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Investigating the Effect of Sowing Dates and Densities on Phenological Traits, Yield, and Yield Components in Vicia Dasycarpa

Akbar Shabani[1]* and Abouzar Asadi[2]

[1]Assistant Professor, Legumes Department, Dryland Agriculture Research Institute of Iran

[2]Assistant Professor, Department of Plant Genetic and Production Engineering, Plant Improvement and Seed Production Center, Azad University, Isfahan, Iran

***Corresponding Author:** Akbar Shabani, Assistant Professor, Legumes Department, Dryland Agriculture Research Institute of Iran.

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Abstract

Vicia dasycarpa is a highly adaptable plant found naturally in many pastures and rainfed fields of Iran. It is suitable for arid and semi-arid regions. To study the sowing dates (autumn, waiting, spring), line spacing (25, 30 cm), and plant density (100, 150, 200, 250, 300 per m^2) in Maragheh Vetch a split-split plot with a randomized complete block design in three replications was performed during 2020-2022. The result shows that the years, planting dates, and density of plants per m^2 have a significant effect on all studied traits at 1%. The highest fodder, grain, and biomass yield, plant height, and weight of 100 seeds, as well as the longest flowering, podding, and physiological ripening days were achieved through autumn sowing in both years. The highest fodder and grain yield was achieved with 300 and 200 plants per m^2 density, respectively. The plants with 150 and 200 per m^2 dens were taller than others. While the highest weight of 100 seeds, and the longest flowering, podding, and physiological ripening days were obtained in 100 plants per m^2 density. In conclusion, the study recommends autumn sowing, 200 to 300 plants per m^2 density, and 30cm line spacing for the cultivation of Maragheh Vetch.

Keywords: Maragheh Vetch; Fodder; Line spacing; Dryland; cover plants

Introduction

The world's growing population and insufficient food supply, particularly in developing countries, have raised concerns about the future of food production [9]. Fodder legumes are proving to be crucial in livestock feeding, which in turn helps meet the increasing demand for animal products by humans. Therefore, the role of fodder legumes in ensuring sufficient food production cannot be overstated [14, 19]. *Vicia dasycarpa* is an annual herbaceous plant from the Fabaceae family and is one of the most important legumes in temperate regions [6, 20]. This particular plant is capable of adapting to various environmental stresses, making it useful for diverse purposes such as rejuvenating overused pastures, providing vegetation cover, and feeding livestock due to its high-quality fodder and palatability. It is also ideal for green manure and enhancing soil structure. To attain the best outcomes, it is suggested to cultivate it in a rotation and mixed pattern [6, 11, 7, 1].

Several factors contribute to increasing agricultural plant yield, including climatic factors, variety type, substrate preparation, crop rotation, selection of suitable dates, and planting method [3, 15]. Agricultural plants grow best at a specific density. If the density is too high, the plant's energy will mostly be used for vegetative growth and respiration, rather than reproductive growth. On the other hand, if the density is too low, while a single plant's production may increase, the overall performance per unit area will decrease. The density of plants directly impacts the availability of resources, such as water, nutrients, and solar radiation [18, 5, 8].

The effective growth of plants is dependent on the amount of space they are given, which is determined by the distances between planting rows and individual plants within the rows. If the density and distribution of plants per unit area are appropriate, they can utilize moisture, nutrients, and light more efficiently, leading to better performance [13, 4]. When planting, it's crucial to consider the distance between plants. If the distance is too great, there will be fewer plants per unit area, and the yield will decrease. On the other hand, planting too closely will result in competition among the plants of the same species, leading to a decrease in yield [5].

The current study is focused on determining the optimal planting date, suitable planting density, and ideal distance between planting lines for fodder vetch.

Materials and methods

Plant materials

The Maragheh variety was the first of the Vatch species that was released in Iran in 2009. it was prepared by Dryland Agriculture Research Institute of Iran.

