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Aims and Scope

Turkish Journal of Range and Forage Science is the official publication of Society of Rangeland and Forage Science. The Journal is dedicated to publishing quality original material that advances rangeland management and forage crops production.

Turkish Journal of Range and Forage Science is a peer-reviewed, international, electronic journal covering all aspects of range, forage crops and turfgrass management, including the ecophysiology and biogeochemistry of rangelands and pastures, terrestrial plant–herbivore interactions, rangeland assessment and monitoring, effects of climate change on rangelands and forage crops, rangeland rehabilitation, rangeland improvement strategies, conservation and biodiversity goals. The journal serves the professions related to the management of crops, forages and grazinglands, and turfgrass by publishing research, briefs, reviews, perspectives, and diagnostic and management guides that are beneficial to researchers, practitioners, educators, and industry representatives.

Publication Date and Subscription Information

Turkish Journal of Range and Forage Science is published twice a year (June and December) as online.

SOCIETY OF RANGE AND FORAGE SCIENCE

TURKISH JOURNAL OF RANGE AND FORAGE SCIENCE

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When a revision is required by the reviewer or reviewers, the author(s) are to consider the criticism and suggestions offered by the reviewers, and they should be sent back the revised version of manuscript in twenty days. If revised manuscript is not sent in twenty days, the manuscript is removed from reviewer evaluation process. Reviewers may request more than one revision of a manuscript. Manuscripts which are not accepted for publication are not re-sent to their authors.

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The author(s) that submit an article to the Turkish Journal of Range and Forage Science consider accepting of these peer review conditions and procedures.

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Research

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Effects of Different Row Spacing and Seeding Rate on Seed Yield and Some Yield Components of Birdsfoot Trefoil (*Lotus corniculatus* L.) in Tokat Region

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A R T I C L E I N F O

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A B S T R A C T

Birdsfoot trefoil (*Lotus corniculatus* L.); is a considerable component of natural meadow-rangelands and grassland, besides producing sufficient forage in environmentally restricted fields. In order to for increase birdsfoot trefoil cultivation, it is necessary to the sufficient quantity produce quality seeds. The information regarding the row spacing and seeding rate is important for achieving yield targets and better economic returns of birdsfoot trefoil. This study was carried out in order to determine the optimum row spacing and seeding rate for seed production of Sarıyıldız 60 variety that new registered in the semi-arid climate conditions of the Central Black Sea transition zone, where this plant was not grown before. The field experiment was conducted at the using a randomized complete block split-plot design with three replicates in 2017 to 2019 growing seasons. The study was tested four different (20,40, 60 and 80 cm) row spacings and (5, 10, 15 and 20 kg ha^{-1}) seeding rates. Results of connectedly analysis showed that row spacing and seeding rate application on that the effect of on seed yield and number of pods per plant, 1000 seed weight was significant statistically but didn't have any significant effect on number of seed per pod and harvest index. The interaction between row spacing and seeding rate did not show any significant statistical be different on seed yield and yield components. In general accepted, the number of pods per plant, the number of seeds per pod, the weight of thousand seeds and the harvest index decreases with the increase in the seed rate in all row spacings. Results showed that seed yield increases with narrower row spacing. The mean data from the three years experimental showed that the highest seed yield was obtained with plants grown in 20-40 cm row spacing's at a seeding rate of 10-15 kg ha^{-1} (248.0 and 257.0 kg ha^{-1}).

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1. Introduction

For many crop growers, production guides are very important to help them be successful both agriculturally or economically. One of the most considerable the difficulty encountered in forage plants cultivation and meadow and pasture improvement is the inability to obtain sufficient quantity and quality seeds (Acıkgoz et al.,2002).

While not commonly grown in our country, birdsfoot trefoil produces high quality forage, that supports, animal performance from ruminant livestock, that are often superior to alfalfa or other forages. Birdsfoot trefoil (*Lotus corniculatus* L.) is a special perennial legume plant with a medium lifespan that grows in different geographical region of the world. It is a forage plant that is commonly used in different parts of the world and is mostly for fodder, silage and cover crop, or a managed pasture is grown in pure or mixed form (Hannaway et al., 2004; Anonymous, 2014). Birdsfoot trefoil is a quality forage with its high crude protein content (16.66-20.50 %) beside that as well low neutral detergent fiber (33.38-40.85 %) and acid detergent fiber content (28.4-38.4 %) in dry matter (Churkova et al., 2016). Concentrated tannins in the birdsfoot trefoil recude urinary N excretion and prevent bloat in ruminants, together with anthelmintic activity (Waghorn, 2008; Anonymous, 2014). Lotus corniculatus can tolerant some soil salinity,it thrives in area where alfalfa and other forage legumes cannot grow because of acid soil and humid soil (Hannaway et al., 2004; Anonymous, 2006; Anonymous, 2014). Birdsfoot trefoil is an N-fixing legume, contribute for wildlife, it is o good pollen plant for bees and bumble bees (Bush 2002; Hannaway et al.,2004). The difficulty of optaining consistently high yields of seeds has restriction the use of the birdsfoot trefoil importantly. The pods shattering are easily and the seeds often spill over (Fairey, 1994). Potential seed yield of the birdsfoot trefoil is estimated at 1200 kg ha-1 while the mean yields the global be below 200 kg ha-1(Turkington and Franco, 1980; Gullien, 2007). McGraw et al. (1986a) to test the plant's seed yield have conducted a research in three apart geographic region and have determined that genotype with environment had important interactions between each other. The researchers, have concluded that the seeds yields test have to be conducted in the geographic region where the plant is trading zone cultivated. Brecke (1995) reported, low density or high-density of plant spacing may reason adverse influence, like diseases, weed and increased pressure from other plants.

Row spacing and seeding rates are two crucial factors that affect at plant production yield and yield components. In our country, little is known about the effects of interactions between these two factors on the amount of yield main elements and quality traits of birdsfoot trefoil.

This research, for recognize on the influence of plant density on the seed yield and some yields components of *Lotus corniculatus* and aims to determine the requsite optimum row spacing and seeding rate in order to obtain maximized high-quality seed yield. The results obtained from this study can be used as guidelines the implementation to generalize *Lotus corniculatus* cultivation and to improve high-quality forage production.

2. Materials and Methods

The experiment was effected at during three growing seasons (2017 to 2019) at the region of Kazova (geographic latitude 40° 18', longitude, 36° 34', altitude 585 m above sea level), to the city of Tokat.

The according to results from soil lab analysis the trial area soil:
texture of medium heavy textured (clay-loam) structure and the total salt content of (0.028%) the soils is low. Soil pH (7.6) of the they are slightly alkaline (Anonymous, 1993). The textures of the soil samples are the medium-heavy (clayey-loamy) structure, and the total salt content of (0.028%) the soils is low. The plant-consumable phosphorus concentrations of soil samples (kg P_2O_5 13 ha^{-1}) and organic matter content (% kg N 9 ha^{-1}) was low. Apart from this, lime content of the soil samples (kg $CaCO_3$:77 ha^{-1}) is optimum and the potassium content of (kg K_2O: 813 ha_{-1}) are high (Ulgen and Yurtsever, 1995).

Climate of Tokat-Kazova region; It has a transition climate between the Black Sea climate with the Central Anatolia region steppe climate. The spring last frost, summer and early spring droughts and increasing temperatures in the years of the experiment affect plant production negatively. The monthly average temperatures and maximum temperature averages of years in which the experiment was conducted, were higher than the temperature averages for previous years and were much lower in terms of minimum temperatures. The field experiment had important less receive annual precipitation throughout the growing season as compared to the past. The experimental year and long-term average (1929-2019) temperature, relative humidity and average rainfall values are shown in (Table 1).

Table 1. Monthly lowest, highest and mean temperature, relative humidity and rainfallin values of the experimental years and long-term average (1978- 2018) *

	Monthly mean temperature (˚C)				**Highest monthly temperature mean (°C)**				**Lowest monthly temperature mean (°C)**			
Years / Months	2017	2018	2019	Long term	2017	2018	2019	Long term	2017	2018	2019	Long term
January	0.4	4.7	2.2	1.9	-13.5	-3.3	-14.5	-1.7	14.0	14.3	14.3	6.1
February	2.7	7.4	5.9	3.5	-12.2	-5.2	-2.3	-0.7	21.4	21.6	16.6	8.2
March	9.2	11.0	7.2	7.4	-4.2	-1.8	-3.5	2.4	23.8	28.1	20.4	13.0
April	11.8	13.4	11.5	12.5	-2.7	-3.1	-0.3	6.6	29.5	30.0	27.6	19.0
May	15.6	17.9	19.1	16.5	0.3	2.4	6.7	10.1	32.2	31.5	34.8	23.5
June	19.8	21.3	23.1	19.9	5.4	6.4	14.9	13.1	34.3	36.7	33.5	26.8
July	17.7	23.8	21.9	22.3	7.5	9.4	9.7	15.4	41.8	37.3	38.7	29.0
August	24.5	22.7	22.4	22.4	12.8	9.8	12.2	15.6	39.4	36.7	38.0	29.7
September	20.6	19.4	19.0	18.8	4.8	6.3	4.1	12.1	36.9	38.6	30.9	26.5
October	11.9	15.7	15.9	13.7	0.2	2.8	5.9	8.1	29.3	28.3	31.3	20.7
Novembe	6.2	9.2	7.0	7.9	-6.1	-1.7	-0.7	3.4	20.4	20.0	16.3	13.7
December	4.8	5.1	5.3	3.8	-5.8	-8.9	1.3	0.2	17.9	15.0	10.1	7.8
Total/ Mean	12.1	14.3	14.3	12.6	-1.12	1.09	2.9	7.05	28.4	28.1	27.5	18.6

Table 1 (continued). Monthly lowest, highest and mean temperature, relative humidity and rainfallin values of the experimental years and long-term average (1978- 2018) *

	Monthly precipitation total (mm)				**Monthly relative humidity mean (%)**		
Years/ Months	2017	2018	2019	Long term	2017	2018	2019
January	53.5	26.9	71.6	40.9	76.3	81.0	76.5
February	3.3	9.9	14.7	33.8	66.2	75.6	67.0
March	27.5	74.7	36.8	40.8	60.1	74.5	61.8
April	32.6	4.3	63.5	54.2	58.2	63.4	65.2
May	66.6	68.1	49.1	58.9	68.1	77.2	59.7
June	102.4	46.6	26.2	38.2	71.3	71.3	63.4
July	0.0	8.2	16.9	11.2	59.2	67.6	59.6
August	0.7	4.5	52.2	5.6	62.7	63.1	63.0
September	4.0	40.5	1.6	17.7	56.7	65.4	61.7
October	31.3	39.6	3.7	39.3	73.3	69.3	70.6
November	32.6	8.2	9.9	44.0	83.3	73.8	75.7
December	44.6	49.4		47.1	86.3	80.4	82.4
Total/ Mean	399.1	380.9	346.2	431.7	68.5	71.8	65.0

* Official climatology statistics, Directorate General of Meteorology. https://mgm.gov.tr› provinces-and-counties-statistic

Birdsfoot trefoil cultivar “Sarıyıldız 60” which was newly registered by our institute, was used as plant material in the field experiment. Cultivar is of erect or semi-erect growth characteristic. Cultivar has forage yield of 32.0/51.0 tons ha^{-1} under different conditions, while it has a seed yield that vary between 287 and 347 kg ha^{-1} (Karadag et al., 2016; Çınar et al.,2016).

