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Forage Pea Pure Lines: Winter Hardiness, High Seed and Biological Yield

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HIGHLIGHTS

- Forage pea is an important forage crop used in animal nutrition with its rich content of protein, fibre and other nutrients and plays a fundamental role in sustainable agriculture and livestock systems.
- Winter forage pea is a valuable plant species that can grow in cold climates and is used in animal nutrition.
- Forage peas not only feed animals but also significantly increase soil fertility with *Rhizobium* bacteria.

Abstract

Winter forage pea is a plant that grows in cold climates and is a valuable source of protein for animal feed. In this study, 13 pure forage pea lines (PS3057M1, PS3057M2, PS3073G1, PS3073G2, PS3073G3, PS4028H1, PS4028H2, PS4028H3, PS4028H4, PS4053M1, PS4053M2, PS4053M3 and PS4053M4) and Emirbey and Şahin varieties were used as material. The research was conducted at Selçuk University Prof. Dr. Abdülkadir AKCİN Research and Application Station in the trial fields during the 2020-21 and 2021-22 plant growth periods without irrigation. The trials were established in both years according to randomized block design with 3 replications. Meteorological data indicated that despite variations in the lowest temperatures between the two years, all pea lines remained undamaged. This highlighted the adaptability of forage pea lines to the region's winter conditions, which is consistent with previous studies. Statistically significant differences were determined between the two years of the study in terms of all traits analyzed in the research. Higher values were recorded in the second year for all traits. The main reason for these differences is the precipitation and temperatures in the spring months, which is the period when the plants grow actively. Again, significant statistical differences were determined between the lines in all the traits analyzed in the study. This shows us that genetic traits and environmental conditions are important in determining the traits analyzed in this study. The forage pea lines used in the study performed better than the standard varieties in terms of seed and biological yield. In conclusion, this research shows that newly developed winter forage pea lines can be successfully grown in the Konya region and these lines have important genetic and environmental effects on various yield parameters.

Keywords: Seed yield; pea; biological yield; winter hardiness

1. Introduction

Forage pea is a valuable forage plant that plays an important role in animal nutrition. The nutritional value of this plant for animals is especially its high protein content. In addition, forage pea is an ideal protein source in feed mixtures used in animal production. The high-quality protein content supports the healthy development of animals, increases muscle mass and improves overall productivity. In addition, forage peas

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offer a balanced protein profile with essential amino acids, which helps animals meet their basic nutritional needs (Açıkgöz 2001, Ates 2012, Sözen et al. 2018).

Forage peas are also rich in fiber, vitamins and minerals. These nutrients support the digestive system, strengthen the immune system, and improve overall health. Another advantage of forage peas in animal nutrition is their ability to fix nitrogen. Thanks to this feature, forage peas provide nitrogen to the soil and stimulate the growth of other plants, thus increasing soil fertility (Sözen and Karadavut 2018, Karadavut and Sözen 2020). Forge pea is an important cool climate plant with its wide adaptation ability and its yield and quality characteristics, which are preferred in regional conditions, nitrogen fixation to the soil between 5-15 kg ha^{-1} and leaving a clean stubble for the following plant (Açıkgöz 2001, Ceyhan et al. 2005, Geren and Alan 2012, Uzun et al. 2012, Sözen and Peker 2023).

Winter sowing of forage peas is an important agricultural practice providing diversity and sustainability to farmers as an alternative between agricultural seasons. Forage pea is known for its resistance to cold weather conditions and this feature allows it to grow in winter (Ceyhan et al. 2005, Sözen and Karadavut 2017). Winter sowing of fodder peas is usually carried out in the autumn months and the rainfall in the spring months, when the plants actively grow vegetatively, is very well utilized. Winter sowing of forage peas is an important agricultural practice providing diversity and sustainability to farmers as an alternative between agricultural seasons. In addition, winter sowing of forage peas can contribute to preventing soil erosion and improving soil structure. In addition to diversifying farming practices, this practice has the potential to provide farmers with a more stable source of income by extending the production cycle. Winter sowing is a strategy that allows fodder peas to grow successfully in various climatic and soil conditions, thus offering farmers a more flexible production plan.