Experimental design

An experiment was conducted in Sararoud region, Kermanshah, Iran to investigate the effect of line spacing, planting time, and seed density on *Vicia dasycarpa* (Maragheh Vetch) during the 2020-2022 cropping season. The experiment was designed as split split plot based on a randomized complete blocks design with three replications. Line spacing was considered as the main factor (A) and had two levels of 25 and 30 cm. Sowing dates were considered as a sub-factor (B) and had three levels, including autumn (October 26), waiting Sowing (5 December), and spring Sowing (March 15). Seed density was considered as another sub-factor (C) and had five levels of 100, 150, 200, 250, and 300 plants per unit area.

Climatic conditions

The experiment was conducted at the Sararoud Dryland Agriculture Research Institute Station, located 22 kilometers away from Kermanshah city, with a geographic longitude of 20° and 47′ east, and a latitude of 20° and 34′ north at an altitude of 1351.6 meters above sea. The station has a silty-clay-loam soil texture. The climate is cold and moderate with an average annual rainfall of 478 mm and an average annual temperature of 13.8 °C. The absolute maximum temperature recorded is 44 °C and the minimum of that is -27 °C.

Planting

Land preparation operations, including plowing and discing, were completed. The seeds were disinfected with a Carboxin Thiram fungicide at a ratio of 2:1000 before planting, and cultivation was carried out according to plan. Weeding was performed in several stages.

Measurement of characteristics

During the growing season and at the end of the season, following traits were measured:

Days to 50% flowering; the number of days from the first rain until 50% of the plants entered the flowering stage.

Days to the start of podding; the number of days from the first rain until 50% of the plants entered the podding stage.

Plant height; the distance between the collar and the last leaf of the plant was measured in meters.

Fresh fodder yield; after flowering, marginal effects were removed and two rows of plants of each plot were harvested and weighed separately.

Yield of dry fodder; fresh fodder was placed inside paper envelopes and transferred to an oven at 70 °C. After 48 hours, it was weighed using a digital scale.

Days to physiological ripening; the number of days to ripening seeds was calculated.

Biomass yield; after physiological ripening, the marginal effects were removed and the rest of the plants of each plot were harvested separately and after weighing, it was recorded as biomass yield (sun dry biomass) in unit area.

Seed yield; after measuring the biomass yield, the seed amount of each plot was weighed separately and considered as the seed yield per unit area, and the result was generalized to hectares.

Weight of 100 seeds; the number of 100 seeds per plot was counted separately and weighed using a digital scale.

Data analysis

Normality test for the data and their residuals, variance analysis, mean comparison with Duncan's test, and homogeneity of variances test with Hartley's Fmax were performed using Microsoft Excel 2019, Minitab 21, SAS 9.4, and MSTAT-C software.

Results

The results of the composite variance analysis presented in Table 1 indicate that the year had a statistically significant effect on all studied traits, except the weight of 100 seeds. The crop row spacing had a statistical significance of 1% on fresh and dry fodder yield, 50% flowering day, and podding start day, and 5% on the 100 seed weight trait. The planting date had a significant statistical effect of 1% on all studied traits. Furthermore, the seed density had a significant statistical effect of 1% on all studied traits. Since the year had a significant effect on various traits, a simple analysis was conducted separately for each trait, based on the year.