The field experiment was conducted at using a randomized complete block split-plot trial design with three replications. In research were tested four different row spacing (20,40,60 with 80 cm) in the main plots and seeding rates (5, 10, 15 and 20 kg ha^{-1}) in the subplots.

The field soil was applied 200 kg ha-1 diammonium phosphate (It contains 18% nitrogen (N) and 46% phosphorus (P) as P_2O_5.) bottom fertilizer before sowing.

The birds foot trefoil "Sarıyıldız 60" cultivar was sowing with a in single file machine at a depth of 1.5-2.0 cm at 19 April 2016. Weed control was made hand hoe and mechanical rotary hoe during in the experiment. Field trials were conducted under precipitation dependent natural terms and conditions. Some components of yield were determined infield: number of pods per plant (counting on ten randomly selected plant from in the subplots), number of seeds per pod (was determined from a sample of 10 mature pods selected at randomized) each from in the subplots. The later mature pods were hand threshed and the seeds were cleaned, sieved and numbered in laboratory were determined. The seed yield was determined during the stage where 70 to 80% of the pods were return brown (Winch and Macdonald 1960). Every sub-parcel was mowed in 5 to 7 cm height using a parcel weedeater. In the current study, twice yearly mowed were made for seed production in 2017 and 2019, a once cutting was made due to late spring frosts in if 2018. All the cut up plants materials were gathered by hand and dried exposure to natural weathering for during 4 weeks. The air-dried haystack in sub-parcels was then threshing using a parcel thresher.

The seed yield every seed sample after was siffed using 11.2 and 2.5 mm siffers and cleaned using a portable fan set and weighed in laboratory were determine. The obtained seed weights were recorded in kg ha converted value.

The 1000 grain weight (g) was calculated by counting 4 repetitions of 100 seeds for each sub-subject in the laboratory and multiplying by 10.
The harvest index (%) was calculated as the percentage ratio of the total seed weight obtained from each subplot to the total dry biomass above ground (Garcia-Diaz and Steiner, 2014).

The obtained data statistical analysis was subjected to analysis of variance by the combined variance (Anova 2-Factor) analysis using. Resultant all significant of treatment means was grouped data using the Least significant difference test at 5% level of significance (Yurtsever, 2011).

3. Results and Discussion

Seed Yield

When the row spacing and seeding rate were changed in the study, the differences between the seed yields were found to be significant ($p<0.01$) the experiment years. The highest seed yield (258.5kg ha^{-1}) was found in 2017 and the lowest yield (142.6 kg ha^{-1}) was determined in 2018 (Table 2). The late spring frosts in 2018 had a negative impact on seed yield and the yield components examined (Table 1). The results showed that both row spacing and seeding rate had a significant ($p<0.01$) influence on seed yield, and seed yield increases significantly with narrow row spacing but as row spacing increased, decreased yield. The highest seed yield was obtained with application of 20 and 40 cm row spacing (248.0 and 257.0 kg ha^{-1}) and 10 and 15 kg hectare seeding rate (230.3 and 231.0 kg ha^{-1}) which are in the same group as statistically. Seed yield decreased significantly in 60 and 80 cm row spacings and in the applications of 5 kg ha^{-1} seed rate (183.0 and 175.0 kg ha^{-1}) (Table 2). The result there were no statistically influences of the row spacing x seeding rate interaction on seed yield.

In previous studies evaluating the response of the birdsfoot trefoil plant to various seed ratios and row spacing:

Seed yields of birdsfoot trefoil in USA range between 50 and 170 kg ha^{-1} (Fairey and Smith, (1999) in Uruguay between 120 and 150 kg ha^{-1} (Garcia et al. 1991) and Argentina between 25 and 150 kg ha-1 (Mazzanti et al., 1988). Pankiw et al. (1977) found that the 'Leo' cultivar from Alberta, Canada produced the highest seed yield in narrow rows (15 cm) and at a seeding rate of 8.8 kg ha^{-1}. Hare (1984) obtained maximum (86 to 88 g m^2) seed yield in the first year of the experiment in populations of 22 to 33 plants/m^2 at row spacings of 0.30 or 0.45 m. It was determined that the seed yield decreased significantly at 66 and 133 m^2 densities and in rows with 0.15 m spacing. Vinc et al. (1985) noted that although seed yield could potentially go up to 750 kg ha^{-1} the average yield in

Ontario was about 110 kg ha^{-1} meaning 85% was lost due to seed coat fragmentation. According to McGraw et al. (1987) reported, the average seed yield of birdsfoot trefoil vary 50-175 kg ha^{-1} or about 100 kg ha-1. Bologna et al. (1996) reported that the seed yield various from 45.8- 65.1 (g/m^2) and 1000 seed weight 1.385-1.528 (mg). Vojin et al. (2001) obtained 272 kg ha^{-1} birdsfoot trefoil seed yield in Banja Luka region. Churkova (2006) reported that the seed yield varied between 185-313 kg ha^{-1} and the highest seed yield (313 kg ha^{-1}) was obtained from the K-30 variety. In the study by Stevovic et al. (2013) sowed birdsfoot trefoil varieties using 10 kg ha-1 seeds at 20 cm row spacing, Rocco variety (408.6 kg ha^{-1}), K-37(85 kg ha^{-1}) and It has been reported that it has a significantly higher seed yield than the Zora variety (54 kg ha^{-1}). Karadag et al. (2016) reported that the seed yield ranged between 280-347 kg ha^{-1} and Cınar et al. (2016) reported ranged between 243-287 kg ha^{-1} in their study conducted in different locations. Stevovic et al. (2017) reported the pre-sowing seed inoculation of with bacteria *M. loti*, had significant influence on the seed yield and yield components and the seed yield ranged between 1186 with 1422 kg ha^{-1} Ozpınar et al (2019) determined that the seed yields ranged between 97-234 kg ha^{-1}. Seaney and Henson (1970) reported that seed shattering pod is a be important problem in lotus, and the gap between theoretical and actual seed yield is very large and seed yield of *Lotus corniculatus* vary between 50-560 kg ha^{-1}. Steiner et al. (1995) reported that the seed yield of perennial leguminous plants is determined firstly by the plant's genetic basis, which was followed by ecological factors, first harvest time, presence of insects and pollinators and the interaction between genotype and environment. Basic (2014), Delic (2014) have reported that the ecological factors, plant cultivation techniques, biotic factors (host plant, vegetation, plant diseases and insect pest) are important.

Table 2. Effect of years row spacing and seeding rate birdsfoot trefoil seed yield

Years Row spacing (A)	**2017** Seed yield (kg ha^{-1})	**2018** Seed yield (kg ha^{-1})	**2019** Seed yield (kg ha^{-1})	**Avarage of 3 Years** Mean for the period (kg ha^{-1})
20 cm	279.4	164.0	301.0	248.0a
40 cm	311.5	167.0	294.0	257.0a
60 cm	203.5	134.0	213.0	183.0b
80 cm	239.2	106.0	179.0	175.0b
F-test	**	*	**	**
Lsd value	2,19	4,46	1,22	3.16
Seeding rate (B)				
5 kg ha^{-1}	229.7	1310	181.0	181.0b
10 kg ha^{-1}	281.3	152.0	267.0	230.3a
15 kg ha^{-1}	276.0	148.0	270.0	231.0a
20 kg ha^{-1}	246.7	139.0	271.0	219.0a
F test	**	ns	**	**
LSD value	1,86	2,33	1,50	1.87
Coefficient of variation. CV(%)	11.9	19,4	21.0	18.4
AXB	ns	ns	ns	3.74 ns
Years yield	258.5a	142.6b	247.7a	216.2

Years*Row spacing: 0.05 ns, lsd: 5.47, Years*Seeding rate: 0.05** lsd:3.24, Years*Row spacing* Seeding rate: ns

Components of seed yield

The combined results obtained from the analysis of variance showed that the influence of year on the examined yield main component was statistically significant (P<0.01). The influence of row spacing, seeding rate, row spacing x seeding rate, year x row spacing, year x seeding rate and year x row spacing x seeding rate interactions on studied characteristics are presented in Table 3.

Table 3. Effects of years row spacing and seeding rate on birdsfoot trefoil seed yield components

	Number of pods per plant				**Number of seeds per pod**			
Years	2017	2018	2019	Mean	2017	2018	2019	Mean
Row spacing A								
20 cm	85.70b	42.71	101.2ab	76.6b	20.7	16.2	24.1	20.3
40 cm	122.02a	56.91	125.2a	101.3a	20.5	17.2	24.7	20.8
60 cm	93.5b	41.79	97.9ab	77.7b	20.5	18.1	23.4	20.7
80 cm	82.3b	44.65	82.6b	69.8b	20.1	16.1	23.4	19.9
F-test	*	ns	ns	**	ns	ns	ns	ns
LSD value	22.3	17.20	34.9	12.9	1.28	2.93	2.77	1.17
Seeding rate B								
5 kg ha^{-1}	110.2a	53.6a	105.3a	89.7a	20.6	17.1	24.6	20.7a
10 kg ha^{-1}	101.7a	47.9ab	113.7a	87.8a	20.5	17.9	24.2	20.9a
15 kg ha^{-1}	93.3ab	44.8ab	98.8ab	79.0b	21.2	16.4	24.4	20.6a
20 kg ha^{-1}	78.1b	39.5b	89.1b	68.9c	19.4	16.2	22.5	19.4b
F-test	*	*	*	**	ns	ns	*	ns
Lsd value	19.43	9.34	15.7	8.6	1.89	2.77	1.71	1.21
Coefficient of variation CV (%)	24.0	23.8	18.0	22.4	10.9	10.5	8.0	12.6
AXB	ns	ns	ns	ns	ns	ns	ns	ns
Years	95.87a	46.52b	101.78a	81.39	20.47	16.93c	23.94a	20.44b

Table 3 (continued). Effects of years row spacing and seeding rate on birdsfoot trefoil seed yield components

	Thousand-seed weight (g)				**Harvest index (%)**			
Years	2017	2018	2019	Mean	2017	2018	2019	Mean
Row spacing A								
20 cm	0.96	1.04	1.25ab	1.09ab	1.80ab	4.93	2.28	3.00
40 cm	1.08	1.13	1.29a	1.17a	1.83a	4.72	2.14	2.90
60 cm	1.00	1.03	1.20bc	1.08ab	1.24c	4.98	1.70	2.64
80 cm	0.96	1.01	1.15c	1.04b	1.44bc	3.92	1.47	2.27
F test	ns	ns	*	**	*	ns	ns	ns
LSD value	0.10	0.19	0.07	0.06	0.37	1.13	2.30	0.73
Seeding rate B								
5 kg ha^{-1}	1.06a	1.08	1.23	1.11	1.44b	4.87	1.54b	2.75
10 kg ha^{-1}	1.00ab	1.04	1.22	1.09	1.67a	4.61	1.95a	2.83
15 kg ha^{-1}	0.94c	1.06	1.22	1.08	1.74a	4.68	2.06a	2.62
20 kg ha^{-1}	1.00bc	1.03	1.21	1.08	1.45b	4.39	2.03a	2.75
F test	**	ns	ns	ns	**	ns	*	ns
LSD value	0.05	0.06	0.05	0.03	0.17	0.70	0.37	2.26
Coefficient of variation CV (%)	6.6	7.5	4.0	6.3	12.8	18.0	23.6	20.7
AxB	ns	ns	ns	ns	ns	ns	ns	
Years	1.01b	1.06b	1.23a	1.10	1.54b	4.64a	1.90b	

*- F test significant at p<0.05;**-F test significant at p<0.01;ns-F test not significant

Evaluation made; showed that the influence of row spacing and seeding rate on the number of pods per plant and 1000 seed weight was quite significant (P <0.01). The number of seeds per pod and the harvest index were not statistically affected by the variability in row spacing and seeding rate.

