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Phone: +90 362 408 25 15

Fax: +90 362 408 25 15

Email: bsjagri@blackseapublishers.com

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DETERMINATION IN FORAGE YIELD AND QUALITY OF CHICORY AND DIFFERENT PLANTS MIXTURES IN GRAZING MATURITY PERIOD

Elif ÖZTÜRK[1]*, İlknur AYAN[1]

[1]*Ondokuz Mayıs University, Faculty of Agriculture, Department of Field Crops, 55200, Samsun, Türkiye*

Abstract: This study was conducted to determine forage yield and quality of chicory (*Cichorium inthybus* L.) in a pure stand and a simple pasture (two-species) in the grazing maturity period. The experiment design was a Randomized Block Design with 3 replications. The experimental site was located on the grounds of the Ondokuz Mayıs University Agricultural Faculty during the 2017 and 2018 growing periods. In this study, chicory (C), orchardgrass (OG), and red clover (RC) were grown as forage plant materials in a rainfed cropping system in North Türkiye. Simple pastures comprised of 80%C + 20%OG, 60%C +40%OG, 40%C + 60%OG, 20%C + 80%OG, 80%C + 20%RC, 60%C + 40%RC, 40%C + 60%RC, 20%C + 80%RC. Five sequential harvests were made when chicory plants reached 25 cm of plant height in both years. The average plant height ranged from 17.3 to 35.6 cm, and 29.1 to 38.3 cm in 2017 and 2018 respectively. The highest fresh forage yield was determined in red clover mixtures (6519-5443 kg/da) in 2017 and 80%C+20%RC mixture (as 7137 kg/da) in 2018. Total dry matter production was ranged from 216 to 1238 and 279 to 1164 kg/da in 2017 and 2018, respectively. In pure stand chicory pasture, dry matter production was evaluated 216 kg/da in 2017 and 908 kg/da in 2018. Considering the calculated area equivalence ratios (LER) of mixed planting plots in both years and in all forms, it was determined that all mixtures were superior to plain plantings (LER≥1).

Keywords: Chicory, Orchardgrass, Red clover, Mixture ratios, Competitive

***Corresponding author:** Ondokuz Mayıs University, Faculty of Agriculture, Department of Field Crops, 55200, Samsun, Türkiye
E mail: elif.ozturk@omu.edu.tr (E. ÖZTÜRK)
Elif ÖZTÜRK https://orcid.org/0000-0001-9723-6092
İlknur AYAN https://orcid.org/0000-0002-5097-9013

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1. Introduction

Türkiye has favorable ecological conditions and topography of the environment to grow most of the forage plants. In addition to traditional forage crops, using alternative fodder crops contribute significantly to the solution of the roughage deficit problem (Acar et al., 2020). The compatibility of a forage plant with the ecological conditions and agricultural infrastructure allows becoming widespread in a certain area. Growers prefer forage crops with a shorter economic life, rather than using alfalfa, which has an economic life of 7-8 years, on crop rotation. Chicory (*Cichorium inthybus* L.) is one of the forage crops that can be utilized short economic life pasture plant. Chicory is one of the forage crops that can be utilized as a short economic life pasture plant. It can be used with many traditional pasture plants such as red clover and orchardgrass with its economic life of 4-5 years. (Li et al., 1997; Acar and Ayan, 2000). Chicory is classified high-quality forage plant with high palatability, digestibility, and rich in mineral substances. Also, its good drought-tolerance ability makes it a valuable forage plant, especially warm-season period. In addition to those, chicory helps to reduce bloat hazard and parasite formation in the rumen (Barry, 1998; Athanasiadou et al., 2007; Molle et al., 2008). Thanks to vegetative characteristics such as a low-growing point and deep taproot, it is resistant to intensive grazing. Considering using forage crops from different families in a mixture is substantial to increase yields of high-quality forage in the world due to limited agricultural lands recently. In addition to traditional forage crops, a forb should be used in pasture mixtures. Thus, the nitrogen accumulated by legume plants in the soil is used by forbs that provide balanced feed in terms of nutrients and minerals. However, intermingled mixtures cause interspecies competition for light, energy, and nutrients. Therefore, to achieve the expected benefit from intermingled mixtures, it is necessary to choose appropriate plant species and varieties as well as the most appropriate mixing ratio (Dordas et al., 2012; Uzun and Aşık, 2012). The present study aimed to investigate the most appropriate mixing ratio/ratios and forage yield of chicory with orchardgrass (*Dactylis glomerata* L.) and red clover (*Trifolium pratense* L.) at grazing maturity in ecological conditions of Samsun.