S.o.V	***df***	***Mean of square***								
		FY	***YDF***	***SY***	***BY***	***DF***	***DP***	***DPH***	***PH***	***W100***
Year(Y)	1	19844304**	1273442**	396962**	2290065**	1736**	1792**	1560**	733**	002/0^{ns}
R*Y	8	2272522**	86748**	2362^{ns}	15246^{ns}	577/1*	705/1*	52/23**	4457**	031/0^{ns}
A	2	7851715**	355733**	1232^{ns}	12218^{ns}	25/11**	75/22**	272/0^{ns}	098/0^{ns}	090/0*
A*Y	2	48609^{ns}	836^{ns}	12784*	53216^{ns}	15/0^{ns}	355/0^{ns}	472/1*	214/0^{ns}	026/0^{ns}
A*R(Y)	16	760903*	64666**	4651^{ns}	13052^{ns}	233/3**	905/1*	12/14**	24/19^{ns}	034/0^{ns}
B	1	312480293**	13334722**	2691722*	10960517**	36106**	37590**	640/62**	81/57**	143/3**
A*B	2	431925^{ns}	15034^{ns}	5933**	10359^{ns}	466/6**	60/15**	50/10**	701/6^{ns}	021/0^{ns}
Y*B	1	12532034**	641081**	92106**	254725**	68/56**	27/57**	23/13**	085/16^{ns}	009/0^{ns}
Y*A*B	2	674968^{ns}	39578*	5040^{ns}	31760^{ns}	466/0^{ns}	272/0^{ns}	538/0^{ns}	946/3^{ns}	003/0^{ns}
B*R(Y*A)	24	520719**	32449**	5791**	20229^{ns}	564/4**	822**	638/8**	2328**	022/0^{ns}
C	2	26253656**	1784754**	156368**	679256**	52/46**	20**/59	119/4**	15/169**	995/0**
Y*C	2	277199^{ns}	20761^{ns}	13283**	104070**	269/0^{ns}	536/0^{ns}	555/0^{ns}	740/4^{ns}	016/0^{ns}
A*C	4	917718**	51883**	2456^{ns}	29513^{ns}	403/0^{ns}	075/1^{ns}	883/0^{ns}	666/4^{ns}	58/0*
Y*A*C	4	235180^{ns}	20965^{ns}	3077^{ns}	23905^{ns}	020/0^{ns}	63/0^{ns}	028/0^{ns}	665/5^{ns}	012/0^{ns}
B*C	2	6410640**	372381**	26279**	103603**	619/2**	990/1**	403/3**	3931**	042/0*
Y*B*C	2	1232717**	66459**	8979**	48647**	119/0^{ns}	98/1^{ns}	489/3^{ns}	650/8^{ns}	021/0^{ns}

A*B*C	4	647857**	20816*	1242^{ns}	9983^{ns}	869/1**	195/2**	616/2**	645/6^{ns}	015/0^{ns}
Y*A*B*C	4	57607^{ns}	4209^{ns}	1015^{ns}	12253^{ns}	120/0^{ns}	043/0^{ns}	219/0^{ns}	870/2^{ns}	014/0^{ns}
error	96	221229	9864	2219	13971	479/0	656/0	682/0	924/8	0204/0
CV%		30/8	01/8	15/10	47/12	67/0	74/0	56/0	69/6	44/3

ns, * and ** are not significant and significant at 5%, 1%, respectively.

Days to 50% flowering (DF), Days to the start of podding (DP), Plant height (PH), Fresh fodder yield (FY), Yield of dry fodder (YDF), Days to physiological ripening (DPH), Biomass yield (BY), Seed yield (SY), Weight of 100 seeds (W100).

Table 1: Composite variance analysis of different planting dates and densities on phenological traits, yield, and its components in Maragheh vetch.

Results of simple analysis of variance for the first year

According to analysis of variance (Table 2), distance between crop lines have a statistically significant impact at a 1% level on the fresh yield, dry fodder yield, 100 seed weight, days to 50% flowering, and days to the beginning of pods. The interaction between the distance of crop lines and planting date showed a significant impact only on the phenological traits such as the day to 50% flowering, day to podding, and day to physiological maturity. However, the effect of planting row distance was not significant on other studied traits. The data presented in Table 2 shows that all studied traits were significantly affected by density of seed per m^2 at a statistical level of 1%. The yield of dry fodder, and the yield of fresh fodder were affected by the mutual effects of the levels of distance between crop lines and the levels of planting densities (A*C) at a statistical level of 1%. The interaction effect of planting date and seed density per square meter (B*C) was statistically significant at 1% for forage yield, dry forage yield, and maturity day and, were statistically significant at a level of 5% for biomass yield, the day of 50% flowering, height, and weight of 100 seeds (Table 2). The triple interaction (A*B*C) only had a significant impact on the day of ripening and grain yield, with a statistical level of 1% and 5%, respectively. The other traits that were studied were not affected by the triple interaction.