The number of pods per plant

The number of pods per plant studied is a trait directly related to seed production. In the research conducted, the highest number of pods per plant (101.8 pod/plant) was determined in 2019 and the lowest (46.5 pod/plant) in 2018 (Table 3)

The maximum number of pods per plant was obtained by applying 40 cm row spacing and 5-10 kg ha^{-1} seeding rates, lowest pods per plant by applying 80 cm row spacing and 20 kg ha^{-1} seeding rates (Table 3).

The number of seeds per pod

The number of seeds per pod created statistically significant ($p<0.01$) differences between the experimental years. The highest (23.9 seeds/pod) number of seeds per pod were determined in 2019, and the least (16.9 seeds/pod) in 2018.

In terms of the number of seeds in the pod, the application of row spacing and sowing rate did not have a statistically significant influence while the highest number of seeds per pod in 10 kg ha^{-1} seeding rate at 40 cm row spacing and at least of were determined in the application of 20 kg ha^{-1} seeding rate at 80 cm row spacing. (Table 3).

Thousand seed weight

Thousand seed weight is a considerable matter of seed quality, grain seed size and seed viability. The combined results obtained from the analysis of variance shoved that the effect of year and row spacing on thousand seed weight was quite significant ($P<0.01$), while the application of seeding rate insignificant influence. The thousand seed weight highest with 1.23 g was determined in the last year of the experiment, while the lowest (1.01 g) was obtained in the first year. The highest thousand seed weight is obtained 40 cm row spacing and 5 kg ha^{-1} seeding rate application, while the lowest is obtained 80 cm and 15-20 kg ha^{-1} seeding rate application determined (Table 3).

Harvest index

Harvest index (HI) is determined by interactions between genotypes, ecological factors and cultıvation techniques. The effect of row spacing and seeding rate applications on the harvest index was statistically insignificant. However, the differences establish between years were statistically significant. The highest harvest index (4.6%) value was determined in the second year of the experiment, while the lowest (1.5-1.9%) value was determined in the first and last years of the experiment. Although the application of row spacing and seeding rate did not have a statistically significant effect, the harvest index tended to be low except for applications with 20-40 cm row spacing and 10 kg ha^{-1} sowing ratio (Table 3).

Hare (1984) emphasized that the weight of pods per inflorescence, seeds per pod and 1000 seeds was not affected by row spacing and population density. Vınc et al. (1985) reported that the weight of one thousand seeds in the birdsfoot trefoil varied between 0.78-1.26 g. In a study by McGraw et al. (1986b) the harvest index decreased as the plant population density increased, while plant population densities required for optimum seed production (19.0 plants/m²) were required for optimum hay production (26.5 plants/m²). Therefore, it was emphasized that lower seed sowing rates could be used in the establishment of seed production fields. Chourkova (2006) reports have number of pods per plant range between 49.4-172.2 number seeds per pod 15.9-25.4 varies between. The same study reports a high positive correlation were be found between the number racemes per plant with number of pods per plant and number seeds per pod in seed productivity.

Vuckovic et al. (2006) determined that average number of seeds per pod vary between 8.4-12.9 and 18.3-25.6 in the collected populations. Ayres et al. (2008) determined that the average number of thousand seed weight vary between 0.72-1.17. Churkova and Lıngorskı (2011) reported that number of seeds per pod was least 10.8, highest 26.4 and the weight of 1000 seeds was lowest 1.09 and highest 1.38 g. Gataric et al. (2013) determine that number of pods per plant vary between 257.8-566.6 the number of seeds per pod 12.4-20.3 the thousand-seed weight vary between 1.01-1.26 g. Stevovic et al. (2017) report that number of seed per pod was 22.7-24.6 piece and thousand seed weight was 1.16-1.27 and that seed yield was in positive correlation with these values. Garcia-Diaz and Steiner (2014) reported that the harvested seed yield vary between 130 and 790 kg ha^{-1} and the harvest index varies between 1.5 and 13.6% by applications and years. Radic et al. (2014) concluded that number of pods per plant varies between 361 with 960, one thousand seed weights in the plant collection samples various from 0.87 g to 1.32 g. Ozpınar et al. (2019) it was determined that 1000 seed weight vary between 1.04-1.21 g.

4. Conclusions

Generating reliable information on some agronomic practices such as appropriate row spacing and seeding rate is quite considerable to come up with profitable and sustainably birdsfoot trefoil production. The results of the present study demonstrated that birdsfoot trefoil can be successfully grown in the under rain-dependent agriculture in the Tokat-Kazova region and similar agro-ecological conditions, reaching yields. This experiment result showed:

1-The effects of row spacing and seeding rate on seed yield and number of pods per plant, thousand-seed weight were also found to be significant of birdsfoot trefoil. The effects of different row spacing and seeding rates on number of seeds per pod and harvest index ratios were found to be insignificant.

2-The effect of row spacing x seeding rate interaction on seed yield and character traits was not influence significant.

3- Based on these data, it is recommended that birdsfoot trefoil Sarıyıldız 60 cultivar production in the Tokat-Kazova region and similar agro-ecological conditions use 20 or 40 cm row spacing and seed 10 kg ha-1.

4- Besides that the results of this test indicate that narrow row spacing (20-40 cm) has positive effects on weed control.

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Effects of Different Forage Pea and Rye Mixtures on Forage Yield and Quality

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A B S T R A C T

This study was carried out in the 2018-19 vegetation period to determine the appropriate mixture ratios of forage pea (*Pisum sativum* ssp. *arvense* L.) and rye (*Secale cereale* L.) under rainfed conditions of Kırşehir province, Türkiye. The layout of the experiment was randomized blocks with three replications and the treatments were pure rye, pure forage pea and four different mixtures of forage pea and rye (20% FP + 80% R, 40% FP + 60% P, 60% FP + 40% R, 80% FP + 20% R). The highest green forage yield (2395.1 kg da^{-1}), dry matter yield (833.3 kg da^{-1}), and crude protein yield (71.0 kg da^{-1}) were obtained from pure rye sowings. The highest crude protein ratio (15.6%), the lowest NDF (39.3%) and ADF (31.1%) ratios were obtained from pure forage pea sowings. The increase in the rye ratio of the mixtures increased the yield, while the increase in the forage pea ratio caused an increase in the forage quality. The results revealed that pure rye and a mixture of 20% FP + 80% R can be recommended to obtain high dry matter yield, and 40% FP + 60% R mixture for yield and quality under continental climate conditions as in Kirsehir province of Türkiye.

1. Introduction

The cultivation of at least two similar or different species together in the same field is defined as mixed cropping, which is recommended to increase yield and quality in forage crops (Acar et al., 2006). Crop yield increases when different species and varieties had better utilize the resources such as soil, water, light and plant nutrients (Francis and Smith, 1985; Baumann et al., 2002; Seydosoglu and Bengisu, 2019). High quality forage is obtained due to the high protein content of legumes and carbohydrate content of cereals used in the mixtures. Therefore, the cultivation of cereal-legume is the most common among mixed cropping systems.

Forage pea is existed in the natural flora of Türkiye and it is a delicious and nutritious annual forage legume for ruminants (Konuk and Tamkoc, 2018). Rye (*Secale cereale* L.), which is resistant to low temperatures and productive in humid and cool climates, is used in the production of forage as well as a valuable crop with the seeds around the world (Newell and Butler, 2013). The rye can grow in extreme conditions by using soil moisture very efficiently in addition to very good adaptability (Ceri and Acar, 2019). The rye, which is a cereal crop, loses its palatability rapidly by the maturation, which reduces the preference of producers to cultivate as a forage crop. Therefore, the appropriate species and varieties and the cereal + legume mixture ratios should be determined to obtain high forage yield and quality in a particular region or ecological conditions (Lithourgidis et al., 2006). The average green forage yield of Taşkent

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pea variety in Çanakkale ecological conditions was reported as 2136.2 kg da^{-1}, dry matter yield as 394.4 kg da^{-1}, crude protein ratio as 18.1%, NDF ratio as 40.8, and ADF ratio as 31.8% (Alaturk et al. (2021). Yolcu et al. (2009) investigated the yields of barley, wheat, rye, oat and their mixtures with Hungarian vetch, and they recorded the highest green forage and dry matter yields from pure rye and rye + Hungarian vetch mixture. The researchers stated that forage obtained with pure Hungarian vetch was high in crude protein and low in NDF and ADF ratios (Kocer and Albayrak, 2012; Onal et al., 2015; Baxevanos et al., 2017) Cherney et al. (1985) stated that both the anatomical structures and chemical compositions of cereals and legumes can lead to differences in ADF ratios. In this study, forage yield and quality of different rye-forage pea mixture combinations were investigated in Kırşehir ecological conditions.

2. Materials and Methods

The research was carried out in the experimental fields of Kırşehir Ahi Evran University during 2018-2019 vegetation period. Total precipitation and relative humidity were lower than the long-term average, and the temperature was above the long-term average values during the experiment (Table 1).

The soils of the experimental field were clayey-loam textured, highly calcareous (22.23%), rich in available potassium (159.9 kg da^{-1}), insufficient in available phosphorus (5.95 kg da^{-1}) and poor in organic matter (1.00%) content (Karaman, 2012). Pure and mixed sowings were carried out manually on 13 November using 20 cm inter row spacing. In order to use rainwater more effectively in dry agricultural areas where the annual precipitation distribution is irregular, the trial was established in winter seasons. Each plot had 10 rows with 5 m length. Aslım-95 rye (*Secale cereale* L.) and Taşkent forage pea (*Pisum sativum* ssp. *arvense* L.) cultivars were used as plant material of the experiment. Six treatments composed of pure sowings of forage pea (FP) and rye (R), and four different mixtures (20% FP + 80% R, 40% FP + 60% R, 60% FP + 40% R, 80% FP + 20% R) were examined. The amount of seeds used in pure sowing was calculated as 100 seed m^2 in forage pea (Konuk and Tamkoc, 2018), and 500 seed m^2 in rye (Anonymous, 2022). The amount of seeds in the mixtures was calculated considering the amount of seeds used in pure sowing and the ratio in the mixture (Onal and Egritas, 2017).

The layout of the experiment was randomized blocks with three replications. Before sowing, 6 kg da^{-1} P_2O_5 and 4 kg da^{-1} N fertilizers were applied to the plots, and 4 kg da^{-1} N fertilizer was applied during tillering-stem elongation period (Aydın, 2009). The forage peas were in full flowering, while rye was in early flowering, and the plants were harvested on 15 June, 2019. The heights from the soil surface to the plant tip were measured in 10 randomly selected plants for pure species in each plot and in 10 plants of each species in mixtures before the harvest. During the harvest, one row from the edges of each plot and 50 cm from the beginning and end of each plot were considered as side effects (Gocmen and Parlak, 2017). The plants in the remaining part of the plots were harvested with a scythe and weighed to determine the green forage yield (GFY). In each plot, a 500 g of harvested fresh plants were sampled and were dried at 60 ºC until reaching a constant weight to calculate dry matter yields (DMY) (Sleugh et al., 2000).