Forage pea is a plant suitable for winter sowing in the Central Anatolia region because it is a cool-season plant, its growing period is short, and its cold resistance is high compared to many forage plant species (Ceyhan et al. 2005). Winter forage pea is a plant that grows in cold climates and is a valuable source of protein for animal feed. This pea variety is usually sown in early autumn. Conducting a soil analysis and applying appropriate fertilization before sowing ensures that the plant grows healthily and yields a productive crop. Preparing the sowing area well; the soil should be cultivated and leveled. Peas are generally cold-resistant and resistant to frost events in winter. When the correct sowing and maintenance methods are applied, winter fodder peas grow efficiently and provide a quality protein source in animal nutrition. For this purpose, this study tried to determine the biological yield and some agronomic characteristics of newly developed winter fodder pea lines.

2. Materials and Methods

Within the scope of the research, pea genotypes with different characteristics were crossed according to the full diallel crossing method in 2015. The genotypes obtained from this crossing were selected according to winter-resistant high biological yield, seed yield, and upright growing or winding characteristics. In this study, 13 pure forage pea lines (PS3057M1, PS3057M2, PS3073G1, PS3073G2, PS3073G3, PS4028H1, PS4028H2, PS4028H3, PS4028H4, PS4053M1, PS4053M2, PS4053M3 and PS4053M4) with superior characteristics were used as material. In addition, Emirbey and Şahin varieties were used as control material in the study. The study used Emirbey and Şahin varieties as control materials. Emirbey and Şahin varieties were developed by Prof. Dr. Ercan CEYHAN and registered by the private sector.

This study was conducted in the winter growing season of 2020-21 and 2021-22 in the ecological conditions of Konya (1020 m above sea level), which has a continental climate. According to the long-term (2007-2019 year) average of the trial locations, the annual average temperature, relative humidity, and rainfall during the vegetation period (October-July) were 11.7 °C, 58.3% and 346.4 mm, respectively. However, the average temperature and total rainfall during the vegetative period in 2020-21 were 11.2 °C and 350.4 mm, while during the active vegetative growth stage (April-June) they were 18.3 °C and 55.4 mm, respectively. In the second year of the experiment, the average temperature and total rainfall were 11.8 °C and 304.2 mm, and 16.0 °C and 158.0 mm, respectively, during the active vegetative growth stage (April-June). In the second year of the

experiment, total rainfall was higher, and temperatures were lower in the active vegetative growth stage (April-June) compared to the first year (Table 1).

Table 1. Long years, 2020-21 and 2021-2022 average temperature, relative humidity, and rainfall data for Konya province.

Months	Average Temperature (°C)			Relative Humidity (%)			Rainfall (mm)		
	13-years	2020-21	2021-22	13-Years	2020-21	2021-22	13-years	2020-21	2021-22
October	14,3	14,1	14,5	56,9	49,2	60,6	33,2	0,0	43,4
November	8,1	10,1	9,7	67,2	63,1	62,7	35,1	25,6	14,2
December	3,2	3,7	6,3	77,8	73,9	72,5	54,5	76,2	5,4
January	1,6	-0,1	3,7	77,2	72,9	66,7	51,0	81,6	8,8
February	4,2	3,2	1,0	67,4	72,0	64,8	26,6	43,4	16,0
March	8,4	2,2	9,1	56,2	63,4	57,8	34,7	47,6	57,8
April	13,0	15,6	11,6	50,8	38,8	54,8	28,0	1,2	36,2
May	17,3	17,0	16,0	49,5	52,0	57,6	41,0	26,4	47,0
June	21,8	22,3	20,3	44,8	50,3	58,4	37,9	37,8	74,8
July	25,5	24,1	25,7	35,1	41,4	35,0	4,6	10,6	0,6
Mean/Total	11,7	11,2	11,8	58,3	57,7	59,1	346,4	350,4	304,2

[1] Meteorological data were obtained from the Konya Meteorological Regional Directorate.

