7.5de	7.4e	990f	820h	18.33ij	18.60l
10	26a	26a	128lm	324jk	31.4j	70.6f	8.3a	8.4a	317k	761i	20.47h	21.51k
11	12k	14h	95mn	111p	9.7p	10.5s	7.7c	7.6d	99n	128t	37.45de	35.07g
12	24b	26a	446h	521ef	62.8f	75.1e	7.5de	7.7cd	1825c	2122c	52.27c	54.62d
13	16hi	16g	247k	229m-o	23.0kl	22.8o	7.0hi	7.3ef	257kl	257p	54.59c	49.31e
14	18fg	18f	227k	230m-o	32.9j	33.6mn	8.0b	7.8bc	479j	484l	33.13e	36.66g
15	14j	16g	119lm	227m-o	24.2k	31.3n	7.3e-g	7.4e	151m	263p	32.58e	35.28g
16	21cd	20de	215k	214no	41.1i	39.5l	8.2a	7.9b	665h	642k	31.02e	31.34h
17	24b	25a	1054c	994c	126.4c	128.2c	7.5de	7.7cd	1090ef	1042f	23.25gh	28.01i
18	9mn	10kl	1665b	1543b	199.7b	191.4b	7.3e-g	7.2f	3015b	2856b	41.88d	35.65g
19	20de	19ef	330i	291kl	17.5no	15.2r	6.9ij	6.8h	525ij	449m	23.19gh	23.69j
20	8n	9lm	229k	214no	15.8o	15.3r	6.6l	6.6i	321k	306o	18.32ij	18.81l
21	10lm	9lm	252jk	213no	16.6no	15.1r	6.7kl	6.6i	330k	320o	18.97hi	18.91l
22	20de	22bc	337i	332ij	39.0i	35.1m	6.8jk	6.9gh	634h	619k	51.33c	47.21ef
23	16hi	16g	591e	268lm	39.1i	19.2p	6.8jk	7.0g	802g	387n	38.59de	42.48f
24	17gh	18f	153l	233m-o	8.3p	14.7r	7.2f-h	7.1fg	198lm	271p	54.55c	50.72e
25	8n	8m	78mn	67r	15.5o	12.7rs	6.7kl	6.5i	131mn	109t	29.36ef	28.46i
26	22c	21cd	497g	560e	41.2i	50.4j	6.8jk	7.0g	1249de	1543d	19.17hi	22.65jk
27	15ij	14h	229k	221no	22.6kl	20.8op	7.0hi	7.0g	228l	217rs	36.33de	32.99h
28	19ef	19ef	148l	202o	18.1no	22.0op	7.2f-h	7.2f	256kl	329o	83.24a	80.44a
29	18fg	19ef	201k	204o	22.0k-m	21.7op	7.3e-g	7.3ef	232l	237pr	75.55b	78.65b
30	22c	23b	832d	774d	104.8d	98.1d	7.4d-f	7.4e	1112e	990g	52.11c	61.36c
31	18fg	18f	120lm	129p	8.0p	10.5s	6.8jk	6.9gh	247kl	262p	31.46e	29.30hi
Mean	16.35	16.90	442.35	410.79	49.31	48.61	7.28	7.28	835.32	794.68	33.91	33.75