Table1. Climate data of Kirsehir province*

	Precipitation (mm)		**Relative Humidity (%)**		**Temperature (°C)**	
	2018-19	LTA	2018-19	LTA	2018-19	LTA
October	41.4	30.4	62.3	62.7	14.4	13.1
November	21.0	41.6	66.8	72.4	8.2	6.3
December	101.1	47.1	81.4	79.0	3.3	2.0
January	42.2	44.3	79.3	79.0	0.8	-0.1
February	42.8	31.6	71.4	74.1	4.2	1.3
March	10.2	36.7	56.4	67.2	6.3	5.6
April	29.0	42.4	64.0	63.3	9.7	10.9
May	17.1	45.6	52.7	61.3	17.5	15.4
Average/Total	304.8	319.6	66.8	69.9	8.1	6.8

* Turkish State Meteorological Service, LTA = Long-Term Average

In pure sowings, quality analyses were carried out using single species and both species were separately analyzed in mixture sowings, and calculated considering amount of ratio in the mixtures. The nitrogen content of the species and mixtures was determined by the Kjeldahl method, and the nitrogen contents were multiplied by the coefficient of 6.25 to calculate the crude protein ratios (CPR) (AOAC, 2005). Crude protein yields (CPY) of species and mixtures were calculated by multiplying crude protein ratios with dry matter yields. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents were determined using an ANKOM200 Fiber analyzer (Anonymous, 2020). The data were subjected to analysis of variance in the MSTAT-C statistical software and the LSD test was used for the comparing the means for different treatments (Yurtsever, 2011).

3. Results and Discussion

The difference between plant heights of rye was statistically significant ($p<0.05$) while the difference between plant heights of forage peas was not statistically significant. Plant height of pure sowing and mixtures varied between 147.2 and 154.5 cm in rye and between 43.6 and 53.9 cm in forage pea (Table 2). The increase of tillering in rye plants and the related competition within the species can be associated with the increase in the heights of rye plants. Hatipoglu et al. (1999); Tas (2011) indicated that the cereals are tillered rapidly in the spring, and plant heights increase following the cool winter months. The plant heights of 80 local rye populations in Bingol province ecological conditions was reported between 120.9 and 146.5 cm and the mean plant height for Aslım-95 rye variety was 130.7 cm (Kabak and Akcura (2017). In a similar study conducted under Erzurum ecological conditions, the plant heights of 8 rye genotypes were reported between 145.7 and 168.02 cm (Karatas et al., 2020). The plant height of forage peas at the center of Konya province ranged between 94.1 to 119.2 cm in summer sowings, and between 76.21 and 110.3 cm in winter sowings (Konuk and Tamkoc, 2018). The researchers indicated that plant heights of forage peas at Konya Altınekin ecological conditions were between 94.0 and 110.3 cm in summer sowing, and between 170.0 and 181.0 cm in winter sowings. The difference in plant height between summer and winter sowings was associated to the differences in genotypes. In addition, the researchers stated that the plants were weak due to the late winter sowings, which caused damage due to frost heave and low temperatures, and the plants could not reach sufficient height (Konuk and Tamkoc, 2018). The reason of the shorten plant height were related to the severe terrestrial radiation in winter season and sudden temperature increase in spring season in research. The differences in plant heights reported by different researchers may be related to the fact that plant height is a genotypic character but is affected by different ecological conditions and agricultural practices (Ozer et al., 2005).

The green forage yield varied between 888.5 and 2395.1 kg da^{-1} and the differences in green forage yield between the treatments were statistically significant ($p<0.01$) (Table 3). Konuk and Tamkoc (2018) stated that the harsh winter conditions and high terrestrial radiation could damage forage pea and negatively affect the yield. The green forage yield in pure rye sowings and in mixtures increased as the rye ratio increased. The highest green forage yield was obtained from pure rye and 20% FP + 80% R mixture sowings.

Table 2. Plant Heights of Rye and Forage Pea

	Plant Height (cm)	
Species and Mixtures	**Rye**	**Forage Pea**
Pure Rye / Pure Forage Pea (%100)	154.5 a*	43.6
%20 FP + %80 R	151.3 ab	46.7
%40 FP + %60 R	149.9 ab	46.3
%60 FP + %40 R	147.2 b	45.9
%80 FP + %20 R	151.7 ab	53.9
Mean	150.9	47.3
CV	11.56%	11.27%

*: The means with different lowercase letters in the same column are significantly different ($p<0.05$)

Rye increased the green forage in the mixture and this might be due to its rapid tillering in the spring and increased height, which was caused by its competitive ability (Lithourgidis and Dordas, 2010). Karatas et al. (2020) reported the biological yield of Aslım 95 rye cultivar and 8 different rye genotypes between 1307.7 and 1487.4 kg da^{-1} in Erzurum ecological conditions. In a similar study conducted by Konuk and Tamkoc (2018) stated that the biological yield of forage pea ranged between 234.8 and 1359.2 kg da^{-1} in two different locations.

The effect of species and mixture ratios on average dry matter yield was statistically significant ($p<0.01$). The lowest mean dry matter yield (233.2 kg da^{-1}) was recorded in pure forage pea sowing and the highest dry matter yield (833.3 kg da^{-1}) was obtained in pure rye sowing (Table 3). The dry matter yield increased with the increase in rye ratio and decreased with the increase in forage pea ratio of the mixtures. Hatipoglu et al. (1999); Gündüz (2010) stated that cereals grow very vigorously in spring compared to legumes and caused higher dry matter yield and higher carbohydrate content. Dordas et al. (2012) stated that the dry matter yield could change depending on the legume ratio in the mixtures. The dry matter yield of pure forage pea in Kirsehir ecological conditions was reported as 308.3 kg da^{-1} by Yavuz (2017), and between 166.9 and 1190.3 kg da^{-1} in Konya-center and Konya-Altınekin ecological conditions by Konuk and Tamkoc (2018). The average yield of 50% vetch + 50% rye mixture in Bursa ecological conditions was reported as 635.5 kg da^{-1} by Acıkgoz and Cakmakci (1986). Yield differences among different studies may be due to pure and mixed sowings, differences in environmental conditions, especially in winter, and the effects of seasonal distribution of precipitation on plant growth.

Crude protein ratio was significantly different ($p<0.01$) between pure sowing and mixtures. The highest crude protein ratio was obtained from pure sown forage peas (15.6%), while the lowest ratio was recorded in pure rye (8.5%) sowing (Table 3). The increase in the ratio of forage peas of mixtures caused an increase in the crude protein ratio. Acar et al. (2017), which decreased with the decrease in the ratio of forage peas. In addition, crude protein ratio of pure forage pea and all mixtures were higher than the pure rye sowings. Similarly, Yavuz (2017); Lithourgidis et al. (2011); Pozdisek et al. (2011) indicated that protein ratio of legumes and legume + cereal is higher than the pure cereal sowings. Yavuz (2017); Lithourgidis et al. (2011); Pozdisek et al. (2011) also stated that the highest crude protein ratio was recorded in pure forage pea sowings, and the crude protein ratio of forage pea + cereal mixtures was higher than the pure cereal sowings. The crude protein ratio of Taşkent forage peas in Kirsehir ecological conditions was reported as 17.54% by Yavuz (2017). Uzun et al. (2012) showed that the crude protein ratio of forage pea varieties in Bursa ecological condition was between 15.4 and 14.2%, Acikgoz and Cakmakci (1986) reported the crude protein ratio as 5.1%, 5.8%, 7.6% and 9.5% in different agricultural applications of rye.

Crude protein yields varied between 36.3 and 71.0 kg da^{-1} and the effect of treatments on the crude protein yield was statistically significant ($p<0.01$) (Table 3). The lowest crude protein yield was obtained from pure forage pea sowings. The crude protein yield of pure rye and mixtures were statistically similar but higher than pure forage pea.

Table 3. Yield and Quality Traits of Species and Mixtures

Species and Mixtures	GFY (kg da^{-1})	DMY (kg da^{-1})	CPR (%)	CPY (kg da^{-1})	NDF (%)	ADF (%)
Pure Rye (%100)	2395.1 a**	833.3 a**	8.5 f**	71.0 a**	61.3 a**	39.5 a**
%20 FP + %80 R	2177.8 ab	708.1 b	9.9 e	70.0 a	56.6 b	38.1 ab
%40 FP + %60 R	1931.3 bc	599.7 bc	11.3 d	67.8 a	52.3 c	36.6 bc
%60 FP + %40 R	1810.3 c	531.5 cd	12.8 c	67.5 a	48.0 d	35.2 cd
%80 FP + %20 R	1662.8 c	468.3 d	14.2 b	66.2 a	43.6 e	33.7 d
Pure Forage Pea (%100)	888.5 d	233.2 e	15.6 a	36.3 b	39.3 f	31.1 e
Mean	1811.0	562.4	12.1	63.1	50.2	35.7
CV	9.81%	10.93%	3.47%	11.39%	2.05%	3.29%

**: The means with different lowercase letters in the same column are significantly different ($p<0.05$). GFY; Green forage yield, DMY; Dry matter yields, CPR; Crude protein ratios, CPY ;Crude protein yields, NDF: Neutral detergent fiber ratio, ADF; Acid detergent fiber rate

The crude protein yield was directly related to the crude protein ratio and dry matter yield. Therefore, obtaining high crude protein yield in pure rye sowings that had a high dry matter yield is an expected outcome (Table 3). Acıkgoz and Cakmakci (1986) indicated that crude protein yield of 50% vetch + 50% rye mixture at the beginning of spiking varied between 22.2 and 71.8 kg da^{-1}. Yavuz (2017) reported that the crude protein yields of the forage pea + oat mixtures were higher than the crude protein yields of pure sowing. Mut et al. (2006) determined the crude protein yield of Aslım-98 Rye variety was 60 kg da^{-1} at the beginning of spiking and 83 kg da^{-1} during milk dough period. The differences between the results may be attributed to the differences in dry matter yield and crude protein yield, as well as pure and mixed sowings of the species and cultivars used in the experiments.

The NDF ratio was significantly different ($P<0.01$) between pure sowings and mixtures. The lowest NDF ratio was obtained in pure-sown forage pea (39.3%), and the NDF ratio increased with the increase in the rye ratio of the mixtures. The highest NDF ratio was obtained from pure rye (61.3%) (Table 3). The difference between cereals and legumes has been associated with high cell wall substances of cereals than legumes, while legumes have more cellular compounds and less cell walls Cherney et al. (1985); Tan and Mentese (2003). The results revealed that the NDF and ADF ratios of rye was high, and the ratios of NDF and ADF were lower in forage peas (Table 3). The NDF ratio of Aslım-98 rye variety was reported as 59.08% by Kose et al. (2019) and Taşkent forage pea variety was reported as 40.15 % by Yavuz (2017).