2. Materials and Methods

The study was conducted at the Ondokuz May University, Faculty of Agriculture Research Center in Samsun Türkiye (41 ° 21'N, 36 ° 15'E). The site was located on the south–west facing slope (8%) of the hill. The altitude of the site was 120 m and the depth of soil was 23 - 40 cm (Gülser et al., 2003). Soil tests indicated the site had the following conditions: organic matter, 3.37%; clayey soil, 45%; available N, 0.16; available P_2O_5, 65.4; K, 340; Ca, 2.18 meq/100 g; and soil pH, 6.34. The average temperature and total precipitation values were 15.2 ^oC and 657.3 mm in establishment year. In the following year the average temperature and total precipitation data from January to October were determined 17.5 ^oC and 648.5 mm. It was determined that the dry period was between June and September in 2017, and between April and July in 2018.

In the present study, the "Commander" variety of chicory, "Lidacta" of orchardgrass, and "Suez" varieties of red clover were used as plant material. The experiment designed in a randomized complete block design with 3 replications, with 12 pasture treatments. Pasture mixtures were: (1) 80%C + 20%OG; (2) 60%C + 40%OG; (3) 40%C + 60%OG; (4) 20%C + 80%OG; (5) 80%C + 20%RC; (6) 60%C + 40%RC; (7) 40%C + 60%RC; and (8) 20%C + 80%RC. Also, 3 pure stand pasture were used for each of three species. The twelve pasture were sown on 25 February 2017 at 20-cm row spacing by hand. Each plot was 0.8 x 3 m (2.4 m^2). The sowing rates of the pasture treatments were 1 kg chicory + 2 kg red clover + 3 kg orchard grass per hectare in pure stand pastures. A total of 4 kg da^{-1} Ammonium Nitrate, and 8 kg Triple Super Phosphate were applied to each plot. The experiment was rainfed and no irrigation was applied. Plots were harvested when the chicory plants reached an average height of 25 - 35 cm to mimic grazing. A total of six harvests were made between June 14 and July 29 in 2017, and 4 April and 29 May in 2018 (three each). Contrary to planned, plots were harvested earlier than planning cutting height due to the tendency to bolting was observed on chicory plants before reaching 25 cm height. Only chicory plants reached grazing maturity in the plots in the third cutting in 2017 and the first cutting in the second year. Samples were sorted into different botanical species before fresh matter yields were determined. A 500 gram of subsamples forages dried in an oven at 60 °C to a constant weight to determine yield and forage quality. Dried samples were ground for chemical analyses. The significance of differences among treatment means was compared by Duncan test with a significance level of 0.05 (Açıkgöz, 1993). The computations were carried out using SPSS 17.0 statistical software.

3. Results and Discussion

3.1. Plant Height

In terms of plant height, while the highest plant height was measured with 45.4 cm in the red clover in the plot with a mixture ratio of 80%C + 20%OG in the first cutting time, and the lowest plant height was 29.9 cm in pure stand orchard grass. In the pure stand chicory parcel, the plant height was 31.2 cm. In the second cutting, the highest plant heights were determined 30.2 cm in the chicory plant in the 60%C + 40%OG parcel, and 29.5 cm in the pure stand chicory parcel, the lowest plant heights were determined 21.4 cm in the orchard grass in 40% C+ 60%OG the mixture parcel. In the third cutting, only chicory plants thrived in the plots. During this period, since chicory plants started to stem elongation early, the plant was cut without waiting for the plant height to be 25 cm in height. In the third cut, the plant height of the chicory varied between 20.2 cm and 13.2 cm (Figure 1).