Table 6. PL, PD, PFW, PDW in male and female asparagus by location

Code	Male								Female							
	PL (mm)		PD (mm)		PFW (g)		PDW (g)		PL (mm)		PD (mm)		PFW (g)		PDW (g)	
	Years		Years		Years		Years		Years		Years		Years		Years	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
1	2163.7a	2057.8a	10.1bc	9.9c	121b	116e	77fg	74gh	1435.5ef	1864.2a	9.6cd	9.6gh	143b	146b	103b	105c
2	1440.1h	1412.0g-i	9.5c-e	9.4d	112c	107f	86e	83de	1518.7e	1492.8h-j	9.9c	9.7g	125c	118gh	104b	100d
3	1286.4ij	1145.3n	7.1o	7.2l	72lm	71m-o	39p	38o	1515.1e	1450.7jk	7.2ij	7.5m	77f	75n	44i	42o
4	1266.3j	1252.5k-m	8.4g-i	8.6fg	71m	68o	30s	28r	1642.2d	1555.2fg	10.4bc	9.7g	144b	135d	82e	77i
5	1441.2h	1420.2gh	8.9f	8.7f	71m	69no	36r	34p	1305.3fg	1450.5jk	9.9c	9.8g	136bc	140c	80e	82h
6	1649.1e	1554.8f	8.2i	8.2h	71m	68o	29s	26r	1775.5c	1647.6cd	8.5de	8.6j	83ef	80m	45i	43o
7	2108.8ab	1616.9e	7.1o	7.2l	96e	91i	69hi	66j	1230.4h	1258.2	7.4hi	7.5m	78f	83lm	49hi	54l
8	1412.0h	1459.2g	7.2no	7.5jk	75j-l	84jk	44no	41n	1670.4d	1577.5ef	7.6fh	8.1k	181a	170a	119a	113b
9	1798.9cd	1549.7f	7.9j	7.7ij	102de	97h	75g	72h	1493.1e	1507.6f-h	9.4cd	9.2i	89e	85l	66g	63k
10	1310.2i	1394.2h-j	10.6b	10.5b	123b	129a	97c	101b	1995.5ab	1788.8b	11.1b	11.1c	153b	141c	110ab	107c
11	1427.4h	1360.7j	9.3de	9.2e	88f	81k	54k	49l	1407.5ef	1404.7kl	9.6cd	9.4h	86e	85l	55h	54l
12	1432.3h	1448.0g	10.5b	10.4b	132a	130a	99bc	97c	1644.7d	1627.5c-e	10.7b	10.6d	141b	137cd	108ab	105c
13	1230.1j	1250.7k-m	9.7c	9.3de	99de	101g	78fg	80f	1333.1fg	1464.4ij	8.9d	9.1i	112d	121fg	89cd	96e
14	1975.3b	1460.8g	12.0a	11.5a	105d	96h	80f	75g	1994.9ab	1665.5c	10.4bc	10.4e	117cd	111i	93c	90f
15	1316.6i	1364.5ij	6.9op	7.8i	73l	87j	47lm	72h	2088.9a	1760.3b	8.6de	9.1i	107d	101j	68g	65k
16	1630.5e	1559.5f	8.5f-i	8.2h	124b	107f	91d	84d	1683.3d	1646.8cd	12.8a	11.5b	129bc	112i	94c	86g
17	1322.1i	1395.9h-j	8.3hi	8.4gh	79h-j	90i	42o	73gh	1560.4de	1526.9f-h	10.2bc	10.1f	111d	104j	86d	81h
18	1116.9k	1214.3m	4.8t	6.3n	104d	117de	67i	81ef	1324.4fg	1314.2m	5.1l	7.2n	147b	149b	114a	119a
19	1317.8i	1288.3k	5.8s	6.0op	78ij	77l	44no	43mn	1542.3e	1494.3h-j	6.0k	6.1p	89e	85l	51hi	49n
20	1216.5j	1210.0m	5.7s	5.7r	75j-l	74lm	45m-o	44m	1249.8h	1240.2n	4.9l	5.3r	81f	85l	47i	50mn
21	1314.2i	1274.1k	6.6p	6.5m	79h-j	75lm	46l-n	43mn	1502.7e	1364.8lm	7.5f-i	7.4mn	90e	87l	54h	52lm
22	1507.1f	1459.3g	8.3hi	8.2h	103d	102g	71h	69i	1508.1e	1516.4h-i	8.2e	8.2k	108d	111i	75f	76i
23	1593.9ef	1452.7g	7.3m-o	7.4k	112c	109f	77fg	75g	1601.0de	1554.0fg	7.4hi	7.3n	119cd	115hi	84de	81h
24	1269.0j	1244.9k-m	5.7s	5.9pr	101de	102g	75g	76g	1224.0h	1219.4n	7.0j	6.9o	103d	101j	74f	73j
25	1619.2ef	1522.8f	6.2r	6.1no	80h	69no	49l	44m	1832.0bc	1474.7h-j	7.6fh	7.3n	89e	85l	54h	52lm
26	1231.6j	1217.1lm	7.8j-m	7.8i	74kl	72mn	49l	47l	1815.3bc	1606.8de	12.9a	12.4a	113cd	111i	86d	85g
27	1289.4ij	1267.2kl	7.6lm	7.6j	93ef	91i	62j	61k	1411.3ef	1239.9n	7.9f	7.8l	99de	94k	65g	64k
28	1845.6c	1790.5c	7.7k-m	7.8i	129a	122bc	87e	84d	1922.1b	1863.0a	8.5de	8.5j	125c	123f	92c	91f
29	1769.5cd	1775.8c	7.6lm	7.6j	121b	120cd	101b	100b	1794.7bc	1796.1b	8.4de	8.4j	127c	129e	100b	102d
30	2108.1ab	1877.3b	8.2i	8.4gh	130a	125b	107a	104a	1887.7b	1859.9a	8.4de	8.5j	123c	121fg	99b	100d
31	1712.8d	1683.4d	8.4g-i	8.3h	117bc	115e	96c	95c	2110.2a	1903.9a	8.5de	8.5j	125c	122fg	98b	97e
Mean	1516.40	1450.98	8.00	8.03	97.10	95.53	66.10	66.47	1613.55	1552.79	8.73	8.73	114.52	111.70	80.26	79.20