S.o.V	***df***	***Mean of square***								
		FY	***YDF***	***SY***	***BY***	***DF***	***DP***	***DPH***	***PH***	***W100***
Replication	1	688726 ^{ns}	26356 ^{ns}	2124 ^{ns}	2524 ^{ns}	*74/2	*23/3	**7/39	*0/46	034/0 ^{ns}
A	2	**4567957	**161036	10978 ^{ns}	7218 ^{ns}	**10/8	**40/14	84/2 ^{ns}	011/0 ^{ns}	*106/0
E(a)	2	865849 ^{ns}	37695 ^{ns}	4717 ^{ns}	63015 ^{ns}	**03/3	63/1 ^{ns}	**14/22	7/26 ^{ns}	048/0 ^{ns}
B	2	**99931988	**4071943	**895155	**3843976	**1/18	**18869	**310	**2939	**62/1
A*B	2	259326 ^{ns}	8604 ^{ns}	10117 ^{ns}	34597 ^{ns}	**20/5	**0/10	**41/5	68/1 ^{ns}	005/0 ^{ns}
E(b)	8	*184718	**50094	5076 ^{ns}	17623 ^{ns}	**54/5	**40/4	**7/10	5/25 ^{ns}	022/0 ^{ns}
C	5	**13295264	**956397	**72429	**304370	**2/22	**3/28	**3/54	**9/96	**574/0
A*C	4	*835390	**60524	4600 ^{ns}	*51032	183/0 ^{ns}	317/0 ^{ns}	483/0 ^{ns}	76/6 ^{ns}	032/0 ^{ns}
B*C	8	**142122	**92623	6415 ^{ns}	*41926	*34/1	14/1 ^{ns}	**83/2	*9/33	*041/0
A*B*C	8	414980 ^{ns}	18917 ^{ns}	1569 ^{ns}	14106 ^{ns}	17/1 ^{ns}	958/0 ^{ns}	**55/1	18/4 ^{ns}	015/0 ^{ns}

E(c)	48	295756	13070	3344	13796	572/0	800/0	783/0	9/11	018/0
CV%		19/10	89/9	86/13	53/15	76/0	84/0	62/0	39/7	25/3

ns, * and ** are not significant and significant at 5%, 1%, respectively.

Days to 50% flowering (DF), Days to the start of podding (DP), Plant height (PH), Fresh fodder yield (FY), Yield of dry fodder (YDF), Days to physiological ripening (DPH), Biomass yield (BY), Seed yield (SY), Weight of 100 seeds (W100).

Table 2: Analysis of variance of different planting dates and densities on phenological traits, yield, and its components in Maragheh vetch in the first year.

Results of simple analysis of variance in the second year

The analysis of variance conducted in the second year of the experiment revealed that the distance between crop lines affected fresh fodder yield, dry fodder yield, 50% flowering day, and podding start day at a statistical level of 1%, whereas biomass yield was affected at a statistical level of 5%. However, no significant difference was found in the rest of the traits in this regard (Table 3). All the studied traits showed a significant difference in the levels of sub-factor B (planting date) at the statistical level of 1%. The mutual effect of the distance of the crop lines on the date of planting (A*B) had a statistical level of 1% on the yield of fresh fodder, the yield of dry fodder, the day of podding, and the day of physiological ripening, whereas the number of days of 50% flowering had a statistical level of 5% (Table 3).

