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Original article

The Determination of Botanical Properties of Forage Kochia Population Grown in Konya Conditions

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Abstract

Adverse soil and environmental factors cause a decrease in pasture yield in our country. Shrub species are given importance in breeding studies carried out in order to increase the yield in marginal pastures in the world. Forage kochia (*Kochia prostrata*), which is a naturally growing and semi-shrub in Turkey's flora, shows tolerance to adverse soil and climatic conditions. This research was established in Konya in October 2017 according to the Randomized Complete Block Design with 4 replications. In the research, the morphological and yield values of the forage kochia populations collected from 5 different locations in Konya (i.e., Karapınar Kartal Kayaları, Bahri Dağdaş I.A.R.I, Campus Beltway-Selçuklu, Ardıçlı Rural- Selçuklu, and S.U.F.A. Forage Kochia Demonstration Garden) were examined during 2018-2019. We investigated the blooming time (Scoring), plant height (cm), canopy diameter (cm), number of branch, stem diameter (mm), shape of habitus (Scoring), leaf length (mm), leaf width (mm), color of anther and stigma (Scoring), fodder yield per plant (g) and hay yield per plant (g). In this study, the Campus Beltway- Selçuklu Population (3P) bloomed the earliest in this area between the end of August and early September (Score 5,36). Among the forage kochia populations showing semi-decumbent habitus (Score 7,05-7,63) the Karapınar Kartal Kayaları Population (1P) had the highest yield potential regarding plant height (i.e., 46,63 cm), canopy diameter (i.e., 50,50 cm), fodder yield per plant (i.e., 112 g), and hay yield per plant (i.e., 45,28 g). In line with the findings obtained in the study, while the Karapınar Kartal Kayaları Population (1P) and the Campus Beltway-Selçuklu Population (3P) stand out in terms of yield and yield components. These results show us that each population is a valuable gene resource in plant breeding for pasture improvement.

Keywords: *Bassia prostrata* (L.) A.J. Scott (Syn. *Kochia prostrata*), Forage Kochia, Forage Crops, Yield

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INTRODUCTION

Adverse soil and climate affect the yield of pastures where are precious feed sources in livestock. The pastures yield in Turkey is about 700 kg ha^{-1}, and this yield is one of three in the world's product due to these adverse environmental conditions (Babalık and Fakir, 2017). Researches in the world suggest using the shrub species in marginal rangeland improvement (Acar et al., 2013). Forage kochia [*Bassia prostrata* (L.) A.J. Scott (Syn. *Kochia prostrata*)] uses in dry and salty rangeland's advance owing to being tolerant to salinity and drought in the Jordan, Russia, and U.S.A. (Blauer et al., 1993; Harrison et al., 2000; Shamsutdinov and Shamsutdinov, 2009; Bailey et al., 2010). Furthermore, it uses firebreaks to protect pasture and forestry (Waldron et al., 2013).

Forage kochia, a C4 bush plant, is found in the pastures in Europe, Asia, and North Africa (Acar, 2013; Anonymous, 2019). It grows naturally in Turkey and shows the distribution in Central and East Anatolia (TUBIVES, 2021).

The *Kochia* (*Bassia*) genus, which belongs to the *Chenopodiaceae* family, has demonstrated a wide variation in morphology due to cross-pollination. *B. prostrata* differ phenotypically from similar forage types such as *B. scorpia* (Benson, 1955). Their anthers, stamens, leaves, and stems come in various colors (Acar and Dursun, 2010; Guo et al., 2014; Acar et al., 2016).

Bassia prostrata cv. Immigrant and Snowstorm developed in America from material in Central Asia origin. Clements et al. (2020) stated that plant heights of these varieties were 45 cm and 76 cm, respectively. Also, its forage yields were 1505 kg ha^{-1} and 2528 kg ha^{-1}, respectively.

In researched to forage kochia in Anatolian origin material, Acar et al. (2016) determined that plant height of forage kochia grown in Bahri Dağdaş I.A.R.I (Konya) was 88 cm. In another study, Acar and Koç (2019) obtained plant height was between 61 cm and 81 cm, forage yield was between 1070 and 2580 kg ha^{-1} in S.U.F.A. Forage Kochia Demonstration Garden (Konya). The research aimed to grow the forage kochia populations collected from 5 different locations in Konya in the marginal area, which has got problematic soil, such as very high lime, extreme salinity, and boron toxicity, and showing the difference between the morphological and yield values of these populations.