The ADF ratio in pure rye was significantly ($p<0.01$) higher (39.5%) than the ADF ratio of pure forage pea (31.1%) and other mixtures, except for 20% FP + 80% R (Table 3). The difference in ADF ratios between forage pea and rye is an expected situation because the difference in the ADF ratios may be associated with the low leaf/stem ratio of the cereals in addition to the rapid maturation (Tan and Mentese, 2003). The increase of the forage pea ratio in the mixture decreased the ADF ratio, while the ADF ratio increased with the increase in the rye ratio (Table 3). Linn and Martin (1989); Lithourgidis et al. (2006) stated that the ADF ratio of the mixtures increased with the increase in the cereal ratio and decreased as the legume ratio increased. The ADF ratio of Aslım-98 rye variety under Yozgat ecological conditions was 35.74% (Kose et al. (2019). The ADF ratio of wheat + rye at the first and second harvest was 33.41% and 37.16%, respectively (Guney (2020), and the ADF ratios of forage pea was 30.33 % (Yavuz, 2017).

4. Conclusion

The increase in drought under changing climatic conditions increased the importance of sustainable agriculture and adequate quality food supply. Limited environmental resources could be used more effectively by mixed cropping systems, and this is an efficient solution to sustain agricultural production, especially in arid and semi-arid regions. In this study, forage pea and rye were evaluated by sowing purely or as mixture in different ratios to increase the hay quality. The results revealed that the purely-sown rye or rye + forage pea mixtures, which contains more than 60% rye had higher yield but the increase of forage pea ratio in mixtures increased the quality. A mixture of pure rye and 20% FP + 80% R can be grown to obtain high dry matter yield. However, a mixture of 40% FP + 60% R can be recommended to obtain high yield and quality.

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Drought Stress Mitigation of Bermudagrass Grown in Farmyard Manure Media with Coated Seed

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A B S T R A C T

Bermudagrass is one of the most commonly used warm-season turfgrasses worldwide. In this study, the tolerance to drought stress with uncoated seeds and seeds coated with biological preparations containing *Trichoderma harzianum*, Bacillus subtilis, and *Bacillus megaterium* in bermudagrass were assessed separately in soil media and farmyard manure respectively. Seeds of Gobi (registered cultivar) were used as plant material. Seeds of Gobi were planted in 2 different growing media, uncoated grass seeds were sown in the A (A = garden soil + river sand + peat) group growing medium and coated seeds were sown in the B (B = garden soil + river sand + farmyard manure) group growing medium. As the coating material, which is a new generation seed coating preparation containing *Trichoderma harzianum*, *Bacillus subtilis* and *Bacillus megaterium*, was preferred. Io create drought stress [I0 (0), I1 (25%), I2 (50%) and I3 (75%)], 4 doses of irrigation regimes were determined. The traits of clipping yield, shoot dry weight, root dry weight, leaf burning and turfgrass quality were all affected by levels of drought stress. However, farmyard manure and seed coating mitigated the adverse effects of drought stress.

1. Introduction

Bermudagrass (*Cynodon species*) is one of the most commonly used turfgrasses in tropical and subtropical regions (Arslan and Cakmakci, 2004; Karimi et al., 2018). Bermudagrass species form a very dense, strong and thick turfgrass layer (Juraimi, 2001) with narrow width leaf, which makes the grass surface vary between thin, very thin or medium-textured. The color of the leaves ranges from very light green to dark green, and growth occurs entirely horizontally via stolons and rhizomes (Ihtisham et al., 2018). This specie produces a vigorous, low-growing turfgrass stand with high density and tolerances to both traffic and drought stress (Xiong et al., 2007).

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Furthermore, bermudagrass is a turf species that is ideally suited for golf courses, sports fields, parks, and recreational places in hot, dry, or tropical regions. As known, urban green areas have grown in popularity over the previous decade (Ihtisham et al., 2020).

Drought is defined as a prolonged absence of precipitation that causes a significant decrease in soil water content and plant growth (Janmohammadi et al., 2008). Drought directly affects the growth and development of the plant, resulting in decreased yield potentials (Tiryaki, 2016; An and Liang, 2012). It is estimated that drought has affected an approximately 25-30% area used for agricultural purposes.

In agricultural terms, drought is related to the amount of water that the plant can absorb with its roots from the field during the growth period rather than the total amount of precipitation throughout the year (Blum, 1989; Kalefetoglu and Ekmekci, 2005). Plants that experience water deficiency during their growth period suffer from stunted growth and yield losses (Tuberosa, 2012; Turner et al., 2014). Furthermore, drought is one of the abiotic stress factors that have the significant impact on plant growth and development. (Farooq et al., 2009). Drought is becoming more severe in Türkiye as the temperature rises and precipitation decreases. Therefore, it is necessary to take measures to reduce the effects of drought on agriculture (Ozturk, 2015).

In the fight against such stress factors, the development of resistant/tolerant species and varieties is seen as the most permanent and practical solution (Samancioglu and Yildirim, 2015). However, since these methods and applications are expensive and time-consuming, so more practical and economic solutions are being studied. Nowadays, seeds are coated with several active substances to give tolerance to plants grown under stress conditions (Kaufman, 1991). Furthermore, the coating approach promotes plant growth and development, and it also includes materials that are resistant to various diseases and pests (Taylor et al., 1998). For this purpose, the transfer of rhizobacteria group bacteria to seeds for biocontrol purposes is one of the appropriate techniques (Deaker et al., 2004; Junges et al., 2013; Vavrina and McGovern, 1990).

Farmyard manure is an organic material mainly produced from animal excreta, other than in the case of green manure, which is mainly composed of plant sources, and it may be utilized as an organic source of nutrients in the soil (Wu and Ma 2015). These are comparatively inexpensive and eco-friendly inputs (Dauda et al. 2008). Farmyard manure also aids in improving soil's physical characteristics and enhances the chemical characteristics of the soil by strengthening soil organic nitrogen, carbon, potassium, and phosphorous content in the soil (Bayu et al., 2006a). Chahal et al. (2020) reported that it is evident that adding farmyard manure to the soil increases soil health and plant development.

The aim of this study is to examine the growth of uncoated seeds in A media and coated seeds in B media to observe whether applying farmyard manure and biological seed coating preparations containing *Trichoderma harzianum*, *Bacillus subtilis* and *Bacillus megaterium* results in mitigating the effects of drought stress in bermudagrass.

2. Materials and Methods

The trials were performed in plastic pots with a height of 22 cm and a diameter of 20 cm at the Akdeniz University of Agriculture Faculty Research Area. The trials were conducted in a fully open field environment between May 2021 and September 2021. During the trial (May-September) minimum, maximum and average temperatures with relative humidity values of the trial area in the province of Antalya were recorded and, are given in Table 1.

Table 1. Meteorological data of Antalya province, May-September 2021

Months	Ave. temp. (ºC)	Min. temp. (ºC)	Max. temp. (ºC)	Relative humidity (%)
May	22.93	16.34	28.75	64.44
June	25.45	19.35	31.32	61.11
July	31.28	24.95	37.68	46.07
August	31.13	24.66	37.48	47.71
September	26.08	19.96	31.95	56.85

For trial sieved garden soil was used. Pots were filled with 2 different growing media A and B mixed in a 4:1:1 volumetric ratio for coated and uncoated seeds respectively.

A media= garden soil + river sand + peat (4:1:1), used uncoated seeds

B media= garden soil + river sand + farmyard manure (4:1:1), used coated seeds

This prepared growing medium mixture was analyzed in laboratories and some of its chemical and physical properties are given in Table 2.

Bermudagrass-Gobi variety was used in this experiment. Uncoated grass seeds were sown in the A group growing medium, while coated seeds were sown in the B group growing medium. As the coating material, the commercial product called Panoramix, which is a new generation seed coating preparation containing *Trichoderma harzianum*, *Bacillus subtilis* and *Bacillus megaterium*, was preferred. Panoramix was obtained from Koppert Biological Systems. The coating preparation was applied to bermudagrass seeds at a rate of 4 L/1000 kg of seeds.

Table 2. The chemical and physical properties of the soil and sand mixture used in the plastic pots

A Media			B Media		
Characteristics	Determined amount	Evaluation	Characteristics	Determined amount	Evaluation
pH	7.8	Light alkali	pH	8.0	Light alkali
EC, μS/cm	222	Low	EC, μS/cm	597	Medium
Lime, %	29.4	Too limy	Lime, %	18.0	Too limy
Organic material, %	10.5	Low	Organic material, %	11.9	Low
Total nitrogen, %	0.336	Low	Total nitrogen, %	0.728	Enough
Phosphorus, ppm	0.8	Low	Phosphorus, ppm	1.45	Low
Potassium, ppm	34.32	Low	Potassium, ppm	498.5	Too much
Calcium, ppm	520.7	Enough	Calcium, ppm	658.7	Enough
Magnessium, ppm	27.0	Enough	Magnessium, ppm	50.25	Enough
Iron, ppm	1.72	Enough	Iron, ppm	7.66	Too much
Manganese, ppm	0.77	Low	Manganese, ppm	0.86	Low
Zinc, ppm	0.56	Enough	Zinc, ppm	0.63	Enough
Copper, ppm	1.14	Enough	Copper, ppm	1.46	Enough

Grass seeds were sown in the prepared pots with the seed number adjusted to cover the pot surface on May 25, 2021 and grown until they completely covered the surface of the pot. From the sowing till the end of the experiment, all pots were fertilized once every two weeks with NPK (15.15.15) compound fertilizer at a rate of 5 gr/m^2/month. The plants were reaped from a height of 4 cm once every 2 weeks. The grass completely covered the surface of the pots as well as the drought practices also started on 20th August and ended on September 30.

To create drought stress [I0 (0), I1 (25%), I2 (50%) and I3 (75%)] 4 doses of irrigation regimes were determined. Control pots (I0) were not treated with water during the trial period. As a result of the weighing, the amount of water lost in the pots was determined and water was given in appropriate amounts for the selected irrigation regime.

The experiment design was a level factorial design with 4 replicates for each stress level, with divided parcels consisting of 2 growing media and 4 drought stress levels forming the main parcels of varieties of turfgrass and the sub-parcels of the drought stress levels.

During the experiment, leaf burning rate (0-100% scale), turfgrass quality (1-9 scale), Clipping yield per pot (g), root dry weight (g) and shoot dry weight (g) values were measured.

The leaf burning (drying) rate of the grass leaves in each pot was determined using a 0–100% scale. On this scale, 0% indicates that there is no burning in the leaves, and 100% indicates that all the leaves in the pot are completely burned (Uddin et al., 2009).

Grass quality was evaluated every 15 days using a visual 1-9 quality scoring scale. On this scale, 1 = very bad with completely dead/yellow grass texture, 6.0 = minimum acceptable grass quality, 9.0 = ideal shoot density, texture, green color and homogeneity with excellent quality (Alshammary et al., 2004). Grass clipping was performed every two weeks throughout the trial at a considerable height, leaving 2 cm of grass on the plant., and the shot dry weight was recorded after drying for two days at 75°C.

The date was collected during the field trial were statistically analyzed by ANOVA and Duncan's multiple range test for comparisons were determined by SAS 9.3 (SAS Institute, 2011).