Table 7. BL, NBS, NCB, CL, PedL, PetalL in male and female asparagus by location

Code	Male												Female											
	BL (mm)		NBS (number)		NCB (number)		CL (mm)		PedL (mm)		PetalL (mm)		BL (mm)		NBS (number)		NCB (number)		CL (mm)		PedL (mm)		PetalL (mm)	
	Years		Years		Years		Years		Years		Years		Years		Years		Years		Years		Years		Years	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
1	371.8a	311.4b	50cd	54cd	30d	30f	85.2b	83.2ab	3.89j	3.72n	3.98g	3.94u	299.9ab	302.2ab	57e	58f	24ij	26g	91.1a	90.4ab	3.23m	3.21r	3.71r	3.67s
2	189.5h	204.4kl	61c	59c	25d-f	26g	78.8cd	83.2ab	3.89j	3.69n	4.02fg	3.95tu	273.2b	266.1b	68bc	66d	21k	23hi	89.9a	88.4b	3.26lm	3.25p	3.79o-r	3.71rs
3	171.6ij	159.7no	30e	37de	15i	16m-o	66.3g	64.1gh	3.92ij	3.78m	4.08e-g	3.97s-u	222.6bc	212.4bc	37i	40l	17l	17k	71.5hi	70.4g	3.24m	3.25p	3.79o-r	3.73r
4	171.6ij	168.6n	45d	44d	14i	15no	64.3hi	65.7g	3.91j	3.85l	4.03fg	3.99r-t	259.4bc	243.8bc	51f	50hi	25hi	23hi	72.6h	75.3ef	3.32kl	3.28o	3.85m-r	3.76pr
5	220.4fg	216.7jk	48cd	46d	23ef	24hi	70.9f	68.1ef	3.99h	3.83lm	4.03fg	4.00p-s	279.6b	286.4ab	67c	68cd	27gh	27fg	82.4cd	80.6d	3.31k-m	3.30n	3.83n-r	3.80op
6	209.4g	206.5kl	53cd	51cd	18gh	19kl	70.4f	70.5e	3.97hi	3.88kl	4.08e-g	4.03o-r	189.7d	220.2bc	71b	69cd	22jk	23hi	69.9i	72.2f	3.32kl	3.30n	3.86m-p	3.82no
7	333.9bc	272.5e	74b	72b	26de	26g	90.3a	86.7a	4.01gh	3.93jk	4.09e-g	4.04n-p	264.4b	267.1b	63d	66d	32e	31de	62.5jk	63.5hi	3.36g-i	3.33m	3.83n-r	3.81no
8	259.3d	267.6e-g	64bc	65bc	48b	46b	81.9bc	83.9ab	4.07ef	3.95ij	4.01g	3.99r-t	320.7a	332.3a	58e	68cd	46b	46b	87.5ab	87.9b	3.40f-h	3.36l	3.75pr	3.83no
9	214.7g	197.8l	85a	83a	70a	66a	59.7k	60.7ij	4.05fg	4.02gh	4.10e-g	4.05m-o	161.0d	199.9bc	69bc	71c	58a	60a	61.8jk	62.8i	3.33j-l	3.35l	3.88l-p	3.85mn
10	227.9f	256.1gh	57c	58c	26de	31ef	79.7c	79.6b	4.08d-f	4.00hi	4.12e-g	4.07mn	309.1ab	294.9ab	67c	66d	27gh	32d	88.7ab	87.4b	3.41e-h	3.39k	3.86m-p	3.85mn
11	190.5h	261.2fg	36de	39de	17g-i	20j-l	60.2jk	53.7lm	4.09c-f	3.99hi	4.09e-g	4.06m-o	348.7a	325.6a	59e	57f	22jk	22i	79.6e	74.7ef	3.43c-h	3.41jk	3.80n-r	3.82no
12	329.9c	295.5c	62c	63bc	41c	40c	85.4b	85.5a	4.10b-f	4.05f-h	4.10e-g	4.08lm	334.9a	341.2a	77a	78a	58a	61a	83.1c	93.0a	3.38f-i	3.40k	3.93k-o	3.89lm
13	265.6d	260.8g	57c	58c	47b	44b	80.5c	74.7c	4.10b-f	4.05f-h	4.15e-g	4.11kl	268.1b	274.3b	34j	52h	44b	44bc	79.6e	80.6d	3.44b-h	3.42ij	3.99j-m	3.93kl
14	337.9bc	285.4d	58c	57c	23ef	25g-i	84.3b	81.7b	4.09c-f	4.08d-g	4.15e-g	4.13k	333.5a	296.5ab	57e	60ef	28fg	30e	86.5b	87.6b	3.42d-h	3.43hi	3.94k-n	3.93kl
15	243.6e	254.2gh	34de	48d	19g	23h-j	79.6c	73.0c-e	4.12a-e	4.07e-g	4.13e-g	4.14k	285.7b	285.4ab	70b	68cd	24ij	26g	83.4c	85.3bc	3.44b-h	3.43hi	3.99j-m	3.97jk