MATERIAL AND METHODS

Field work and Experimental Design

The seeds of populations collected from 5 different locations in Konya were used as material in this search. The population codes, places, and status of culture were given in Table 1. Populations were grown in a greenhouse, and within the population was selected seedling with varying phenotypes, and seedling height did not exceed 15 cm for use in the trail.

Table 1. The populations codes, places, and status of culture

Pops Code	District Collected Locations	Status of Culture
1P	Karapınar: Karapınar Kartal Kayaları	Grown naturally for long years in there
2P	Karatay: Bahri Dağdaş International Agricultural Research Institute	Planted in 2014 from collected KOP region
3P	Selçuklu: Campus Beltway	Grown naturally for long years in there
4P	Selçuklu: Ardıçlı Rural	Grown naturally for long years in there
5P	Selçuklu: S.U.F.A. Forage Kochia Demonstration Garden	Planted in 2013 from collected Konya region

This research was established in the forage crops production area of Panagro Aslım Farm, Kaşınhanı- Konya, on 14th October 2017 according to the Randomized Complete Block Design with four replications. Parcel length was 10 m in the study, and each parcel had two rows. In planting, row spacing was 1.40 m, and intrarow was 1.00 m. The sprinkler irrigation was done once after sowing. There was no fertilization during and after planting. The weed control in the area was provided by hoe in total four times, including twice in 2018 and 2019.

Table 2. Soil properties of the experimental field

Soil Parameter	Value	Category	Soil Parameter	Value	Category
pH	7,8	Slightly Alkaline	Mg (%)	0,069	Excess
EC (µS cm^{-1})	1003,75	Extreme saline	B (mg kg^{-1})	57,356	Toxic level
Ca (OH) $_2$ (%)	68,4	Very high Lime	Cu (mg kg^{-1})	0,343	Sufficient
Organic Matter (%)	5,41	High	Fe (mg kg^{-1})	9,67	Sufficient
K (%)	0,058	Excess	Zn (mg kg^{-1})	0,333	Insufficient
Ca (%)	0,371	Excess	Mn (mg kg^{-1})	2,36	Medium

[1]The soil analysis were made by Research Laboratory of Department of Soil Science and Plant Nutrient, Faculty of Agriculture, Selcuk University

It showed soil analysis results in Table 2 and climate characteristics in Table 3. The soil texture is clay loam, and the experimental field has problematic soil, such as very high lime, extreme salinity, and boron toxicity.

Table 3. Climate characteristics of the experimental field in Konya-Turkey

	Annual Total Precipitation mm)	Monthly Average Temperature (°C)	Monthly Average Relative Humidity %)
1995- 2016	315,31	12,06	58,99
2017	375,60	11,86	58,20
2018	443,60	13,78	55,34
2019	367,20	12,85	62,38

Data Collection

We investigated the morphological and yield properties between June and November in this research from 2018- 2019 2018. We defined the blooming time showing at least one flower in the plant within forage kochia populations. We determined this time in plants by Scoring 1-11 (1: end of June-early July, 3: end of July- early August, 5: end of August-early September, 7: end of September- early October, 9: end of October- early November, 11: end of November). Also, we specified the plant height (cm), canopy diameter (cm), number of branches, stem diameter (mm), leaf length (mm), leaf width (mm), the color of anther and stigma (scoring), the shape of habitus (scoring), fodder yield per plant (g) and hay yield per plant (g). We determined by measuring the plant height from the soil surface (Van Riper and Owen, 1964; Tamkoç, 1992), canopy diameter for the maximum diameter (Acar et al., 2019). According to Aygun and Olgun (2018), we counted the number of branches. While we surveyed stem diameter the 5 cm from the soil surface (Aygün and Olgun, 2018), leaf length and width were gauged on five leaves, showing the best evolving (Özköse, 2012) by a digital caliper. We scored the color of anther and stigma by scoring 1-9 (1: Yellow, 3: Orange, 5: Pink, 7: Dark Red, 9: Anther or Stigma absent in flower) (Guo et al., 2014). We observed the shape of habitus by scoring 1-9 (1: Perpendicular, 3: Semi- Perpendicular, 5: Medium, 7: Semi- Decumbent, 9: Decumbent) (Özköse, 2012). Fodder yield per plant was obtained by weighing plants cut 10 cm from soil surface between September and November. We determined the hay yield per plant by drying the samples at 60 ºC in the ventilated incubator until they reach a constant weight (Kacar, 1972; Tamkoç, 1992).