3. Results and Discussion

Drought stress significantly influenced the growth and development of plants and grass quality in Bermudagrass (Table 3). However, the effect of drought stress exhibited distinct results in both the growth medium and the biological seed coating applications (A and B media) (Table 3). In Bermudagrass grown clipping yield levels under drought stress conditions ranged between 2.31 g and 3.17 g. When the drought stress severity increased, the clipping yield decreased. However, as observed in Table 3, the clipping yield was significantly affected by the growth medium. Shoot dry weight varied between 5.14 g and 9.56 g, whereas root dry weight ranged between 4.06 and

6.36 g. Drought stress negatively affected shoot and root growth in Bermudagrass. When the leaf burning rate, an essential quality attribute of grass plants, is evaluated, it has been observed that drought stress induces a leaf burn rate of 96.67 % (Table 3). Turfgrass quality, which is the most important indicator of general plant development in turf areas, was also considerably affected by drought stress, and drought at I0 level had the lowest (1.00) degree, while it had the highest value (8.50) in I3 application. When Table 3 is thoroughly evaluated, it has been seen that the growth medium (GM) treatments (A and B) likewise cause statistically significant variations in terms of the evaluated parameters (except for root dry weight). In addition, the GM*D interaction was also revealed to be important for shoot dry weight, leaf burning, and turfgrass quality.

Table 3. Mean comparison of main effects drought stress levels in Bermudagrass

Drought stress	Clipping yield (g)	Shoot dry weight (g)	Root dry weight (g)	Leaf burning (%)	Turfgrass quality (1-9)
I0	2.55 AB[x]	5.74 B	4.45 A	96.67 A	1.00 D
I1	2.31 B	5.14 B	4.06 A	77.17 B	4.50 C
I2	2.88 AB	9.56 A	6.32 A	39.00 C	6.00 B
I3	3.17 A	8.91 A	6.36 A	7.33 D	8.50 A
Growing media (GM)	***	***	Ns	***	***
Drought (D)	*	**	Ns	***	***
GM*D	ns	**	Ns	**	*

[x]: Means with different letter(s) in each trait is significantly at 5% probability level according to Duncan's multiple range test. *, **, ***, ns: represent significant at 5%, 1%, 0.1% and non-significant, respectively.

Drought resistance mechanisms of turfgrass species fall into the categories of drought avoidance (or desiccation avoidance), drought tolerance, and drought escape (Pornaro et al., 2020).

In this study, the effect of drought stress on the Gobi Bermudagrass variety was studied. As multiple studies (Aydinsakir et al., 2014; Baldwin et al., 2006; Zhou et al., 2013; Carrow and Duncan, 2003) reported, drought stress severely affected the turf growth and quality and increased the rate of leaf burn in two different growing conditions were determined. Etemadi et al. (2005) revealed that considerable variations exist among the accessions regarding their drought resistance. Also, a selection of drought resistance among accessions may be achieved based on the total root length. Also, leaf burning provides a practical evaluation of total turfgrass drought resistance (Carrow and Duncan, 2003).

Aydinsakir et al. (2014) in their study to assess the responses of Seaspray and TifBlair grass varieties to water restriction, observed that drought stress severely damaged the quality of the grass by causing leaf burns. From this point of view, it has been discovered that the delivery of water up to 75 % of the evaporation gives both water savings and continuity in grass quality. Despite the negative effects of drought stress, plants with additional farmyard manure and biological seed coating preparation treatments (Application B) were less affected by drought stress (Table 3).

Similarly, it is mentioned by Arslan and Citak (2016) that farmyard manure techniques assist in the continuation of growth and development by mitigating the negative effects of existing stress such as salinity and drought on plants. Again, Bicakci et al., (2020) reported that biological seed coating increases germination and development by minimizing the effects of drought stress in the alfalfa plant. Sheaffer et al. (1988) revealed that seeds coated with chemical and biological solutions are particularly beneficial in providing healthy seedling development and better plant establishment under harsh environmental conditions. Essentially, the most prominent characteristic of the coating approach is to promote to plant development under varied stress conditions (Taylor et al., 1998). In other words, seed applications are important in terms of revealing the genetic and physiological potentials of plants. For this reason, several biological products are transferred to seeds by the coating approach an effectively applied as seed coating before sowing (Junges et al., 2013).

Farmyard manure is readily available in the crop-livestock farming systems and it has the potential for use in the fertilization programs of all crops to reduce dependence on inorganic fertilizers while maintaining good soil health (Bayu et al., 2006b). Similarly, Du et al. (2020) report that farmyard manure treatment has a lot of positive effects on soil properties as well as plant growth, development, and yield.

Parallel to the gradual increase / proliferation of grass areas, it also causes an increase in the amount of water used in these areas, often even the city's main water supply is used for this purpose (Sahin and Kara, 2005). For this reason, lawn managers show great interest in water conservation, research ways to reduce water consumption or prefer grass species and varieties that consume less water (Bastug and Buyuktas, 2003).

4. Conclusion

The gradual increase in grass areas also increases the amount of clean water used for these areas. It is very important to use existing water resources more effectively under the threat of global climate change. In this study, the response of Bermudagrass under drought stress conditions was investigated. It has been seen that the effects of drought stress would be tolerated to some extent by farmyard manure and seed coating application. The results of this research showed that it is possible to maintain the quality of Bermudagrass under drought stress conditions with limited applications.

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Crude Fiber, Ether Extract, and Some Mineral Contents of the Corn Silage Grown at Different Weed Densities

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A R T I C L E I N F O

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Silage quality has great importance in animal feeding as much as yield. Quality characteristics are generally evaluated over crude protein and digestibility, but parameters related to mineral, total fiber, and sugar contents are also important indicators of silage quality and its nutritive value. Plant characteristics could affect these parameters, as silage material, and thereby, any environmental factors could affect these parameters indirectly. Weeds are one of the main environmental problems in silage corn production and in this study, the effect of weed density (0, 2, 4, 6, 8, 10, 12, 14 weeds plant m^{-2}) on ether extract, crude ash, crude fiber, starch, and mineral (Mg, Ca, P) contents of the silage was investigated in the years of 2019 and 2020. Inter-annual climatic variations had significant effects on ether extract, crude fiber, starch, Ca, and P contents of corn silage. The effect of weed densities was observed only on starch and Ca content. Increasing weed density decreased the Ca content but starch content showed an irregular variation. Weed density did not cause any significant variations in ether extract, crude ash, crude fiber, Mg, and P contents of the corn silage, but the total amount of the nutrition could be increased in silage by decreasing the competitive ability of the weeds at growth conditions of the silage corn.

1. Introduction

More than half of the livestock production costs consist of forage inputs. However, good quality forage is necessary for the proper nutrition of livestock because forage quality has a significant effect on animal performance (Kara et al., 2021). The quality of forage is determined by plant species, climate, soil fertility, and growth conditions. Besides, some manageable factors such as fertilization, irrigation, and weed struggle directly affect the quality (Lukangila, 2016).

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The quality degree could be related to the maturity level and/or the participation of some parts such as stem, leaf, and generative organs in the forage (Hassannejadd and Navid, 2013). Losses of plant tissues or organs could cause significant yield losses as well as quality. Therefore, management practices could be carried out properly to avoid low yield and lower quality than expected. For example, the yield of silage corn could be decreased by about 20-80 % depending on weed density in the stand (Shrestha et al., 2019) because weed competition causes yield losses by decreasing plant height, leaf area, and photosynthetic efficiency (Butts et al., 2017). Thereby, lignification decreased, while other quality parameters increased. This increment in quality is only ratio-based and decreased due to significant yield losses (Rajcan and Swanton, 2001). Indeed, the contribution of the plant part could also affect the silage quality significantly.

The photosynthetic efficiency of silage corn decreases due to competition with weeds for light, water, and nutrients, and consequently, the growth rate and dry matter ratio are decreased. Decreasing the dry matter ratio causes significant variations in CP, fiber, NDF, ADF, ether extract, starch, ash, mineral, amino acid contents, and digestibility of silage corn positively or negatively (Carvalho et al., 2006; Abdelqader et al., 2009; Azevedo et al., 2011; Heuze et al., 2017). Weed competition is for limited resources and negatively affects the seedling growth of silage corn. Production performance decreases and the contribution of leaf, cob, and stem change due to poor growth. In some cases, even cob could not be formed. The cob ratio is a significant parameter for quality and silage quality significantly decreases if cob did not exist (Kilic, 1986). The quality of silage prepared using the plants, which did not complete their potential growth, could be high, but despite the high quality, this type of production could not compensate for the needs due to low yield.

This study was planned to examine the silage quality of the corn (crude ash, ether extract, crude fiber, starch, Ca, Mg, and P) grown at different weed densities.

2. Materials and Methods

The research was carried out in the experimental station of Eskişehir Osmangazi University, Faculty of Agriculture during the main crop season of 2019 and 2020 years. The experiment was conducted due to a randomized complete blocks design with 6 replications. Simpatico was used as the corn cultivar and ensilaged after growing in different weed densities as 0, 2, 4, 6, 8, 10, 12, 14 weeds m^{-2}. Weed species were identified as *Chenopodium album*, *Amaranthus blitoides*, *Amaranthus hybridus*, *Solanum nigrum*, *and Xanthium strumarium* in the plots. In every plot, 70 kg ha^{-1} N and 180 kg ha^{-1} P_2O_5 were applied while sowing. Additional fertilization was carried out using 70 kg ha^{-1} N both during the V1-V5 and V6-V8 stages. Plants were irrigated once a week for 15 hours using drip irrigation that has a 1.9 l h^{-1} flow rate.

Harvest was carried out when corns reached to dough stage in weed-free plots for both years. Harvested plants were mechanically processed and ensilaged. All samples were subjected to the same mechanical process and any inoculant was not used. After filling, silage bags were vacuumed and strapped to avoid air intake of the bags.

Silage bags were opened and investigated after 8 weeks of the fermentation period. Samples from each bag were oven-dried at 70 ºC until reached constant weight. Dry samples were grounded to pass through a 2 mm sieve and ash, ether extract, crude fiber, starch, Ca, Mg, and P contents were determined using FT-NIR (Fourier Transform Near-Infrared, Bruker MPA) spectroscopy.

All data were subjected to analysis of variance using SAS statistical software (SAS Institute, 2011). Means were compared using Bonferroni/Dunn multiple comparison test.

3. Results and Discussion

Average crude ash was determined as 7.67%. Despite it varied between years and among the weed densities in the range of 7.07 – 8.54%, the variation between the years and among the weed densities was statistically non-significant. The interaction was also non-significant (Table 1).

Ether extract of the silage significantly varied between the years ($p<0.01$) but weed densities and interaction were statically non-significant. The ether extract was 1.85% in 2019 and increased to 2.27% in 2020 (Table 1). Ether extracts of the silages prepared from weed-free plots were numerically higher but this variation was statically non-significant (Table 1).

The variation of crude fiber content was statically significant between the years ($p<0.01$). It was 17.75% in 2019 and significantly increased to 22.30% in 2020 (Table 1). Weed densities did not have a significant effect on crude fiber content and the interaction was also non-significant. However, the crude fiber content of the silage was numerically the highest for the plants that were grown at the weed density of 14 weeds m2, which was 21.19% (Table 1).