16	228.0f	223.7ij	61c	60c	16hi	19kl	70.1f	68.1ef	4.13a-d	4.11a-g	4.19e-g	4.15k	345.5a	305.0ab	73ab	71c	29fg	29ef	83.2c	80.4d	3.44b-h	3.43hi	4.02i-l	3.99ij
17	321.1c	321.8a	35de	44d	16hi	21jk	80.8c	82.0b	4.11a-f	4.12a-f	4.16e-g	4.15k	298.7ab	325.4a	42gh	44k	22jk	25gh	86.3b	84.4c	3.43c-h	3.43hi	4.02i-l	4.00ij
18	140.7l	147.5op	49cd	55cd	25d-f	25g-i	54.2m	56.2k	4.13a-d	4.09c-g	4.54cd	4.47h	140.9e	157.2c	79a	79a	23i-k	24h	58.8kl	64.0hi	3.41e-h	3.40k	4.11g-j	4.07gh
19	191.6h	188.1m	38de	45d	22f	22i-k	65.5gh	65.1g	4.12a-e	4.12a-f	4.30d-f	4.26i	237.9bc	221.5bc	42gh	47ij	24ij	24h	71.0hi	71.7fg	3.44b-h	3.44gh	4.05h-k	4.03hi
20	155.0k	147.9op	39de	39de	16hi	17lm	59.3kl	54.6kl	4.13a-d	4.10b-g	4.34de	4.22j	144.4e	151.8c	43gh	44k	15l	20j	60.1k	57.7j	3.41e-h	3.42ij	4.14f-i	4.08g
21	184.2hi	153.4o	36de	38de	17g-i	18k-m	66.0g	63.1hi	4.14a-c	4.11a-g	4.52cd	4.28i	254.6bc	174.6c	48fg	47ij	21k	21ij	75.6f	74.1ef	3.45a-h	3.43hi	4.14f-i	4.10fg
22	153.1k	193.1lm	60c	59c	44bc	42bc	59.1kl	62.2i	4.14a-c	4.13a-e	4.71c	4.57g	148.8e	221.3bc	52f	54fh	38c	40c	60.6k	65.7h	3.47a-f	3.45fg	4.18f-h	4.14f
23	77.9m	100.3r	35de	38de	39c	36d	52.3n	52.3m	4.14a-c	4.13a-e	4.66c	4.60fg	79.5f	116.6d	43gh	45jk	30ef	30e	53.4m	53.6k	3.46a-g	3.46ef	4.25e-g	4.19e
24	64.9m	84.5s	21f	35e	41c	40c	51.1n	53.8lm	4.14a-c	4.14a-d	4.69c	4.63f	88.5f	94.8d	49fg	51h	40c	43bc	55.7lm	56.2j	3.47a-f	3.47de	4.25e-g	4.22de
25	187.8hi	160.8no	44d	41de	15i	14o	62.2ij	56.2k	4.15ab	4.15a-c	5.24b	5.21b	305.1ab	264.8b	67c	64de	23i-k	23hi	81.4d	74.1ef	3.50a-d	3.49c	4.42cd	4.36c
26	244.8e	227.0i	48cd	52cd	14i	17lm	63.1h-j	63.4hi	4.15ab	4.16ab	5.00b	4.90e	290.0ab	277.3b	69bc	72c	21k	22i	76.0f	77.7e	3.47a-f	3.48cd	4.27ef	4.25d
27	189.1h	193.3lm	57c	55cd	19g	19kl	63.7hi	64.4gh	4.16a	4.16ab	5.18b	5.10d	215.5c	208.7bc	65cd	64de	22jk	21ij	64.1j	65.8h	3.49a-e	3.48cd	4.35de	4.32c
28	242.9e	226.4i	54cd	55cd	15i	17lm	74.2e	72.0de	4.16a	4.17a	5.21b	5.14c	227.3bc	224.0bc	65cd	64de	24ij	24h	68.7i	73.2f	3.51a-c	3.51b	4.58b	4.43b
29	247.3de	256.9gh	59c	57c	18gh	18k-m	69.0f	70.1e	4.16a	4.17a	5.14b	5.15c	261.6b	277.8b	57e	62e	23i-k	23hi	72.5h	74.8ef	3.50a-d	3.51b	4.53bc	4.46b
30	348.0b	298.9c	72b	70b	29d	32e	78.1d	72.1de	4.17a	4.17a	5.73a	5.44a	292.5ab	288.2ab	76a	75b	22jk	30e	76.8f	81.0d	3.53a	3.54a	4.76a	4.60a
31	154.2k	140.8p	27ef	31e	15i	15no	56.6lm	54.4kl	4.16a	4.17a	5.50a	5.43a	150.4e	167.8c	40h	40l	35d	32d	57.9l	60.9i	3.52ab	3.52b	4.58b	4.57a
Mean	221.6	215.6	49.97	51.87	25.90	26.55	69.77	68.53	4.08	4.03	4.46	4.40	246.2	246.0	58.4	60.0	28.6	29.7	73.9	74.7	3.41	3.41	4.08	4.04