Statistical Analysis

According to Split-Plot in Randomized Complete Block Design, the data was analyzed to determine the result of variance analysis by using JMP 7 software packet program (Sall et al., 2017). In addition, the LSD test was performed using MSTAT-C software packet programs for grouping (Freed et al., 1989).

RESULTS and DISCUSSIONS

Tables 4 and 5 gave the sum of variance analysis belonging to botanical properties of populations collected from different locations in Konya. Table 6-7 shown their mean values.

Table 4. Sum of Variance Analysis Table (F Value)

Source of Variation	DF	Blooming Time	Plant Height	Canopy Diameter	Number of Branches	Stem Diameter	Shape of Habıtus
T	39						
R	3	0,811	1,837	1,622	8,615	0,573	0,898
A	1	30,308*	8,561	0,001	33,483*	10,400*	0,326
E (1)	3						
B	4	0,922	1,06	1,059	0,654	0,522	1,162
A* B	4	0,588	0,562	0,308	0,755	0,496	1,394
E (2)	24						
CV (%)		16,30	31,49	37,83	62,62	33,11	10,10

T: Total, R: Replication, A:Year; B: Population; E: Error; CV: Coefficient of Variation * ;p <0.05;

As shown in Table 4-5, blooming time, the number of branches, the color of anther and stigma, and leaf width values were significantly different in terms of year factor. On the other hand, the color of anther value was statistically significant regarding population.

Table 5. Sum of Variance Analysis Table (F Value)-continue

Source of Variation	DF	Leaf Length	Leaf Width	The Color of Anther	The Color of Stigma	Fodder yield per plant	Hay yield per plant
T	39						
R	3	9,114	5,311	1,47	0,29	1,103	1,147
A	1	0,028	149,740**	15,508*	34,276**	4,384	4,904
E (1)	3						
B	4	0,445	1,497	3,857*	0,701	0,705	0,699
A* B	4	1,643	0,057	0,697	0,85	0,565	0,492
E (2)	24						
CV (%)		16,06	22,05	27,82	4,22	290,55	259,72

T: Total, R: Replication, A:Year; B: Population; E: Error; CV: Coefficient of Variation * ;p <0.05; **; p <0.01;

Forage kochia populations have shown the difference regarding blooming time over the years. While the early flowering obtained from 3P (Score 5,36), the late-flowering population was 4P with Score 6,21 (Scoring 1: end of June- early July, 11: End of November) in 2018 and 2019.

Among populations, 1P was the most developed population with 46,63 cm plant height, 50,50 cm canopy diameter, and 8,80 branches. While 4P had got the thickest stem diameter with 3,30 mm, the stem diameter of 1P was the thinnest with 2,71 mm among populations.

The maximum leaf length was obtained from 3P with 12,88 mm when investigating the leaf length of populations. In contrast, the minimum length was determined in 1P with 11,65 mm. 5P had the largest leaf width (1,40 mm), the narrowest width was obtained from 3P with 1,10 mm.

Table 6. Morphological and yield properties means of forage kochia populations

Year	Pops code	Blooming Time (Scoring[1])	Plant Height (cm)	Canopy Diameter (cm)	Number of Branches	Stem Diameter (mm)	Shape of Habitus (Scoring[2])
2018	1P	7,23	54,23	51,24	7,86	2,25	6,61
	2P	7,15	43,34	41,08	4,58	2,35	6,68
	3P	7,14	45,51	47,13	5,03	2,22	7,79
	4P	7,38	45,78	41,33	6,52	2,29	7,06
	5P	7,36	35,02	37,59	5,97	2,29	7,71
	Mean	7,25[a]	44,78	43,68	5,99[b]	2,28[b]	7,17
2019	1P	3,96	39,04	49,76	9,74	3,17	7,49
	2P	4,65	36,85	46,26	9,11	3,73	7,55
	3P	3,59	36,02	50,33	9,83	3,88	7,47
	4P	5,04	28,28	30,81	6,21	4,31	7,08
	5P	4,35	34,01	41,98	4,94	3,16	7,37
	Mean	4,32[b]	34,84	43,83	7,97[a]	3,65[a]	7,39
Means	1P	5,6	46,63	50,5	8,8	2,71	7,05
	2P	5,9	40,09	43,67	6,85	3,04	7,11
	3P	5,36	40,77	48,73	7,43	3,05	7,63
	4P	6,21	37,03	36,07	6,36	3,3	7,07
	5P	5,85	34,52	39,79	5,45	2,72	7,54
General Mean		5,78	39,81	43,75	6,98	2,96	7,28