Table 1. Means and ANOVA results of the examined characteristics

	Crude Ash (%)	Ether Extract (%)	Crude Fibre (%)	Starch (%)	Ca (%)	Mg (%)	P (%)
Year (Y)							
2019	7.86	1.85 B	17.75 B	26.13 B	0.38 A	0.14	0.16 B
2020	7.48	2.27 A	22.30 A	33.84 A	0.24 B	0.13	0.21 A
Weeds Density (WD)							
0	7.63	2.27	19.13	24.39 D	0.34 B	0.12	0.19
2	7.49	1.93	20.26	26.97 D	0.38 A	0.17	0.18
4	7.48	1.94	20.62	28.32 C	0.32 B	0.13	0.19
6	8.54	2.00	20.00	33.60 B	0.37 A	0.14	0.19
8	8.33	1.96	18.73	29.70 C	0.32 B	0.12	0.19
10	7.07	2.09	19.36	37.61 A	0.33 B	0.10	0.20
12	7.51	2.07	20.92	30.53 C	0.20 C	0.20	0.19
14	7.31	2.22	21.19	28.81 C	0.23 C	0.11	0.18
Average	**7.67**	**2.06**	**20.03**	**29.99**	**0.31**	**0.14**	**0.19**
Y	ns	**	**	**	**	ns	**
WD	ns	ns	ns	**	**	ns	ns
YxWD	ns	ns	ns	**	ns	ns	ns

ns: non significant, *: P≤0,05, **: P≤0,01

Starch content was 26.13% in 2019 but it was significantly higher in 2020 (33.84%) and this variation was significant at the level of 1% (Table 1). Weed densities significantly affected ($p<0.01$) the starch content of the silage and the highest starch content was determined from the plots that contain 10 weeds m^{-2} (37.61%), while it was the lowest (24.39%) for weed-free plots (Table 1). Weed-related variation of silage starch content was different in each year and therefore, a significant year × weed density interaction was determined.

Average Ca content was 0.31% and it was significantly higher ($p<0.01$) in 2019 than in 2020 (Table 1). Ca content significantly varied ($p<0.01$) among the weed densities in the range of 0.20-0.38%. Increasing weed density caused an irregular decrement in the Ca content of the silage. Year × weed density interaction was non-significant.

Silage Mg content did not vary significant between the years, among the weed densities, and year × weed density interaction was also non-significant. Average Mg content was recorded as 0.14% (Table 1).

P content of the silage was 0.16% in the first experimental year and increased to 0.21% in the second year. This variation was significant at the level of 1% (Table 1). Weed densities did not cause significantly changes in P content and year × weed density interaction was also non-significant (Table 1).

High-quality silage could be ensured by avoiding dry matter loss and by providing aerobic stability. Besides, sufficient nutrition content is preferred. The quality of silage could be determined through physical and chemical analyses. Plant characteristics are the most important factor in silage quality as long as the spoilage is prevented. In the study, the crude ash content of the silage, which was prepared using silage corn grown at different weed densities, did not change in different years and depending on weed densities. The crude ash content of silage could change between 4.9 – 9.8% (Azevedo et al., 2011; Heuze et al., 2017).

Silage ether extract and crude fiber contents are changed depending on dry matter and plant organs, which affect the dry matter content of the plant (Seydoşoğlu and Cengiz, 2020). Yearly variations of ether extract and crude fiber content of the silage are possibly related to differences in cob, stem, and leaf ratios between the experimental years. Because a low leaf and stem ratio with a high cob ratio was observed in the first year but contrarily, a low cob ratio was observed in the second experimental year (unpublished data). Consequently, ether extract and fiber content of the silage showed significant variations between the years.

Starch is the main product of photosynthesis and could be stored in plant organs. The starch stored in the leaves is hydrolyzed into sucrose at night but starch is stored longer in the storage organs of the plants and used for metabolic processes (Ölçer and Akın, 2008). For silage corn, most of the starch is stored in cob but if the plant could not develop cobs due to any reason, starch is stored in leaves and stem. Leaves, stems, and cobs of the silage corn contain starch at the harvest stage because it is green-chopped (Figure 1.). Different starch content among the weed densities might be related to differences in leaf, stem, and cob ratios of the silage corn that is grown at different weed densities. Some plant organs might not develop under intense weed density. In this study, weed density increased the leaf and stem ratio but decreased the cob ratio. Therefore, starch content significantly varied. In other words; leaf, stem, and cob ratios change as the weed density increases. Other researchers also stated that plant height, leaf, stem, and cob ratios are closely related (Uremis et al., 2009; Vazin, 2012, Dogan et al., 2004). The great variation between leaf and cob ratios was related to weed density and also weed species (unpublished data). This is another reason for the significant year □ weed density interaction.

Inter-annual climatic variations are a natural phenomena, which directly affects plant production and quality. Weeds, as an environmental factor, could restrict the growth and genetical potential of the plants through competition, and thereby, great variations may occur in mineral contents such as Ca, Mg, and P (Carvalho et al., 2006; Abdelqader et al., 2009; Azevedo et al., 2011; Heuze et al., 2017). This might be the reason for the significant variation in Ca content of the silage among the weed densities in the study.

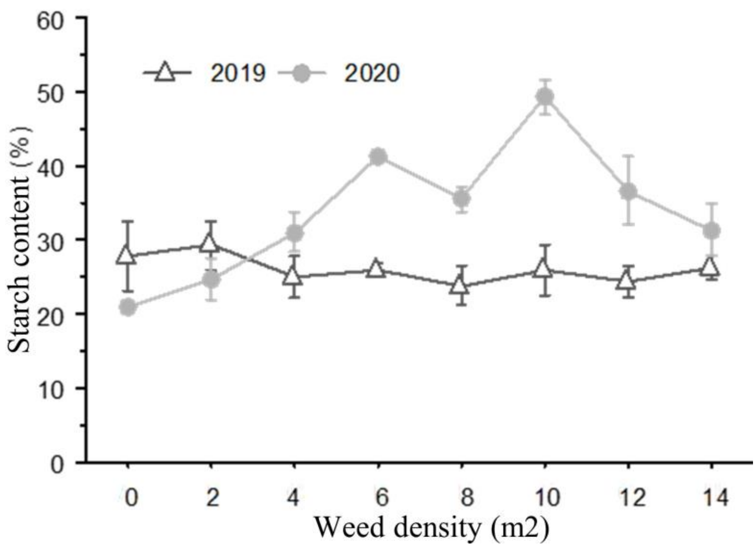

Figure 1. Variation of starch content in both years and at different weed densities

4. Conclusion

Ether extract, crude fiber, starch, Ca, and P contents of the additive-free corn silage, which was prepared using the silage corn grown at different weed densities, showed significant variations between the years. Weed density only affected the starch and Ca content of the silage. Although weed density did not affect some quality parameters of the corn silage, total production and the total amount of nutrients could be increased by weed struggle. The yield and silage quality of the plants could be increased by eliminating or alleviating the effects of weeds and decreasing their competitive ability.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authorship contribution statement

All authors equally contributed to the study.

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Effects of Row Spacing on Yield and Quality of Forage Pea (*Pisum sativum* ssp. *arvense*)

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Peas are globally used as forage, haylage, silage or straw in ruminants' diet. Winter forage pea is also becoming an important forage crop, particularly for haylage production in Türkiye. Row spacing produce different spatial arrangements that influence competition for resources, especially radiation, in forage pea production. The aim of this study is to determine the appropriate row spacing for forage peas depending on hay yield and quality. Field experiments were performed Kızıltepe district, Mardin province of Türkiye during winter growing seasons of 2018-2019 and 2019-2020. Özkaynak pea variety was used in the experiments. Three row spacings (RS) (20, 30 and 40 cm) were applied. The experimental units had an area of 12 m2 (2.4×5) in size and equal seed rate was used in each experimental unit (on 150 kg ha $^{-1}$). Higher plant height (127.8 cm) was recorded under 20 cm RS, compared to 30 (121.8 cm) and 40 cm (121.2 cm). The average green forage yield was 26.7, 27.7, and 28.8 t ha^{-1} for 40, 30, and 20 cm RS, respectively. Whereas the average hay yields for 20, 30, and 40 cm RS were 5.20, 5.34, and 5.79 t ha^{-1}, respectively. Crude protein (CP) ratio was significantly lower for 40 cm (20.2%) RS compare to 20 (22.5%) and 30 (21.6%) cm RS. Average raw ash, dry matter uptake (DMI) and relative nutritional value (RFV) ratios significantly increased in 30 cm and 40 cm RS compared to the 20 cm. However neutral detergent fiber (NDF) ratio decreased in 30 cm and 40 cm RS compared to 20 cm. Acid detergent fiber (ADF) and digestible dry matter (DDM) were not significantly affected from RS. In conclusion, 20 cm RS would be more suitable and economical due to higher plant height, green forage and hay yields, and higher CP and NDF rates for commercial feed producers in the region. However, 30 cm RS may be more suitable for farmers producing feed for their own livestock due to higher DMI and RFV values.

1. Introduction

Pea is a palatable and nutritious cool-season legume (Mihailovic et al., 2013), which is an essential component of human nutrition (Sapre et al., 2021). Like other legumes, peas are rich source of proteins, dietary fiber, micronutrients, and bioactive phytochemicals (Nithiyanantham et al., 2010). There is increasing interest in plant-based protein sources for human and animals due to high contents (23-33%) (Renata et al., 2021). Pea seeds contain high amounts of carbohydrates, proteins,

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amino acids, vitamins C and A, phosphorus, and calcium (Jovicic et al., 2010).

Peas are used as forage, haylage, silage or straw in ruminants' diet in Europe, West Asia and North Africa (Mihailovic and Mikic, 2014). Winter forage pea is becoming an important forage crop, particularly for haylage production in Türkiye. It gives high yield of quality forage even under drought stress. Therefore, dry pea cultivation in Türkiye could be practiced utilizing empty fields by growing it as an intermediate crop in the winter months. In addition, a new/alternative species will be added to the legume crops, which are of great importance for sustainable agriculture and crop rotation. Therefore, it will significantly contribute towards agricultural and economic sustainability.

Local forage pea (*Pisum sativum* ssp. *arvense* L.) ecotypes are commonly cultivated in the Eastern Anatolia region of Türkiye recently. Dry matter yield and yield components of 18 forage pea ecotypes selected from 61 materials collected from Erzurum, Bayburt, Kars and Ardahan provinces were determined under irrigated conditions. Dry matter yield of the ecotypes ranged between 4.86-6.85 t ha^{-1} (Tan et al., 2013). Besides, straw yield of promising local ecotypes selected from different locations in the northern part of Eastern Anatolia varied between 3.37-4.57 t ha^{-1}, whereas seed yield ranged between 1.50-2.21 t ha^{-1} (Tan et al., 2012).

Row spacing affects crop density that drives inter-specific (between crop and weeds) and/or intra-specific (among crop plants) competition (Özer et al., 2001; Liu et al., 2017). Reducing row spacing produces more square spatial arrangements that affects competition for resources, particularly radiation (Mattera et al., 2013). Therefore, row spacing influences both plant size and density throughout initial growth period (Mattera et al., 2009). Row spacing has a great importance in the forage pea production.

This study was carried out to determine the effect of different row spacing on the yield and quality of forage peas under ecological conditions of Kızıltepe district, Mardin province, Türkiye. Optimizing row spacing for pea cultivation in the region was the major objective of the study.

2. Materials and Methods

The study was conducted in Köprübaşı village, Kızıltepe district, Mardin province in South Anatolia region of Türkiye during winter growing seasons of 2018-2019 and 2019-2020. According to the soil analysis (0-30 cm); soil was clay-loam, pH neutral, slightly saline, low in lime, poor in organic matter, high in potassium and low in phosphorus. The soil properties of the study area are given in Table 1.