A cluster constellation analysis was conducted to investigate the genetic diversity of Asparagus genotypes. According to the constellation plot analysis, the asparagus genotype, which was examined in 31 locations for two years, was evaluated according to its morphological characteristics. According to the results from morphological data, Asparagus were divided into 2 main groups and 4 sub-groups (A; A1, A2 and B; B1, B2). Based on the mean values from both years, the Aralık district samples were mostly collected in the B1 (pink) cluster, the Karakoyunlu district in the B2 (blue) cluster, the Tuzluca district in the A1 (red) and A2 (green) cluster, and the Iğdır district mostly in the B2 (blue) cluster (Fig. 5). Constellation plot arranges individuals as endpoints based on morphological

parameters, and each cluster converges as a new point with drawn lines representing membership (Kumari et al., 2017). The fact that the samples from Karakoyunlu and Iğdır districts are in the same cluster strengthens the possibility of their being closer relatives (Fig. 5).

Discussion

It has been observed that the plant generally concentrates in the alluvial soils accumulated by the Aras River and in the semi-shade areas formed by the surrounding arid and semi-arid plants, and it grows in places that are not in direct contact with water. It is thought that they were probably fed by leachate from the riverside. Asparagus is known to be ecologically tolerant of high temperature and arid conditions mainly under forest cover, as well as in various areas including semi-desert steppes (Boubetra et al. 2017). Asparagus can be grown in various regions of Africa, America, Asia and Europe, which makes it not selective in terms of climate requirements due to its high adaptability (Vural et al. 2000) and they do not like precipitation especially during the spear harvest period (Wilson et al. 1996). Especially in terms of temperature requirement, asparagus has a wide climatic tolerance (Altunel, 2021). However, as can be seen in Supplementary Fig. 1a, b, in the research findings, it was identified that the spear emergence and flowering and fruit maturity dates were delayed due to a decrease in temperatures throughout the province in the second year.

Edible spear length and diameter are considered to determine whether it is marketable or not. It has been reported that edible spear length of 180–250 mm (Anido and Cointry 2008; Lee et al. 2014) and spear diameter of 8 mm and above in asparagus (Korkmaz et al., 2020) can be considered marketable. Asparagus spears examined in the Karakoyunlu district seem to be suitable in terms of edible spear properties. Quantitative parameters such as total spear production, total spear number per plant and spear diameter determine yield in asparagus, although diversity can still be seen when considering a general population (Falloon and Nikoloff 1986). In addition, the amount of asparagus produced per plant is significantly affected by appropriate ecological conditions, the harvest density of the plant, harvest quality and harvest frequency (Benincasa et al. 2007; Molina et al. 2012).

It is thought that the variability of spear weights is related to the age of the plant as well as the climatic conditions of the growing area. Lee et al. (2014) determined the mean ESFW of 17.3–24.1 g and the mean ESD of 8.27-11.0 mm in their study on cultured asparagus (*A. officinalis* L.). Alan (2016), on the other hand, reported that the mean ESFW varies between 23.5–51 g in study on the adaptation of asparagus. It was observed that wild asparagus grown naturally in the Iğdır plain formed lighter spears compared to the cultivated asparagus, depending on ecological conditions, and only the samples in the Karakoyunlu district formed average edible spears. Mousavizadeh et al. (2015) stated that ESL was positively related to branch length, number of cladods, spear diameter, spear fresh and dry weight. Our results show that there is a positive relationship between ESL and ESD with ESFW and ESDW.