The research was carried out at Selcuk University Prof. Dr. Abdülkadir AKCİN Research and Application Station in the experimental fields during the 2020-21 and 2021-22 vegetation periods without irrigation. Soil analysis results show that the soil texture of the experimental site is clay loam, slightly alkaline, no salt, extremely high lime content, low phosphorus content, sufficient potassium fertilizer, and low organic matter content (Sözen and Karadavut 2020, Küçük and Ceyhan 2022; Karadaş and Ceyhan 2023).

The experiments were established in both years according to the randomized block design with 3 replications. The plot area was set as 7.50 m^{-2} (5.0 m length x 1.50 m width) and each plot consisted of 6 rows. Sowing was carried out on 20 October 2020 in the first year and 14 October 2021 in the second year when the climatic conditions and soil temperature were suitable, and the soil was at the right temperature. The seeds were sown manually in the rows opened with 100 seeds per square meter. Considering the soil analyses; 150 kg DAP fertilizer was applied per hectare with sowing. Weed control was carried out from the emergence of fodder pea seedlings. Fodder peas were grown under dry conditions without irrigation. When the seeds of each plot matured and harvest time came, the plants were harvested by mowing. During the harvesting period, one row from the edges of the plots and 0.5 m from the heads were discarded as edge effect and the remaining part was measured.

In the study, the number of branches per plant (number), plant height (cm), number of pods per plant (number), number of seeds per pod (number), number of grains per plant (number), grain yield (t ha^{-1}), hundred-grain weight (g) and biological yield (t ha^{-1}) were measured according to the methods described by Ceyhan et al (2005), Sözen and Karadavut (2020) and TTSM (2023).

The data obtained from the study were analyzed using JMP (17.0.1) Statistical Package Programmed (JMP 17.0.1) in a yearly replicated random blocks experimental design. The significant means were grouped according to the LSD test.

3. Results and Discussion

According to the meteorological data of Konya province where the research was conducted, the lowest temperature was -9.0 °C in the first year of the experiment. In comparison, the lowest temperature was -18.0 °C in the second year of the research. This temperature did not damage all pea lines used in the study. The results of this research show that forage pea lines developed for this region can be easily grown for winter. Ceyhan (2004) reported pea genotypes resistant to -25 °C in this region. Ceyhan et al. (2005) also reported that forage pea lines can be easily grown for winter in this region.

Table 2. Mean squares of the characteristics analyzed in the research.

Source	DF	Number of Branches per Plant	Plant Height	Number of Pods per Plant	Number of Seeds per Pod
Total	89				
Year	1	20,544**	804,011**	409,600**	1,344*
Replication (Year)	4	0,311	466,156	4,033	0,844
Lines	14	1,487**	1354,043**	32,219**	1,373**
Year x Lines Int.	14	0,211	271,059**	5,171	0,725
Error	56	0,418	86,072	2,986	0,463
CV		21,47	12,03	8,55	10,84
Source	**DF**	**Number of Seeds per Plant**	**Seed Yield**	**Hundred Seed Weight**	**Biological Yield**
Total	89				
Year	1	21933,611**	12,305**	28,045**	30,750**
Replication (Year)	4	150,356	0,049	0,010	0,105
Lines	14	1428,952**	0,979**	42,346**	2,001**
Year x Lines Int.	14	285,254	0,079	0,090	0,168
Error	56	247,300	0,080	0,112	0,174
CV		12,43	11,98	2,15	11,90

* : $p < 0.05$, ** : $p < 0.05$.

3.1. Number of Branches per Plant

The difference between the years and lines was statistically significant at a 1% level, while the year x line interaction was insignificant (Table 2). The results of previous research also revealed significant differences among pea varieties in the number of branches per plant (Ceyhan 2003, Ceyhan et al. 2005, Temel et al. 2022).

In this study, the average number of branches per plant was 2.53 in the first year and 3.49 in the second year (Table 3). This may be due to the fact that there was less rainfall and higher temperature in the spring months (April and June), which is the growth period of the plant, in the first year compared to the second year. Lack of rainfall in pea plants decreases plant height and encourages branching (Ceyhan et al. 2005, Gençtan 2012).