S.o.V	***df***	***Mean of square***								
		FY	***YDF***	***SY***	***BY***	***DF***	***DP***	***DPH***	***PH***	***W100***
Replication	1	**3856317	**147139	2599 ^{ns}	27969 ^{ns}	411/0 ^{ns}	177/0 ^{ns}	**30/7	**1/43	27/0 ^{ns}
A	2	**3332368	**195533	3039 ^{ns}	*58216	**60/3	**71/8	900/0 ^{ns}	300/0 ^{ns}	009/0 ^{ns}
E(a)	2	*655958	**91637	**7555	10474 ^{ns}	**43/3	*18/2	**10/6	8/11 ^{ns}	020/0 ^{ns}
B	2	**225080338	**9903860	**1888673	**7101266	**18146	**18777	**31606	**2857	**53/1
A*B	2	**847566	**46008	856 ^{ns}	7521 ^{ns}	*73/1	**88/5	**63/5	97/8 ^{ns}	018/0 ^{ns}
E(b)	8	226720 ^{ns}	*14804	**6505	22834 ^{ns}	**59/3	**24/3	**53/6	**1/21	021/0 ^{ns}
C	5	**13235592	**849119	**97223	**478956	**4/24	**4/31	**6/56	**0/77	**436/0
A*C	4	317507 ^{ns}	12324 ^{ns}	932 ^{ns}	2386 ^{ns}	239/0 ^{ns}	822/0 ^{ns}	428/0 ^{ns}	57/3 ^{ns}	038/0 ^{ns}
B*C	8	**6223234	**346218	**28843	**110323	**39/1	953/0 ^{ns}	06/1 ^{ns}	*06/14	022/0 ^{ns}
A*B*C	8	290483 ^{ns}	6108 ^{ns}	688 ^{ns}	3130 ^{ns}	*872/0	*28/1	*29/1	34/5 ^{ns}	015/0 ^{ns}
E(c)	48	146703	6658	1094	11146	381/0	514/0	561/0	93/5	023/0
CV%		39/6	16/6	47/6	96/9	58/0	63/0	50/0	71/5	62/3

ns, * and ** are not significant and significant at 5%, 1%, respectively.

Days to 50% flowering (DF), Days to the start of podding (DP), Plant height (PH), Fresh fodder yield (FY), Yield of dry fodder (YDF), Days to physiological ripening (DPH), Biomass yield (BY), Seed yield (SY), Weight of 100 seeds (W100).

Table 3: Analysis of variance of different planting dates and densities on phenological traits, yield, and its components in Maragheh vetch in the second year.

All of the examined traits showed a significant difference at the 1% level of statistical significance in relation to the sub-factor of planting density. This means that the levels of seed density per unit area have an impact on all of the traits. The interaction effect of the different levels of planting lines in various densities (A*C) did not have a significant impact on any of the traits studied. However, the interaction effects of the planting date levels and seed density levels (B*C) were significant at the 1% level for fresh fodder yield, dry fodder yield, seed yield, biomass yield, and the day of podding start. The triple interaction effect (A*B*C) was significant only in the phenological traits of 50% flowering day, podding start day, and physiological ripening day at a statistical level of 5%.

Comparison of the mean traits in the first year

Based on Table 4, it was observed that the distance between crop lines did not have a significant impact on any of the traits analyzed when comparing their means in the first year. In other words, there was no significant difference between the levels of the main factor and the traits studied. Table 4 categorizes all traits into different groups based on planting date levels.

Factors		***FY***	***YDF***	***SY***	***BY***	***DF***	***DP***	***DPH***	***PH***	***W100***
Line space	25	a 5110	a 1114	a 428	a 846	a 97/99	a 53/107	a 29/144	a 69/43	a 19/4
	30	a 5560	a 1198	a 406	a 826	a 37/99	a 73/106	a 93/143	a 71/46	a 11/4
Planting data	autumn	a 7260	a 1548	a 589	a 1191	a 5/124	a 7/132	a 4/177	a 3/56	a 37/4
	waiting	b 5116	b 1104	b 418	b 837	b 0/99	b 2/106	b 7/141	b 3/47	b 17/4
	spring	c 3629	c 816	c 243	c 475	c 5/75	c 5/82	c 2/113	c 5/36	c 91/3
Density of seed per m^2	100	d 3939	d 796	c 322	c 654	a 66/100	a 33/108	a 05/146	c 88/43	a 38/4
	150	c 5119	c 1077	b 433	b 850	a 05/101	a 50/108	a 77/145	a 55/48	b 27/4
	200	b 5702	b 1235	a 500	a 1021	b 27/99	b 00/107	b 77/143	a 27/49	c 12/4
	250	b 5798	b1284	b 411	b 822	c 61/98	c 94/105	c 61/142	ab 94/46	d 02/4
	300	a 6117	a 1389	b 418	b 825	bc 77/98	c 88/105	c 33/142	bc 83/44	d 95/3

In each column and each treatment group, the averages that have at least one letter in common are not significantly different at the 5% level through Duncan's test.