Table 1. Soil properties of the research area prior to sowing

Soil properties	**2018**	**2019**
Texture	Clay-Silt	Clay-Silt
Ph	7,35	7,28
Salt	0,3	0,28
Organic matter	1,45	1,51
$CaCO_3$ (%)	4,63	4,41
N	0,84	0,95
Phosphorus (P_2O_5) (kg ha^{-1})	27,2	26,4
Potassium (K_2O) (kg ha^{-1})	2580	2620

Total amount of precipitation during the first and second year of study was 396 mm and 488 mm, respectively. Total precipitations in both years were higher than long-term average (272 mm). Average temperature and relative humidity values were similar during both years (Table 2).

Özkaynak pea variety registered by Selcuk University, Agricultural Faculty, Konya/Türkiye in 2008 was used in the experiments. Seeds were sown in November during both years. The field was deeply plowed prior to planting, and a cultivator and press were used for seedbed preparation. The experimental units had an area of 12 m^2 (2.4×5) in size. Row spacing was 20 cm (12 rows/experimental unit), 30 cm (8 rows) and 40 cm (6 rows). Equal seed rate was used in each experimental unit (on 150 kg ha^{-1}). Although the number of rows in the experimental units varied, the amount of seed sown remained constant. A total of 175 kg ha^{-1} DAP (18.46.0) and 20 kg ha^{-1} Urea (46% N) were applied at sowing. Therefore, a total of 80 kg ha^{-1} pure P_2O_5 and 40 kg ha^{-1} pure N were applied to the experimental fields in both years. Weeds were manually controlled. The harvesting was done on 2 April in 2019 and on 5 April in 2020. Hay yield was determined by drying a 500 g fresh plant sample in an oven at 70 °C until constant weight. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined by the method of ENISO 13906, (2008). Nitrogen contents were determined by Kjeldahl method, and crude protein (CP) ratios (%) were calculated by multiplying the obtained values with a coefficient of 6.25 (AOAC, 1990). The method proposed by Moore and Undersander (2002) was used to calculate the digestible dry matter (DDM), dry matter uptake (DMI) and relative nutritional value (RFV) parameters. The equations used in the calculations are given below.

$$DDM = 88.9 - (0.779 * ADF) \quad (1)$$

$$DMI = 120/NDF \quad (2)$$

$$RFV = (DMI \times DDM)/1.29 \quad (3)$$

Statistical analysis was conducted according to Randomized Complete Block Design. The JMP statistical package program was used for variance analysis (Kalaycı, 2005).

Table 2. Weather (temperature, precipitation, and humidity) data during experimental years and long-term averages data of Kızıltepe/Mardin

	Years	Janu	Febr	March	April	May	June	July	Agus	Sept	Oct	Nov	Dec
	2018	8.5	10.2	14.3	17.7	21.8	28.1	30.9	30.2	27.0	21.6	13.2	9.1
Temperature (°C)	**2019**	6.6	8.8	10.7	13.9	22.7	29.5	30.8	31.7	26.3	22.3	13.5	9.9
	2020	3.6	3.8	10.7	14.1	19.9	26.2	31.5	29.9	29.3	22.8	12.0	
	LTA	6.9	9.0	12.2	16.0	21.7	28.5	32.1	30.9	26.2	20.5	13.3	8.1
	2018	48.3	35.7	5.2	12.1	103.8	0.8	0.9	0.2	0.1	48.6	32.2	51.5
Precipitation (mm)	**2019**	44.1	27.4	95.8	79.7	49.2	16.3	1.7	0.1	0.3	32.7	11.8	54.5
	2020	75.9	102.8	157.3	51.6	30.5	31.5	4	0	0	0	35.7	
	LTA	36.0	33.15	59.18	37.62	38.77	3.53	0.73	0.20	1.47	24.51	33.29	33.53
	2018	67.4	70.9	64.1	53.0	60.8	33.9	31.3	38.3	35.3	47.4	77.8	88.1
Humidity (%)	**2019**	86.5	87.5	86.7	94.3	9.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	2020	71.9	71.4	65	59.7	43.4	26	20.6	22.1	20.6	22.5	55.8	
	LTA	71.6	66.1	69.0	63.0	47.0	25.1	21.0	27.6	30.5	38.3	50.7	65.5

*LTA= Long Term Average. Data was obtained from Mardin Meteorology Provincial Directorate.

3. Results and Discussion

Row spacing (RS) and Year × RS interaction was significant for plant height. Higher plant height (127.8 cm) was recorded under 20 cm RS, compared to 30 (121.8 cm) and 40 cm (121.2 cm). The highest plant height was recorded for 20 cm RS in 2019 considering the year × RS interaction. However, the plant heights were the lowest under 30 cm and 40 cm RS in 2018 and 2019, respectively (Table 3).

The RS, year and year ×RS interaction were significant for green forage yield. The average green forage yield was statistically higher in 2019 (27.9 t $ha^{-1)}$ than 2018 (27.6 t ha^{-1}). The average green forage yield decreased as RS increased. The average green forage yield was 26.7 t ha^{-1}, 27.7 t ha^{-1}, and 28.8 t ha^{-1} for 40, 30, and 20 cm RS, respectively (Table 3).

Table 3. Plant heights and green herbage yields depending on row spacing

	Plant heights (cm)			**Green forage yields (t ha^{-1})**		
Row spacing(cm)	**Years**		**Averages**	**Years**		**Averages**
	2018	**2019**		**2018**	**2019**	
20	125.3 b	130.2 a	127.8 a	28.4 b	29.2 a	28.8 a
30	119.2 e	124.3 bc	121.8 b	27.5 d	27.9 c	27.7 b
40	122.3 cd	120.1 de	121.2 b	26.8 e	26.6 f	26.7 c
Average	122.27	124.87		27.6 B	27.9 A	
LSD	RS^{**}: 1.937; Year x RS^{**}: 2.739			Year **: 7.631; RS^{**}: 7.494; Year x RS^{**}:10.598		
CV (%)	1.18			0.20		

RS: Row spacing

The average hay yield and CP ratios (%) decreased as RS increased. The RS, year and year × RS interaction was significant for Hay yield. However, no difference was observed in the CP ratio for years and year by RS interaction. The overall means of CP ratios were statistically different depending on RS. Hay yield was significantly lower in 2018 (5.41 t ha^{-1}) than 2019 (5.48 t ha^{-1}). Hay yield ranged from 5.20 t ha^{-1} to 5.86. The average hay yields for 20, 30, and 40 cm RS were 5.20, 5.34, and 5.79 t ha^{-1}, respectively (Table 4).

Table 4. Hay yields and CP ratios values depending on row spacing

	Hay yields (t ha^{-1})			CP Ratios (%)		
Row spacing (cm)	Years		Averages	Years		Averages
	2018	2019		2018	2019	
20	5.79	5.86	5.79 a	22.1	22.8	22.5 a
30	5.29	5.40	5.34 b	22.1	21.1	21.6 a
40	5.21	5.20	5.21 c	20.3	20.0	20.2 b
Averages	5.41 B	5.48 A		21.3	21.5	
LSD	Year *: 7.103 IRD**: 8.703			IRD**: 1.139		
CV (%)	1.20			4.00		

RS: Row spacing

The RS, year and year ×RS interaction were non-significant for ADF and DDM ratios (Tables 5 and 6). Besides, no difference was observed in raw ash, NDF, DMI, and RFV ratios for years and year by RS interaction. Overall means of raw ash, NDF, DMI, and RFV ratios significantly varied among RS (Table 5, 6, and 7).

Average raw ash, DMI and RFV ratios significantly increased in 30 cm and 40 cm RS compared to the 20 cm. However, NDF ratio decreased in 30 cm and 40 cm RS compared to 20 cm (Table 5, 6, and 7).

Average raw ash contents were %8.0, %8.9 and %8.7 for 20, 30 and 40 cm RS, respectively (Table 5).

Two years' average values of NDF ratio decreased from 44.9% to 42.4% - 42.7% with increase in row spacing (Table 6). However, DMI and RFV ratios increased from 2.67% and 129.9% to 2.82-2.89% and 139.1-139.7%, respectively (Table 7).

Table 5. Raw ash ratios and ADF ratios depending on row spacing

	Raw ash ratios (%)			ADF ratios (%)		
Row spacing (cm)	Years		Averages	Years		Averages
	2018	2019		2018	2019	
20	8.10	7.90	8.0 b	33.90	33.40	33.65
30	9.30	8.50	8.9 a	32.70	33.10	32.90
40	8.80	8.60	8.7 a	32.20	31.80	32.00
Averages	8.73	8.33		32.93	32.77	
LSD	IRD**: 0.442			---		
CV (%)	3.890			5.92		

RS: Row spacing

Table 6. The NDF ratios and DDM ratios depending on row spacing

Row spacing (cm)	NDF ratios (%)			DDM ratios (%)		
	Years		Averages	Years		Averages
	2018	2019		2018	2019	
20	44.50	45.30	44.9 a	62.49	62.88	62.69
30	41.50	43.30	42.4 b	63.43	63.12	63.27
40	42.80	42.60	42.7 b	63.82	64.13	63.97
Averages	42.93	43.73		63.24	63.38	
LSD	IRD*: 1.768			---		
CV (%)	3.07			2.39		

RS: Row spacing

Table 7. The DMI and RFV values depending on row spacing

Row spacing (cm)	DMI			RFV		
	Years		Averages	Years		Averages
	2018	2019		2018	2019	
20	2.70	2.65	2.67 b	130.66	129.11	129.9 b
30	2.89	2.77	2.83 a	142.22	135.94	139.1 a
40	2.81	2.82	2.82 a	138.94	140.45	139.7 a
Averages	2.80	2.75		137.27	135.17	
LSD	IRD*: 0.112			IRD*: 7.851		
CV (%)	3.10			4.329		

RS: Row spacing

Fresh forage yield ranged between 10.4-23.8 t ha$^{-1,}$ whereas dry matter yield varied between2.52-5.89 t ha^{-1} in Mardin province, Türkiye (Sayar and Han, 2016). Total fresh forage yield vales in the current study were higher than reported earlier from the same province. The differences are most probably due to the row spacing differences and varieties used. In addition, the total precipitation amount in two consecutive experiment years was considerably higher than the long-term average precipitation. Therefore, increase in the precipitation positively affected the pea yield. Several researchers emphasized that water stress has a significant effect on the yield of peas; therefore, it is important to use varieties suitable for the agro-climatic conditions of the region (Martin et al., 1993; Olle 2017; Krizmanic 2020). Similarly, dry matter yield of different ecotypes tested by Tan (2013) ranged between 4.86 and 6.85 t ha^{-1}, and the plant height varied between 68.8 and 102.0 cm. The hay yield values were similar to our results. Therefore, the results are generally in agreement with the current study. However, plant height was higher in the current study. The differences in plant height are probably due to the ecological condition and varieties used in the experiments.

4. Conclusions

- The plant height, green forage yield, and hay yield values were increased as RS decreased. Thus, the highest vegetative growth parameters were recorded under 20 cm RS.
- The highest CP and NDF ratios were recorded for 20 cm RS.
- Raw ash, DMI, and RVF values were lowest in 20 cm RS, whereas these values were higher and almost similar for 30 and 40 cm RS.

In conclusion, 20 cm RS would be more suitable and economical due to higher plant height, green forage and hay yields, and higher CP and NDF rates for commercial feed producers. However, 30 cm RS may be more suitable for farmers producing feed for their own livestock due to higher DMI and RFV values.

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