According to the two-year averages, the number of branches of the lines varied between 2.17 (PS4053M2) and 4.17 (PS3057M2). PS3057M2 (4.17 number), PS3073G2 (3.50 pieces), and PS4028H2 (3.50 number) were the first three lines in terms of the number of branches. The number of branches in pea plants generally varies between 1.80 and 10.30, and the number of branches is greatly affected by environmental factors, especially plant density, soil moisture, and fertility, in addition to genetic factors (Ceyhan 2003). Ceyhan et al. (2005) reported that the number of pea branches varied between 3.8 - 7.8, Ateş and Tekeli (2017) 4-6, Temel et al. (2022) 1.2 -2.3. In this respect, the results obtained are largely consistent with the findings of the researchers.

3.2. Plant Height

The difference between the years in terms of plant height was statistically significant according to the 1% probability level (Table 2). As the average of the genotypes, plant height was 74.11 cm in the first year and 80.09 cm in the second year (Table 3). This may be because there was less rainfall and higher temperature in the spring months (April to June), the plants growth period in the first year compared to the second year. Ceyhan et al. (2005) and Gençtan (2012) reported that high rainfall in pea plants encouraged plant growth. In this study, high plant heights were obtained in the second year when rainfall was high during the growth period of the plants.

When pea lines and year x line interactions were analyzed, plant height differences were found significant at a 1% level (Table 2). It has been revealed by many researchers that plant height is affected by genetic structure (Önder and Ceyhan 2001, Ceyhan 2003, Ceyhan and Avcı 2005, Ceyhan et al. 2005, Kavut et al. 2016, Temel at al. 2022). According to the two-year averages, the plant height of the genotypes varied between 39.67 and 108.50 cm. The longest plant height was measured in PS3073G3, and the shortest was measured in PS4053M4 line. The plant height of other genotypes used in the experiment varied between these values. When the year x line interactions were analyzed, the lowest plant height was obtained from the PS4053M4 line in the first year of the experiment at 33.33 cm and the highest plant height was obtained from the PS3073G3 line in the first year with 109.33 cm. According to these results, it is seen that the lines produced different results when compared with each other in terms of plant height. This situation shows that plant height is affected by environmental conditions and is a genotype trait. Some researchers reported that plant height of pea

genotypes was between 35.4-56.3 cm (Önder and Ceyhan 2001), 36.6 - 75.8 cm (Ceyhan and Avcı 2005), 42.00-121.67 cm (Savur and Ceyhan 2011), 131.14-161.64 cm (Kavut et al. 2016), 120.4-135.3 cm (Ateş and Tekeli 2017), 78.9-91 cm (Temel at al. 2022). Although the results obtained from this study are similar to the findings of some researchers (Önder and Ceyhan 2001, Ceyhan and Avcı 2005, Savur and Ceyhan 2011, Temel at al. 2022), lower than the findings of Kavut et al. (2016) and Ateş and Tekeli (2017).

3.3. Number of Pods per Plant

The difference between years in terms of pod number was statistically significant at a 1% probability level (Table 2). The effect of years on the number of pods of peas was also reported in previous studies (Ceyhan et al. 2005, Uzun et al. 2012, Keskin et al. 2021). In the first year of the experiment, 18.07 pods per plant, and in the second year, 22.33 pods per plant were obtained in forage peas (Table 3). In the second year, the increased number of pods in peas can be attributed to higher rainfall between April and June and lower temperatures than the previous year. Similarly, in previous studies, it was determined that forage peas affected the number of pods in the plant depending on the years (Önder and Ceyhan 2001, Ceyhan et al. 2005, Geren and Alan 2012).

Table 3. Means and LSD groups of number of branches per plant, plant height, number of pods per plant and number of seeds per pod of forage pea varieties according to years.