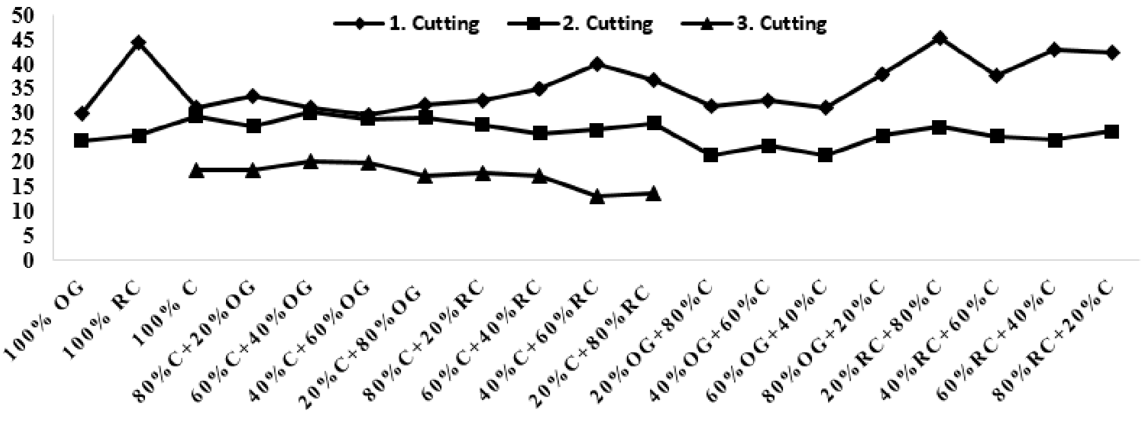

Figure1. Average plant height values determined in 2017 from mixtures at different ratios (cm): OG= orchardgrass, RC= red clover, C= chicory.

As the number of cuttings increased, plant height values decreased in parallel with the increase in temperature and drought. Red clover and orchard grass, which are cool-season grass, were more adversely affected by the increasing temperature and drought. Plant height values were a little low in all plants since it was the establishment year of the study. In addition, the fact that the plant height of the chicory plant in the second and third cuts is higher than the red clover and orchard grass may be due to the fact that the plant starts to develop again and has good tolerance to drought and heat. In the second year of the study, three cuttings were made, the chicory plant started to develop much earlier than the others and the only chicory was harvested in the first cutting.

While the longest average plant height was measured with 30.7 cm in the mixture of 80%C + 20%RC, the shortest average plant height was stated 26.8 cm in the mixture of 20%C + 80%OG. In the second cutting, the highest plant height was determined at 44.6 cm in the mixture of 80% C+20%OG in orchard grass, while the average plant height was 34.8 cm in the pure stand chicory plot. In the third cutting, plant height values varied between 34.9 - 29.8 cm (Figure 2). Kemp et al. (2002), stated that chicory provides to be spread over a wider period of time of the quality feed period, as it develops in the summer months when many plants dry out or become dormant in pastures. Its qualities and drought tolerance make chicory a valuable forage plant especially in the Mediterranean climate zone (Molle et al. 2008).

3.2. Fresh Yields

The fresh yield of the mixtures of chicory with orchard grass and red clover in different seed ratios are given in Table 1. It was determined that the difference between the treatments in terms of fresh yield was statistically significant. In the first cutting of 2017, the highest fresh yield was obtained in the mixture of 40%C + 60%RC (with 5057 kg/da), and the lowest fresh yield was had from the pure stand orchard grass parcel (with 601 kg/da). In the second cutting, the highest fresh yields were determined in the following mixtures with meadow clover, 20%C+80%RC (1489.8 kg/da), 80%C+20%RC (1467 kg/da), 60%C+40%RC (1369 kg/da), and 40%C+60%RC (1363 kg/da). In the third cutting, only chicory plants developed, so they were cutting and the highest chicory fresh yield was determined in the mixture of 80%C+20%OG (496 kg / da), the lowest fresh yield was measured 98 kg/da in the mixture of 40%C+60%RC.

In the first cutting of 2018, as only chicory plants reached grazing maturity, chicory was harvested and the highest fresh yield was determined in the mixture of 80%C+20%RC (2081 kg/da). The lowest chicory fresh yield was determined in 20%C + 80%OG mixture (525 kg / da). In its second cutting, the highest fresh yield varied between 870-3364 kg/da (Table 1).

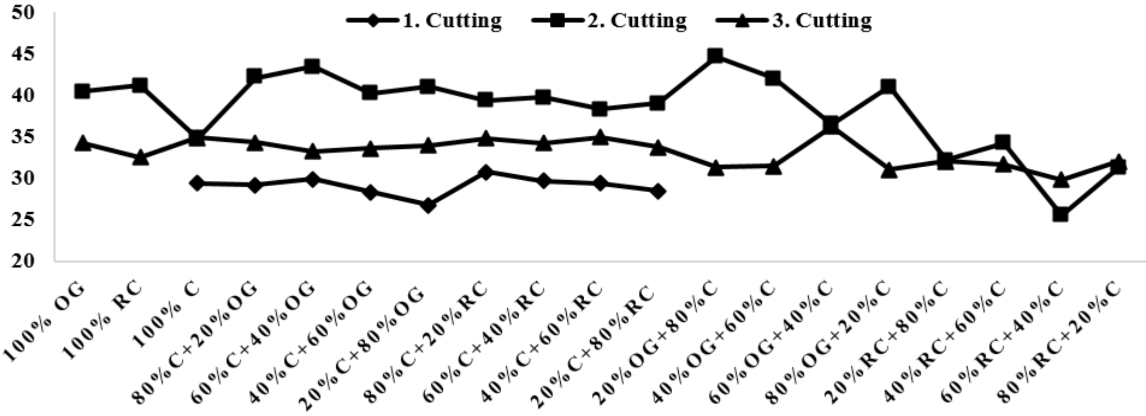

Figure 2. Average plant height values determined in 2017 from mixtures at different ratios (cm): OG= orchardgrass, RC= red clover, C= chicory.