Machon et al. (1995) stated that in the dioecious *A. officinalis*, in female plants, it was estimated that the number of fruit per plant and seeds per fruit, was positively correlated with spear diameter and length and negatively correlated with spear number. Boubetra et al. (2017), on the other hand, in their research reported fruit diameter and number of seeds per fruit respectively as; *A. acutifolius* 4.4-7 mm, 1–2 pieces, *A. albus* 4–6 mm, 1–2 pieces, *A. horridus* 5–7 mm, 1–2 pieces, *A. officinalis* 4.5–5.2 mm, 1–3 pieces and *A. altissimus* 5–6 mm, 1–2 pieces. Our findings showed that fruit diameters can reach a much larger size than the asparagus used this study, and more seeds per fruit (1–5 seeds) can be obtained.

The main vegetative parts that create the asparagus plant are the spears above the ground, and the rhizome body called the claw, which is formed by the differentiation of roots and roots under the ground. The part that creates the above-ground plant is the structure formed by the coming together of a single or more spears. In our research, besides determining the edible spear characteristics of local asparagus, in order to reveal the marketability potential, considering the possibility of botanical identification of regional asparagus and their inclusion in breeding programs, some parameters were investigated in adult spears of male and female plants, separately. This is because genetic structure, environmental conditions and sexual dimorphism affect the yield and quality of asparagus (Pegiou et al. 2020). Observed PL, PD, PFW and PDW parameters were found to be statistically significant in both male and female plants with regard to locations (Table 6).

In general, plant height in commercial asparagus varies between 0.3 and 2 m (Anido and Cointry, 2008). Boubetra et al. (2017) in their study on *A. acutifolius*, *A. albus*, *A. horridus*, *A. officinalis* and *A. altissimus* species, reported plant lengths between 0.5-2 m, 0.95 m, 0.25-1 m, 0.5-2 m and 1–5 m, respectively. Our research findings show that the plant sizes of asparagus in Iğdır plain are higher.

Mousavizadeh et al. (2015), reported that mean shoot dry weight was positively correlated with plant length (r = 0.73), spear length (r = 0.90), spear diameter (r = 0.87), spear number (r = 0.81) and spear fresh weight (r = 0.97), although there were differences among regions from where asparagus samples were taken. The findings of the study showed that there is a positive relationship between plant height and diameter with fresh and dry weights, although there are differences across locations. These researches also reported that there was a positive relationship between the number of branches with the fresh and dry weight of the plant. Similarly, our study findings show that there is a positive relationship between the number of branches in the spear with the fresh and dry weight of the plant. Leaf (cladode) morphology in asparagus varies in number, size and appearance (Fukuda et al. 2005). Cladodes are leaf-like morphology and axillary position, and it's used to identify morphological variations (Nakayama et al. 2012). Boubetra et al. (2017) reported that cladode lengths were calculated in A. acutifolius, A. albus, A. horridus, A. officinalis and *A. altissimus* species, and found between 1.7–7.3 mm, 11-27.2 mm, 19.9–86.2 mm, and 12.9–26.7 mm 14.9–19.7, respectively. In this context, it can be realized that leaf lengths in the present finding are higher than other asparagus species which may be due to ecological variations.

Morphological classification provides useful guidelines for demonstrating species relationships and developing further information for plant breeders and gene bank management (Khadivi-Khub et al., 2012). Although morphological characterization is generally sensitive to environmental effects, it is used to evaluate germplasm resource diversity with economic, simple and intuitive advantages, using traditional approaches (Linda et al. 2009; Sarabi et al. 2010). In addition, morphological variation is positively associated with genetic variation and can provide a lot of valuable information for breeders (Moose and Mumm 2008). It has been reported that 12 species are naturally raised in Turkey and that some of its species are under heavy extinction (Vural et al. 2000; Norup et al. 2015), and it is known that wild asparagus are distributed in many parts of the country, especially in the western parts of the country (Eren, 2014). Iğdır is the

only province of Turkey bordering three countries and is one of the largest microclimate regions (MAF, 2022). Due to its climatic advantages, it is one of the provinces with the largest flora in the Eastern Anatolia Region. Davis (1965; 1985) stated that asparagus is widespread in the flora of Iğdır, and it grows in moist pastures, volcanic soil heaps, salty steppes, edges of bushes and at altitudes between 800–1700 m. Kumlay et al. (2010) reported that *A. officinalis* species is among the wild plants found in the natural flora in Iğdır province and is consumed by the local people. Also, Fayvush et al. (2017) meintoned in their research that *A. officinalis* and *A.verticillatus* species are found in natural flora in sandy-loamy areas in Azerbaijan, Iran, Armenia, Georgia and Eastern Anatolia Region of Turkey, and their fresh spears are consumed raw or cooked by the local people. However, all of the above information is based on a random sample from the region or based on estimates. Our research is the first study to investigate the natural distribution of wild asparagus and reveal some agro-morphological characteristics across the Iğdır plain.