Lines	2020-21	2021-22	Mean	2020-21	2021-22	Mean
	Number of Branches per Plant			Plant Height (cm)		
PS3057M1	2,00	3,33	2,67 bcd[1]	65,00 g-k	91,67 a-e	78,33 b-e
PS3057M2	3,33	5,00	4,17 a	66,33 g-j	75,33 d-j	70,83 de
PS3073G1	2,67	3,33	3,00 bcd	82,00 c-h	101,67 abc	91,83 b
PS3073G2	3,00	4,00	3,50 ab	88,33 b-f	80,33 d-ı	84,33 bcd
PS3073G3	2,67	3,67	3,17 bc	109,33 a	107,67 abc	108,50 a
PS4028H1	2,33	3,67	3,00 bcd	75,33 d-j	66,00 g-k	70,67 de
PS4028H2	3,33	3,67	3,50 ab	61,00 ıjk	81,33 d-h	71,17 de
PS4028H3	2,00	3,00	2,50 cd	68,33 f-j	62,00 h-k	65,17 e
PS4028H4	2,33	3,67	3,00 bcd	72,33 e-j	82,00 c-h	77,17 cde
PS4053M1	2,67	3,67	3,17 bc	81,00 d-ı	93,67 a-d	87,33 bc
PS4053M2	2,00	2,33	2,17 d	80,67 d-ı	67,67 g-j	74,17 cde
PS4053M3	2,33	3,33	2,83 bcd	58,33 jk	82,33 c-g	70,33 de
PS4053M4	2,00	3,00	2,50 cd	33,33 l	46,00 kl	39,67 f
Emirbey	3,00	3,67	3,33 abc	80,67 d-ı	84,33 c-g	82,50 bcd
Şahin	2,33	3,00	2,67 bcd	89,67 a-e	79,33 d-ı	84,50 bcd
Mean	2,53	3,49	3,01	74,11	80,09	77,10
		Lsd_{Lines}: 0.9953			$Lsd_{Year\ x\ Lines}$: 20.20, Lsd_{Lines}: 14.28	
Lines	**Number of Pods per Plant**			**Number of Seeds per Pod**		
PS3057M1	16,67	20,67	18,67 e-h	5,67	7,00	6,33 abc
PS3057M2	22,33	26,33	24,33 a	6,00	6,33	6,17 abc
PS3073G1	14,33	19,33	16,83 h	6,00	6,67	6,33 abc
PS3073G2	21,67	24,00	22,83 abc	5,33	6,00	5,67 c
PS3073G3	18,33	22,67	20,50 c-f	5,67	5,67	5,67 c
PS4028H1	21,67	23,00	22,33 a-d	5,67	6,67	6,17 abc
PS4028H2	17,33	22,33	19,83 d-g	6,33	6,33	6,33 abc
PS4028H3	16,67	18,33	17,50 gh	6,00	6,00	6,00 bc
PS4028H4	17,00	20,67	18,83 e-h	6,67	7,33	7,00 ab
PS4053M1	17,33	24,33	20,83 c-f	6,67	5,67	6,17 abc
PS4053M2	20,00	22,33	21,17 b-e	5,33	6,00	5,67 c
PS4053M3	13,67	21,67	17,67 gh	6,33	6,67	6,50 abc
PS4053M4	16,00	20,67	18,33 fgh	7,00	7,33	7,17 a
Emirbey	17,00	22,33	19,67 d-g	6,00	6,00	6,00 bc
Şahin	21,00	26,33	23,67 ab	7,67	6,33	7,00 ab
Mean	18,07	22,33	20,20	6,16	6,40	6,28
		Lsd_{Lines}: 2.660			Lsd_{Lines}: 1.048	

[1] The differences between the means denoted by the same letter were not statistically significant.

According to the analysis of variance, the difference between genotypes in terms of pod number was found to be statistically significant at a 1% probability level (Table 2). According to the average of the years, the highest number of pods was obtained from line PS3057M2 with 24.33 number/plant, and the lowest number of pods was obtained from line PS3073G1 with 16.83 number /plant. Other genotypes were within these values. Many researchers have reported that the number of pods varies depending on pea genotypes and climatic factors (Ceyhan et al. 2005, Geren and Alan 2012, Uzun et al. 2012, Keskin et al. 2021). The number of pods in peas was reported as 6.5 - 9.9 number/plant (Önder and Ceyhan 2001), 18.3 - 38.3 number/plant (Ceyhan et al. 2005), 12.3 - 24.0 number /plant (Ceyhan and Avcı 2005), 26.7-28.3 number /plant (Geren and Alan 2012), 10.4-15.5 number/plant (Tan et al. 2012), 8.7-11. 4 number /plant (Uzun et al. 2012), 8.2-9.2 number/plant (Kavut and Çelen 2017), 5.8-11.0 number/plant (Kadıoğlu and Tan 2018), and 14.6-17.3 number/plant (Keskin et al. 2021) and the varieties had different pod numbers. While the results obtained in terms of the number of pods of the forage pea lines used in the experiment are in agreement with the results reported by Ceyhan et al. (2005), Ceyhan and Avcı (2005) and Keskin et al. (2021), higher than the results reported by Önder and Ceyhan (2001), Tan et al. (2012), Uzun et al. (2012), Kavut and Çelen (2017), Kadıoğlu and Tan (2018) but lower than the results reported by Geren and Alan (2012). These differences are due to the genetic structure of these newly developed lines.