Scoring[1]: 1: end of June- early July, 3: end of July- early August, 5: end of August- early September, 7: end of September- early October, 9: end of October- early November, 11: End of November Scoring[2]= 1: Perpendicular, 3: Semi- Perpendicular, 5: Medium, 7: Semi- Decumbent, 9: Decumbent [a, b, ···]: $p < 0.05$

1P was the population having the darkest anther color with a score of 4,29 (Group a; Scoring 1: Yellow, 9: Anther absent in flower) when observed the color of anther of populations. Regarding the stigma color, 2P had the darkest color with 5,71 (Scoring 1: Yellow, 9: stigma absent in flower).

We determined that the forage kochia populations showing semi-decumbent habitus (Score 7,05-7,63). While 1P was the most efficient population with 112,00 g fodder yield per plant, 4P had the minimum fodder yield per plant (12,79 g). When investigating hay yield per plant of populations, 1P had the maximum yield of 45,28 g, and the minimum yield obtained from 4P with 6.57 g.

Table 7. Morphological and yield properties means of forage kochia populations- continue

Year	Pops code	Leaf Length (mm)	Leaf Width (mm)	Color of Anther (Scoring[3])	Color of Stigma (Scoring[3])	Fodder yield per plant (g)	Hay yield per plant (g)
2018	1P	12,58	1,38	5,29	5,81	19,82	12,87
	2P	11,56	1,37	5,54	5,92	9,5	5,27
	3P	12,22	1,25	3,85	5,83	9,24	5,04
	4P	12,61	1,3	3,69	5,69	7,6	4,78
	5P	13,49	1,52	4,69	5,95	9,63	5,45
	Mean	12,49	$1,36^{A}$	$4,61^{a}$	$5,84^{A}$	11,16	6,68
2019	1P	10,72	1,04	3,29	5,51	204,18	77,7
	2P	13,75	1,01	2,62	5,5	58,92	27,63
	3P	13,53	0,95	2,32	5,27	116,82	56,47
	4P	12,49	0,99	1,68	5,42	17,98	8,35
	5P	11,7	1,28	3,28	5,33	22,88	10,63
	Mean	12,44	$1,05^{B}$	$2,64^{b}$	$5,40^{B}$	84,16	36,16
Means	1P	11,65	1,21	$4,29^{a}$	5,66	112,00	45,28
	2P	12,66	1,19	$4,08^{ab}$	5,71	34,21	16,45
	3P	12,88	1,1	$3,08^{bc}$	5,55	63,03	30,75
	4P	12,55	1,15	$2,68^{c}$	5,55	12,79	6,57
	5P	12,6	1,4	$3,98^{ab}$	5,64	16,26	8,04
General Mean		12,47	1,21	3,62	5,62	47,66	21,42

[For the Color of Anther $LSD_{POPULATION}$: 1.040]

(Scoring[3]= 1: Yellow, 3: Orange, 5: Pink, 7: Dark Red, 9: Anther or Stigma absent in flower)

$^{a, b, \cdots}$: $p < 0.05$; $^{A, B, \cdots}$: $p < 0.01$

Gintzburger et al. (2003) stated that forage kochia began to bloom between May and August, while Kitchen and Monsen (2008) reported that the blooming period started in May or August until July or September.

Bailey et al. (2009) expressed that plant height with the flower was between 14,6 cm and 38,6 cm. Clements et al. (2020) determined that plant height of forage kochia cv. Immigrant and Snowstorm was 45 cm and 76 cm, respectively, in the blooming period.