In order to analyse the asparagus genotypes in the plain, their natural distribution areas were determined and some agro-morphological features were discussed with a two-year data. Some parameters were also examined and existing literature were reviewed with commercial varieties and other wild species. Although there are differences in some characteristics, it has been revealed that they are generally within acceptable limits in terms of marketability and inclusion in breeding programs. The same species or cultivars may have significant variation in some traits and have the potential to produce a complex phenomenon of intra-species polymorphism. Morphological variations are important because they generally show high phenotypic plasticity (Chen et al. 2020). If these asparagus are included in possible breeding studies, it is important to define the superior locations in terms of some characteristics (such as spear size, weight). Samples taken from Karakoyunlu district can be included in breeding programs primarily due to their high edible spear characteristics and their high density in natural distribution areas. Wide variation of genetic resources will provide rich resources for asparagus cultivation if wild species are cultivated. Because wild asparagus species are considered to be a very important genetic resource for asparagus breeding, due to the narrow genetic basis of commercial varieties available (Regalado et al. 2017). For this reason, the result obtained from the present investigation with regard to variations in asparagus species can be an important preliminary data for breeding programs in the future.

Conclusion

In this study, the natural distribution of wild asparagus grown naturally in Iğdır province was identified. It has been revealed that asparagus spreads especially along the Aras River. The study also revealed considerable agro-morphological diversity among *A. officinalis* L. growing naturally in Iğdır, Turkey. The species showed significant differences in terms of edible spear length, diameter, fresh and dry weight, mean spear number, plant length, diameter, fresh and dry weight, friut weight, diameter, number of seed per plant, branch and cladode length, and pedicel and petal length. The cluster analysis mainly grouped the genotypes according to their agro-morphological classification and probable potential uses. Genotypes included in clusters were divided in two main and four sub-clusters. The reasons for the differences between the morphological characters according to the regions are altitude, geographical distribution coordinates, temperature, humidity, etc. The differences might be attributed to differences in the wild asparagus species or their hybrids. Asparagus germplasms in Iğdır showed good qualities. When the present findings are compared with the data obtained from the literature, it shows that these asparagus can be domesticated and included in the cultivation and improvement strategies of the crop. Therefore, these germplasms have shown good qualities as a starting point for promoting cultivation and breeding efforts.

An important point from the finding is that asparagus in the study locations are intensively collected by people. In addition, due to ecological changes in recent years, asparagus populations have decreased, which we have seen in our two-year studies. Apart from these reasons, asparagus in the plain is heavily destroyed by small cattle. Strategies need to be developed to protect these plants and not to reduce their populations in their natural habitats. For example, seeds should be collected from the Karakoyunlu region, where the density is high, and they can be cultivated by volunteer producers. Through provision of trainings to the people of the region, so that the shoots that develop from a single root should not be harvested because the plant cannot reproduce if it is harvested. Finally, in the present investigation, it has been identified that there are no samples in national and international seed gene banks of these asparagus. Due to the high risk of extinction of the species, seeds from wide distribution areas of the region should be stored in gen banks.

Declarations

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Author's contributions EÖ and MHA designed the study and conducted the experiments, AŞ and MZK collected data, EÖ, AMK, and AZT analyzed the data, EÖ, AZT and MHA wrote article.