Days to 50% flowering (DF), Days to the start of podding (DP), Plant height (PH) (cm), Fresh fodder yield (FY) (kg/ha), Yield of dry fodder (YDF) (kg/ha), Days to physiological ripening (DPH) (kg/ha), Biomass yield (BY) (kg/ha), Seed yield (SY) (kg/ha), Weight of 100 seeds (W100) gr.

Table 4: Mean comparison of different planting dates and densities on phenological traits, yield, and its components in Maragheh vetch in the first.

The highest amount of fresh fodder at 7260 kg was obtained in the autumn crop (b1), then followed by 5116 and 3629 kg/ha in the waiting crop (b2) and in the spring crop (b3), respectively. Dry forage yields in autumn, waiting, and spring cultivations were 1548, 1104, and 816 kg/ha and seed yields in autumn, waiting, and spring cultivations were 589, 418, and 243 kg/ha, respectively. Similarly, biomass yield (biomass performance) levels were 1191, 837, and 475 kg/ha in autumn, waiting, and spring cultivations, individually.

Based on the findings presented in Table 4, it was observed that the plants grown during autumn had an average height of 56 cm, while those grown during spring and waiting cultivation had average heights of 47 cm and 37 cm, respectively. Upon analyzing the planting date, it was found that the maximum weight of 100 seeds was recorded in fall planting, followed by waiting planting, and spring planting.

According to the findings reported in Table 4, the highest fresh fodder yield was obtained at a density of 300 plants per m^2 with 6117 kg per hectare and followed by 250 and 200 plants per m^2. The density of 150 plants per m^2 resulted in a yield of 5199 kg per hectare and ranked third in terms of this trait. The lowest fresh fodder yield was 3939 kg per hectare, which was obtained at a density of 100 plants per m^2.

The present results have shown that the highest dry yield was achieved with a seed density of 300 per square meter. At densities of 200 and 250 plants per m^2. the yield of dry fodder was 1235 and 1284 kg per hectare, respectively, with no significant difference between them. The third highest yield of dry fodder, at 1077 kg per hectare, was observed at a density of 150 plants per m^2. The lowest yield, at 796 kg per hectare, was found at the 100 plants per m^2.

According to Table 3, the highest seed yield of 500 kg per hectare was achieved at a density of 200 plants per m^2. The densities of 150, 300, and 250 plants per m^2 produced 433, 418, and 411 kg/ha respectively, and were grouped next. The density of 100 plants per m^2. had the lowest seed yield with 322 kg per hectare.

The results of the comparison mean for the second-year

According to Table 5, the average comparison results in the second year indicate that the distance between crop lines did not have a significant effect on any of the studied traits. However, different planting dates had an impact on all the studied traits. The maximum yield of fresh fodder was achieved in autumn cultivation, with a yield of 8882 kg per hectare. For waiting cultivation, the yield was 5685 kg per hectare, while spring cultivation resulted in a yield of 3431 kg per hectare. The dry fodder yield values for autumn, waiting and spring crops were 1926, 1266, and 781 kg/hectare, respectively. Similarly, the yield of seeds in autumn, waiting, and spring cultivation was 764, 505, and 263 kg/ha. Lastly, the biomass yield was 1559, 1035, and 587 kg per hectare, respectively, at B factor levels.

Factors		***FY***	***YDF***	***SY***	***BY***	***DF***	***DP***	***DPH***	***PH***	***W100***
Line space	25	a 5807	a 1278	a 505	a 1035	a 09/106	a 75/113	a 06/150	a 72/42	a 17/4
	30	a 6192	a 1371	a 517	a 1085	a 68/105	a 13/113	a 26/150	a 60/42	a 14/4
Planting data	autumn	a 8882	a 1926	a 764	a 1559	a 80/131	a 90/139	a 23/184	a 68/52	a 38/4
	waiting	b 5685	b 1266	b 505	b 1035	b 00/103	b 26/110	b 66/146	b 11/42	b 14/4
	spring	c 3431	c 781	c 263	c 587	c 86/82	c 16/90	c 60/119	c 19/33	c 93/3
Density of seed per m^2	100	d 4602	d 988	c 391	c 797	a 11/107	a 00/115	a 50/152	b 83/40	a 32/4
	150	c 5774	c 1233	b 502	b 1004	a 11/107	a 55/114	b 72/151	a 88/44	a 31/4
	200	b 6365	b 1403	a 571	a 1166	b 61/105	b 33/113	c 88/149	a 83/44	b 12/4
	250	a 6716	a 1511	a 569	a 1156	c 83/104	c 33/112	d 61/148	b 98/41	bc 04/4
	300	ab 6538	a 1486	b 521	a 1177	c 77/104	c 00/112	d 11/148	b 76/40	c 97/3