3.4. Number of Seeds per Pods

In the study, the difference between the years in terms of the number of seeds in pods was statistically significant at 1% probability (Table 2). As the average of the lines, the number of seeds in pods was determined as 6.16 number /plant in the first year of the experiment and 6.40 number/plant in the second year, and it was determined that the number of seeds in the pod was significantly affected by years (Önder and Ceyhan 2001, Geren and Alan 2012, Keskin et al. 2021).

In this study conducted in Konya ecological conditions, the difference between genotypes in terms of the number of seeds in pods was found significant at a 1% level (Table 2). According to the results of the research, the highest number of seeds in pods was obtained from the PS4053M4 line with 7.17 and the lowest number of grains in pods was obtained from the PS3073G2, PS3073G3 and PS4053M2 lines with 5.67. The number of seeds in pods of the other genotypes used in the study was between these values and the average was 6.28 (Table 3). In the studies conducted on this subject, the number of seeds per pod in forage pea was 5.8 - 7.4 seeds per pod (Önder and Ceyhan 2001), 5.93 - 8.27 seeds per pod (Savur and Ceyhan 2011), 5.4-6.6 seeds per pod (Geren and Alan 2012), 4. 3-5.0 seeds per pod (Uzun et al. 2012), 4.9-5.7 seeds per pod (Kavut and Çelen 2017), 4.8-7.6 seeds per pod (Kadıoğlu and Tan 2018) and 2.90-4.20 seeds per pod (Keskin et al. 2021). It is seen that the number of grains in pods was obtained differently in forage pea varieties in different ecologies. These results show that the number of grains in pods is highly affected by environmental conditions and genetic structure (Önder and Ceyhan 2001).

3.5. Number of Seeds per Plant

There were statistically significant differences at 1% level between the pea lines and years used in the study in terms of the number of seeds per plant (Table 2). As the average of the lines, the number of seeds per plant was 110.89 number/plant in the first year of the experiment and 142.11 number/plant in the second year. According to the two-year averages, the number of seeds per plant of the lines varied between 105.00 (PS4028H3) and 162.83 (Şahin).

The number of seeds per plant of the lines varies depending on genetic structure and environmental factors (Ceyhan 2003). Ceyhan et al. (2012), Ceyhan et al. (2013) and Karadaş and Ceyhan (2023) stated that seed number per plant is a very variable character, and this limit varies between 35.50 and 231.93 number. These results support our research results.

3.6. Seed Yield

Regarding the seed yield of pea lines, the years were statistically significant at a 1% level (Table 2). As the average of the genotypes, seed yield was 1.99 t ha-1 in the first year of the research, while 2.73 t ha-1 in the second year. This difference between the years is due to climatic conditions. Some differences were observed between the years of the study, especially in terms of rainfall (Table 1). In the first year of the research, the total vegetation rainfall was 350.4 mm and this value was higher than the value recorded in the second year (304.2 mm). However, there were great differences between the years in terms of the distribution of precipitation to the months, and especially the total precipitation values of March, April, May and June, which are the development period of the plants, were lower in the first year (123.6 mm) than in the second year (216.4 mm) (Table 1). In the same period, average temperatures were slightly higher in the first year. Therefore, the months in which fertilization and fruit setting took place were

drier in the experiment's second year than in the first year. Ceyhan et al. (2012) and Avcı and Ceyhan (2013) reported that high temperatures and insufficient rainfall during the full flowering period negatively affected seed yield. In our research, it can be said that the differences mentioned differences in terms of climatic factors, especially precipitation, were effective in the differences observed between the experimental years in terms of seed yield.