Table 1. Fresh yield values (kg/da) of mixtures of chicory with orchard grass and red clover at different rates

Treatments	Fresh Yields (kg/da)							
	2017				2018			
	1.Cutting	2.Cutting	3.Cutting	Total	1. Cutting	2. Cutting	3. Cutting	Total
100 % OG	601^{d}	286^{d}	--	888^{d}	--	1220^{bc}	306^{e}	1526^{d}
100 % RC	2596^{c}	740^{bc}	--	3336^{b}	--	870^{c}	476^{e}	1347^{d}
100 % C	768^{d}	533^{cd}	285^{bc}	1587^{cd}	1399^{abc}	1500^{bc}	960^{d}	3860^{c}
80%C+20%OG	1349^{d}	800^{bc}	496^{a}	2646^{bc}	1690^{ab}	3010^{a}	1762^{ab}	6462^{ab}
60%C+40%OG	1638^{d}	895^{b}	356^{ab}	2891^{bc}	1741^{ab}	3364^{a}	1375^{bcd}	6481^{ab}
40%C+60%OG	1311^{d}	730^{bc}	286^{bc}	2327^{bc}	1057^{bcd}	2454^{ab}	1421^{bcd}	4933^{bc}
20%C+80%OG	1114^{d}	697^{bc}	130^{c}	1943^{cd}	525^{d}	2174^{abc}	1041^{cd}	3741^{c}
80%C+20%RC	4161^{ab}	1467^{a}	306^{abc}	5934^{a}	2081^{a}	2940^{a}	2116^{a}	7137^{a}
60%C+40%RC	3812^{b}	1369^{a}	261^{bc}	5443^{a}	1738^{ab}	2993^{a}	1682^{ab}	6414^{ab}
40%C+60%RC	5057^{a}	1363^{a}	98^{c}	6519^{a}	1380^{abc}	1997^{abc}	1468^{bc}	4846^{bc}
20%C+80%RC	4684^{ab}	1489^{a}	119^{c}	6293^{a}	802^{cd}	1932^{abc}	1299^{bcd}	4034^{c}
Average	2463	943	260	3619	1379	2223	1264	4616

*There is no difference at the level of 0.05 ($P \leq 0.05$) between the values indicated with the same letter in the same column. OG= orchardgrass, RC= red clover, C= chicory.

In 2017, while the highest fresh yields were determined in the mixtures containing red clover, in 2018, it was determined in the mixtures with 20%-40% of both red clover and orchard grass. The contribution of chicory to the yield of these mixtures is quite high. In the second year of the experiment, while the total fresh yields of both chicory and orchard grass were higher, the yield of red clover was quite low. Red clover plants were adversely affected by drought in the summer of 2017, and many plants died. This proportional decreasing negatively reflected on fresh yield. Chicory fresh yield increased significantly in 2018, and it reached the highest value with the mixture of 80%C + 20%RC (Table 1).

3.3. Hay Yield

It was determined that the difference between treatments in both years in terms of hay yield was statistically significant (Table 2). In the first cutting of 2017, the highest hay yield was found in the mixture of 40%C + 60%RC (919 kg/da), and the lowest hay yield was found in the pure stand chicory (90 kg/da) parcel.

In the second form of the same year, the highest hay yield was determined in the following mixtures containing red clover, 20%C+80%RC (325 kg/da), 40%C+60%RC (296 kg/da), 60%C+40%RC (289 kg/ha) and 80%C+20%RC (276 kg/da). In the third cutting, only chicory plants were cutting, and the highest chicory hay yield was found in mixtures of 80%C+20%OG and 60%C+40%OG (108 and 71 kg / da, respectively).