In each column and each treatment group, the averages that have at least one letter in common are not significantly different at the 5% level through Duncan’s test.

Days to 50% flowering (DF), Days to the start of podding (DP), Plant height (PH) (cm), Fresh fodder yield (FY) (kg/ha), Yield of dry fodder (YDF) (kg/ha), Days to physiological ripening (DPH) (kg/ha), Biomass yield (BY) (kg/ha), Seed yield (SY) (kg/ha), Weight of 100 seeds (W100) gr.

Table 5: Mean comparison of different planting dates and densities on phenological traits, yield, and its components in Maragheh vetch in the second year.

According to Table 5, the highest fresh fodder yield was achieved at a density of 250 plants per m^2. which resulted in 6716 kg per hectare. The next highest yields were 6538 kg per hectare and 6365 kg per hectare, achieved at densities of 300 plants per m^2 and 200 plants per m^2. respectively. There was no significant difference between the average fresh fodder yields of these two densities. A yield of 5774 kg per hectare was obtained at a density of 150 plants per m^2. and the lowest fresh fodder yield of 4602 kg per hectare was obtained at a density of 100 plants per m^2. In general, the maximum amount of fresh fodder is obtained in autumn cultivation at a density of 250 plants per m^2.

According to Table 5, it was discovered that the highest amount of dry fodder was produced when sowing at densities of 250 and 300 plants per m^2. The yield was 1511 and 1486 kg per hectare, respectively with no significant difference between them. The highest seed yield of 571 and 569 kg per hectare was obtained at densities of 200 and 250 plants per m^2. respectively. There was no significant difference between these two densities either. The densities of 300 and 150 plants per m^2 yielded 521 and 502 kg per hectare, respectively, and were placed in the next group. The density of 100 plants per m^2 had the lowest seed yield of 391 kg per hectare and was placed in the last group. According to the Table 5, the highest and lowest biomass yield with 1177 and 797 kg/ha were obtained in 300 and 100 plants per m^2.

Discussion

Year, sowing date, and density affected all phenological traits, yield, and yield components in the current study. According to the results of the study, the distance between crop lines did not have a significant economic impact compared to the planting density and planting date, and it did not affect the measured traits. However, the planting density and planting date had a significant effect on most of the traits. Autumn cultivation resulted in better fresh fodder, forage yields, seed yields, average height, and biomass yield compared to waiting and spring cultivation followed by waiting cultivation. This indicates that the fall crop benefited from sufficient moisture resources and ripened earlier, thus avoiding drought stress towards the end of the season. This is physiologically better than waiting and spring cultivation. The same trend was observed for grain yield and biomass yield traits. As can be observed, the yield of Maragheh Vetch of *Vicia dasycarpa* during spring cultivation is substantially lower than during autumn cultivation. Thus, the promotional efforts for this product should be focused on autumn cultivation, as well as on *Vicia panonica*. Upon analyzing the planting date, it was found that the maximum weight of 100 seeds was recorded in fall cultivation, followed by waiting planting, and spring planting. The long growth period in autumn cultivation allows the plant to increase its seed weight, leading to better yields compared to other levels of this factor. Furthermore, most of the seeds complete their growth before the end of the dry season. Ahmadi et al. [2] found that the biomass production of *V. narbonensis* and *V. hyrcanica* was significantly higher when established during winter as compared to spring. The phenological pattern of both species seemed to be influenced by the time of establishment, with plants established in February displaying consistently superior growth compared to those established in March and April. The findings of Krajnyák et al. [12] confirm that the height of the plants, root length, number of Rhizobium nodules, number of pods per plant, number of seeds per plant, and seed weight of hairy vetch are all influenced by the date of sowing. Mohebby [16] reported no establishment for spring sowing of *Vicia villosa*; however, autumn sowing was successful.