The differences among pea lines regarding seed yield were statistically significant at a 1% level (Table 1). The different results of the lines in terms of seed yield are due to their different genotypic structures (Önder and Ceyhan 2001, Ceyhan et al. 2012, Avcı Ceyhan 2013). The highest seed yield was the PS4053M4 line with 2.84 t ha^{-1} and the lowest seed yield was obtained from the PS4053M3 line with 1.71 t ha^{-1}. The seed yields of the other genotypes used in the experiment were between these values and the average yield was calculated as 2.36 t ha (Table 4). In terms of seed yield, PS4053M4 (2.84 t ha^{-1}), PS3057M2 (2.81 t ha^{-1}), PS4028H4 (2.76 t ha^{-1}), PS4028H3 (2.84 t ha^{-1}), and PS4028H2 (2.84 t ha^{-1}) pea lines had higher seed yield than the average seed yield of standard varieties (2.62 t ha^{-1}) (Table 2). Ceyhan and Önder (2001), 1.12- 1.61 t ha^{-1}, Ceyhan et al. (2005) 1.13 -2.43 t ha^{-1}, Geren and Alan (2012) 2.19-2.85 t ha^{-1}, Uzun et al. (2012) 257.4-362.0 2.19-2.85 t ha^{-1}, Kavut and Çelen (2017) 0.95-3.10 t ha^{-1}, Kadıoğlu and Tan (2018) 196.5-314.7 t ha^{-1} and Keskin et al. (2021) 1.82-2.86 t ha^{-1}. Our research results are in harmony with the researchers findings.

Table 4. Means and LSD groups of number of seeds per plant, seed yield, hundred seed weight and biological yield of forage pea varieties according to years.

Lines	2020-21	2021-22	Mean	2020-21	2021-22	Mean
	Number of Seeds per Plant			Seed Yield (t ha^{-1})		
PS3057M1	94,33	144,67	119,50 cde[1]	1,42	2,35	1,88 c
PS3057M2	134,00	167,33	150,67 ab	2,44	3,18	2,81 a
PS3073G1	86,00	128,33	107,17 de	1,60	2,60	2,10 c
PS3073G2	115,33	143,33	129,33 bcd	1,77	2,36	2,06 c
PS3073G3	102,67	128,33	115,50 cde	1,52	2,12	1,82 c
PS4028H1	122,33	153,33	137,83 bc	2,16	2,94	2,55 ab
PS4028H2	110,00	140,67	125,33 cde	2,31	3,10	2,71 a
PS4028H3	100,00	110,00	105,00 e	2,52	2,95	2,73 a
PS4028H4	113,67	150,33	132,00 bc	2,31	3,22	2,76 a
PS4053M1	115,67	137,67	126,67 b-e	1,76	2,29	2,02 c
PS4053M2	107,33	133,67	120,50 cde	1,79	2,49	2,14 bc
PS4053M3	87,00	144,00	115,50 cde	1,21	2,21	1,71 c
PS4053M4	111,67	151,67	131,67 bc	2,32	3,37	2,84 a
Emirbey	102,00	134,00	118,00 cde	2,18	3,01	2,60 a
Şahin	161,33	164,33	162,83 a	2,52	2,76	2,64 a
Mean	110,89	142,11	126,50	1,99	2,73	2,36
		Lsd_{Lines}: 24.21			Lsd_{Lines}: 0.44	
Lines	**Hundred Seed Weight (g)**			**Biological Yield (t ha^{-1})**		
PS3057M1	12,55	13,53	13,04 g	2,06	3,55	2,80 c
PS3057M2	15,19	15,86	15,52 e	3,61	4,73	4,17 a
PS3073G1	15,50	16,89	16,20 d	2,37	3,94	3,15 bc
PS3073G2	12,79	13,79	13,29 g	2,71	3,63	3,17 bc
PS3073G3	12,39	13,76	13,08 g	2,27	3,25	2,76 c
PS4028H1	14,73	15,98	15,35 e	3,10	4,33	3,71 ab
PS4028H2	17,50	18,37	17,94 b	3,35	4,62	3,99 a
PS4028H3	21,01	22,32	21,67 a	3,62	4,36	3,99 a
PS4028H4	16,95	17,83	17,39 c	3,45	4,84	4,15 a
PS4053M1	12,66	13,84	13,25 g	2,61	3,44	3,03 c
PS4053M2	13,95	15,53	14,74 f	2,61	3,66	3,13 bc
PS4053M3	11,61	12,75	12,18 h	1,78	3,36	2,57 c
PS4053M4	17,27	18,51	17,89 bc	3,31	4,90	4,10 a
Emirbey	17,81	18,71	18,26 b	3,31	4,59	3,95 a
Şahin	13,02	14,00	13,51 g	3,72	4,21	3,96 a
Mean	14,99	16,11	15,55	2,92	4,09	3,51
		Lsd_{Lines}: 0.52			Lsd_{Lines}: 0.64	