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Figures

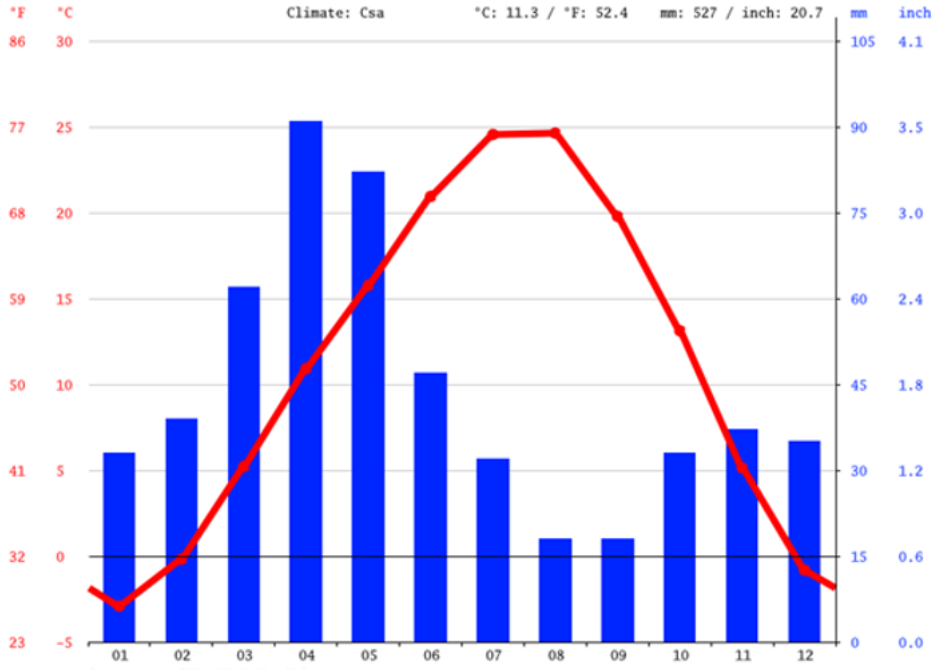

Figure 1

Average precipitation and temperature values for the years 1941-2021 in Iğdır (TSMS, 2022)

Figure 2

Observed locations to assess the natural distribution areas of asparagus

Figure 3

A. officinalis L. density map in the research area, created by GIS

Figure 4

Left to right; a) marking of spears, b) edible spears, c) adult asparagus plant, d) male plant, e) female plant, f) flower, g) fruit, f) seed, h) germinated seedling

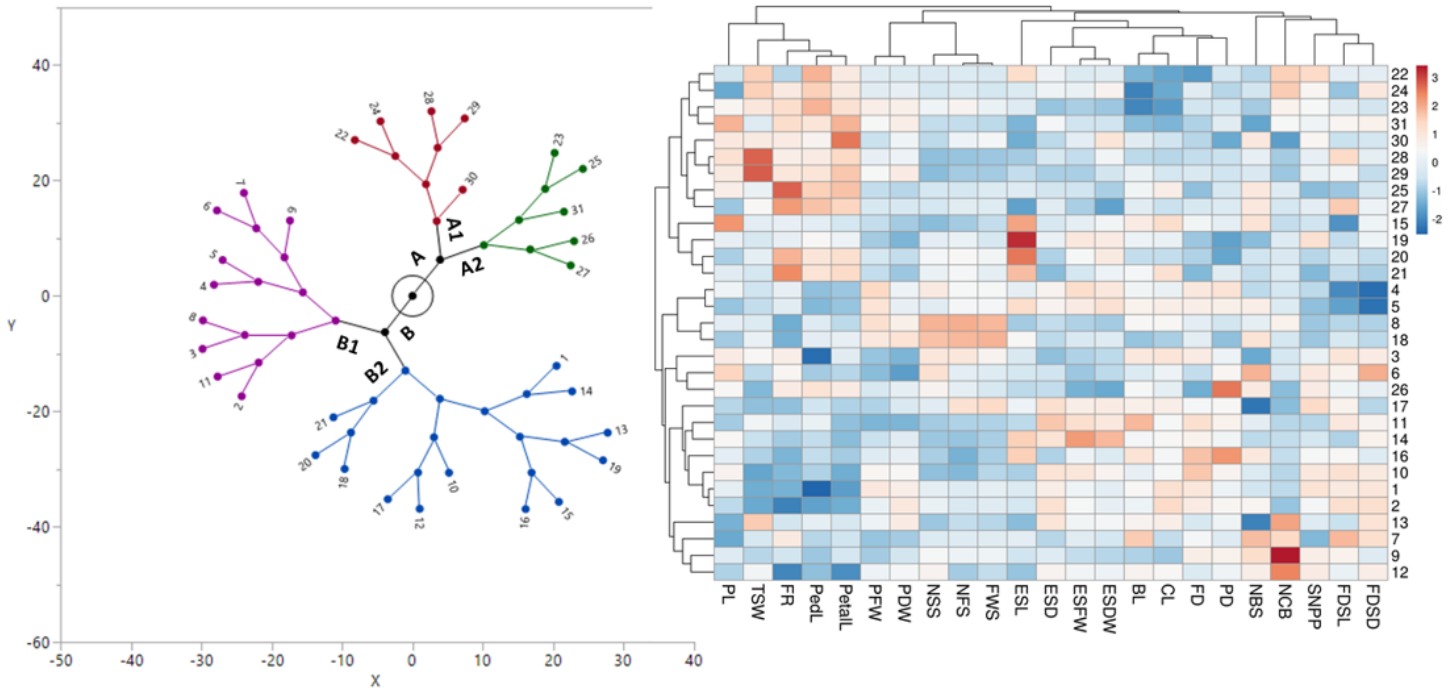

Figure 5

Cluster constellation plot of asparagus groups. See tables 1 and 2 for definition of abbreviations