Lauriault and Waldron (2020), which showed similarity in our results, stated that year did not affect the canopy cover of forage kochia. McFarland et al. (1990) reported that forage kochia grown in salt-affected rangeland had 25 cm of canopy diameter one-year-old while canopy diameter of 3-year-old plants was 68 cm. Canopy diameter was found by some researches such as Waldron et al. (2010) stated as 35- 64 cm, Acar et al. (2016) determined as 99 cm, Acar and Koç (2019) expressed between 95 cm and 121.

Harrison et al. (2000) reported that forage kochia was varying the number of branches. Acar et al. (2016) stated that the branches of forage kochia phenotypes were between 43 and 63. It was expressed that stem in plants showed transverse growth due to seconder growth in dicot, which has a perennial woody stem (Kacar et al., 2013). Harrison et al. (2000) reported that the stem diameter of forage kochia was between 1,6 mm and 6,3 mm.

While Gintzburger et al. (2003) determined that leaf length of forage kochia was as 3-5 mm, some researches were found more prolonged, such as Anonymous (2017) was 8-20 mm, Tilley et al. (2012) was 3-12 mm, and Safiallah et al. (2017) was 4-20 mm of leaf length. Therefore, the leaf width was determined as 0,5-2,0 mm by Gintzburger et al. (2003) and as 1,0-1,5 mm by Anonymous (2017) and Safiallah et al. (2017).

Anthocyanin production increased in plants, restricted growth under stress factors such as drought, salinity, etc. (Heldt and Piechulla, 2015). Furthermore, flower color change may depend on soil properties such as pH, plant nutrients, and adaptation to abiotic stress factors such as temperature, drought, and exposure to UV radiation (Vaidya et al., 2018). The color of the anther in forage kochia was determined as yellow, red- pink by Gintzburger et al. (2003). Guo et al. (2014) stated that the anther and the stigma colors were yellow or red. Anonymous (2017) expressed between purple and brown of stigma color.

Safiallah et al. (2017) reported that forage kochia showed a decumbent habitus. However, Acar ve Koç (2019) stated that the habitus of forage kochia changed depend on phenotypes and was between semi-perpendicular and semi-decumbent in a study related to different forage kochia phenotypes.

Acar and Dursun (2011) weighed 810 g of fodder yield per plant of forage kochia, naturally grown for long years in Konya conditions. Acar et al. (2016) reported that two-years-old forage kochia had 450 g of fodder yield per plant.

Forage Kochia grow the underground organs within two years after sowing owing to adaptation to the environment. Therefore, it raises the aboveground organs from the third year. For this reason, McFarland et al. (1990) suggests that the yield of forage kochia may take from the third year. Therefore, it should not forget to investigate the yield in our study belonging first and second years after sowing.

Davenport (2005) stated that dry biomass weight per plant of forage kochia was between 234 g and 350 g. Waldron et al. (2010) emphasized that forage kochia had 95- 353 g of dry biomass weight depend on varieties and lines and changed between 42 g and 260 g after grazing. Acar et al. (2016) expressed that hay yield per plant of forage kochia was 368 g two-year-old. Acar and Koç (2019) reported that third-year-old forage kochia, which had different phenotypes, was between 97 g and 235 g of the hay yield per plant.

The result obtained in this research showed similarities in some research results while other studies' outputs varied. These differences may be causing the variation in soil and climate conditions, using population, plants' phenology, age of plants, and methods used.

CONCLUSION

The research determined the botanical properties in grow in the marginal area, which has got problematic soil, of the forage kochia populations collected from 5 different locations in Konya. This research, aimed at forage kochia breeding, showed the difference in the growth and development of populations. The Karapınar Kartal Kayaları Population (1P) and the Campus Beltway- Selçuklu Population (3P) are prominent in yield and component, especially canopy diameter, which is a vital criterion in covering the soil. For this reason, these results show us that each population is a valuable gene resource in plant breeding for pasture improvement.

The pasture yield in Turkey decreases gradually due to drought, marginal soil conditions, and non-compliance grazing rules. When considering the resistance under environmental pressure of forage kochia, we believe that using forage kochia in rangeland improvement should be increased and popularized. According to intended use, forage kochia types in our country should be breeding as registered plant varieties.

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