[1] The differences between the means denoted by the same letter were not statistically significant.

3.7. Hundred Seed Weight

There were statistically significant differences at a 1% level among the pea genotypes and years used in the study in terms of hundred seed weight (Table 2). As the average of the genotypes, the hundred seed weight was 14.99 g in the first year of the experiment and 16.11 g in the second year. According to the two-year averages, the highest hundred seed weight among the genotypes was obtained from the PS4028H3 line with 21.67 g, and the lowest hundred seed weight was obtained from the PS4053M3 line with 12.18 g. The hundred seed weights of the other genotypes used in the study were between these values, and the average hundred seed weight was calculated as 15.55 g (Table 4).

Hundred seed weight, one of the important yield components, is closely related to the genetic structure of genotypes and is affected by environmental conditions (Ceyhan et al. 2005). Önder and Ceyhan (2001) found 14.50 - 22.61 g, Ceyhan and Avcı (2005) 8.71-18.31 g, Ceyhan et al. (2005) 10.12-23.63 g, and Savur and Ceyhan (2011) 12.83-27.65 g. Our results are similar to the results of the researchers.

3.8. Biological Yield

The difference between the years in terms of biological yield was found statistically significant according to the 1% probability limit (Table 2). As the average of the genotypes, 2.92 t ha^{-1} biological yield was obtained in the first year of the experiment and 4.09 t ha^{-1} in the second year (Table 2). Many researchers have reported that the effect of years on the biological yield of forage peas is significant (Önder and Ceyhan 2001, Keskin et al. 2021).

The effect of genotypes on biological yield was statistically significant at a 1% probability level. According to the average of the years, the highest biological yield was obtained from the PS3057M2 line with 4.17 t ha^{-1} and the lowest value was obtained from the PS4053M3 line with 2.57 t ha^{-1}. Biological yields of 5 lines were higher than the average of the standard variety (3.96 t ha^{-1}). The results obtained in terms of biological yield of the genotypes used in the experiment are within the results of the research conducted on similar subjects (Önder and Ceyhan 2001, Geren and Alan 2012, Uzun et al. 2012, Tan et al. 2012, Keskin et al. 2021, Temel et al. 2022).

4. Conclusions

In this study in which newly developed fodder pea varieties were tested for two years, it was determined that years significantly affected the parameters examined in the research. In these results, the climatic characteristics (especially the amount of precipitation falling in April-June, when the plants actively show vegetative development) played an important role. These results show that winter sowing is very important for forage pea varieties to benefit from the rainfall in spring months, especially for Konya's ecological conditions.

The two-year results from the research revealed that the newly developed forage pea variety candidates are important in forage pea cultivation under Konya ecological conditions. As a result of this study, it was determined that PS3057M2, PS4028H4, PS4053M4, PS4028H2 and PS4028H2 forage pea lines with high biological yields according to two-year averages are promising variety candidates. It is undeniable that these newly developed forage pea lines will play an important role in closing the roughage deficit in the Central Anatolia region, especially in animal nutrition.

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