The study found that increasing the plant density per m^2 resulted in higher yields as the increase in the number of plants per hectare and more sunlight was able to reach the canopy. During autumn cultivation, the optimal density for obtaining the maximum amount of fresh fodder, and dry fodder yield was found to be 300 plants per m^2 followed by 250 and 200 plants per m^2. This was due to favorable humidity levels and minimal competition among plants for space, nutrients, and sunlight. Whereas the highest seed yield was obtained in 200 and 150 plants per m^2. Therefore, it can be concluded that an increase in seed density per unit area till 200 seeds leads to an increase in seed yield, and beyond that, competition created in higher densities will result in a drop in seed yield, as observed from 200 plants per m^2 onwards. According to Heydarpour, Namdari, and Arani [10] high planting density due to increased competition between plants and low planting density due to insufficient coverage of shading and water evaporation caused a decrease in seed weight.

The research showed that the density of seeds has a significant effect on the biomass yield and also the number of days it takes for the physiological ripening of Maragheh vetch. The lowest biomass yield was recorded at a density of 100 plants per m^2 which was only 654 kg per hectare. However, by increasing the seed density to 200 plants per m^2 the biomass yield also was remarkably improved and reached 1021 kg per hectare in the first year. As the seed density increased to 250, and 300 plants per m^2, plants started competing with each other, resulting in a noticeable decrease in biomass yield, also physiological ripening occurred earlier. But in the second year, the highest biomass yield was achieved at a seeding rate of 300 plants per m^2. In the study conducted by Pouryousef, Alizadeh, and da Silva [17] the highest dry biomass was obtained from a mixture of barley and vetch when seeded at a rate of 200 seeds/m^2.

The study showed that the highest biomass yield was achieved at a seeding rate of 300 seeds per square meter, resulting in a yield of 1177 kg per hectare. The first group, consisting of seeding rates of 200, 250, and 300 plants per m^2 produced yields of 1166, 1156, and 1177 kg per hectare, respectively, and there was no statistical difference between them in terms of biomass yield. Additionally, it was found that the highest average seed yield and biomass were obtained during autumn cultivation, and the seeding rates of 200 and 300 plants per m^2 resulted in the highest biomass yields. Based on the findings of the study, the optimum density for achieving maximum biomass yield in Maragheh vetch is 200 plants per m^2. which should be planted during autumn. On the contrary, as the seed density per square meter increases, the weight of a single seed decreases (Tables 4 and 5). The highest and lowest value of this trait was observed in the density of 100 and 300 grains per square meter, respectively. Although increasing the seed density up to 200 plants per m^2 increased grain yield. However, the grain yield decreased with more seed density above this level. In other words, high densities lead to intense competition among plants, resulting in a decreased share of each seed in receiving photosynthetic materials. Zeiditoolabi et al. [21] found that as planting density increased, weight of 1000 seeds decreased, and the highest weight was observed at a density of 100 plants per m^2 that confirmed the present results.

Conclusion

It has been discovered that Vicia dasycarpa, also known as Maragheh vetch, performs better when given more time to grow under favorable weather conditions. The varieties planted in autumn have a longer lifespan and are more resilient to environmental factors. Additionally, rainfall during autumn has a greater impact on yield compared to other planting dates. Conversely, planting in spring may lead to decreased yield due to a lack of rainfall and shorter lifespan. Therefore, it is recommended to cultivate Maragheh vetch in autumn. Moreover, increasing the planting density leads to higher fodder and plant biomass yield, while medium planting density results in higher grain yield. A reduction in planting density can elongate the duration of flowering, podding, and physiological ripening duration. This demonstrates the crucial role of appropriate planting density in yield optimization. The plants with densities of 150 and 200 plants per m^2 meter were taller than other treatments.

To summarize, it is recommended to cultivate Maragheh vetch under cultivated conditions using the following parameters: autumn planting, line spaces of 30 cm, and a density of 200 to 300 plants per m^2 meter.

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