In 2018, only chicory plants reached grazing maturity in the first cutting of mixtures of chicory, orchard grass + red clover. In this cutting, only chicory was cut, and the highest chicory hay yield was determined in the pure stand chicory treatment (570 kg/da). In the second cutting, many treatments were included in the same statistical group in terms of the highest hay yield, and yields varied between 176 - 719 kg/da. The highest hay yield obtained in the third cutting in 2018 was determined in the mixture of 80%C+20%RC with 318 kg/da. When the hay yields obtained from chicory were examined in both years, the yield of chicory hay increased significantly in 2018 and reached the highest value in the mixture of 80%C+20%RC (858 kg/da). While the total hay yield of the pure stand chicory parcel was 216 kg/da in 2017, it was 908 kg/da in 2018. The lowest chicory hay yield in both years was determined in the mixture of 20%C + 80%OG (Table 2).

When the total hay yields obtained are examined, it is seen that the total hay yields obtained in 2018, the second year of the experiment, were higher. In 2017, the highest hay yields were determined in mixtures containing red clover, and in 2018, in mixtures containing 20 - 40% of both red clover and orchard grass. The hay yields obtained from chicory during the grazing maturity period were found approximate or higher value than the hay yields were determined by Sanderson (2010) and Piluzza et al. (2014) and reported by Tan and Temel (2012). This situation varied according to the soil, environment, type of variety used and the maintenance process applied.

3.4. Land Equivalent Ratio (LER)

The land Equivalent Ratio (LER) indicates the area required to obtain the exact yield from a unit area when crops are grown in a mixed planting compared to when they are grown in a monoculture (Kızılşimşek and Erol 2000). According to Boz (2006), mixed cropping is equivalent to monoculture if the resulting LER value is 1. If the LER value is less than 1, then mixed cropping is unnecessary, and if the LER value is greater than 1, then mixed cropping is superior to monoculture. This conclusion is based on comparing yields obtained from mixed cropping and monoculture. In the first harvest of the year 2017, the average LER values ranged from 0.95 to 2.05. In the second harvest, the average LER value was between 2.02 and 2.19 for mixtures with orchard grass and between 2.06 and 2.19 for mixtures with red clover.

Table 2. Hay yield values (kg/da) of mixtures of chicory with orchard grass and red clover at different rates

Treatments	Hay Yields (kg/da)							
	2017				2018			
	1.Cutting	2.Cutting	3.Cutting	Total	1. Cutting	2. Cutting	3. Cutting	Total
100 % OG	179de	72^{c}	--	252^{cd}	--	327^{cd}	83^{c}	411^{ef}
100 % RC	408^{c}	175^{b}	--	583^{b}	--	176^{d}	102^{c}	279^{f}
100 % C	90^{e}	72^{c}	53^{bc}	216^{d}	570^{a}	207^{d}	130^{c}	908^{abc}
80%C+20%OG	228de	143^{b}	108^{a}	480^{bcd}	193^{bc}	613^{ab}	257^{ab}	1064^{ab}
60%C+40%OG	290de	156^{b}	71^{ab}	518^{bc}	201^{bc}	719^{a}	243^{b}	1164^{a}
40%C+60%OG	248de	145^{b}	61^{bc}	455^{bcd}	120^{cd}	565^{ab}	250^{b}	935^{abc}
20%C+80%OG	229de	151^{b}	27^{c}	407^{bcd}	75^{d}	553^{ab}	212^{b}	841^{bcd}
80%C+20%RC	707^{ab}	276^{a}	62^{bc}	1046^{a}	241^{b}	486^{bc}	318^{a}	1046^{ab}
60%C+40%RC	647^{b}	289^{a}	62^{bc}	998^{a}	196^{bc}	476^{bc}	251^{b}	924^{abc}
40%C+60%RC	919^{a}	296^{a}	22^{c}	1238^{a}	144^{cd}	319^{cd}	219^{b}	683^{cde}
20%C+80%RC	804^{ab}	325^{a}	27^{c}	1157^{a}	96^{d}	284^{cd}	214^{b}	595de
Average	432	191	27	668	204	429	207	804

*There is no difference at the level of 0.05 ($P \leq 0.05$) between the values indicated with the same letter in the same column. OG= orchardgrass, RC= red clover, C= chicory.

In the third harvest, no LER value was calculated as no growth was observed in the orchard grass and red clover plants. These results suggest that mixed cropping can be beneficial in some cases, depending on the plant species and the specific growing conditions. In the first harvest of 2018, no LER value was calculated as no growth was observed in the orchard grass and red clover plants. In the second harvest, the highest average LER value of 2.74 was obtained from a 60%C+40% OG mixture, while in the third harvest, the average LER value ranged from 1.88 to 2.60 (Table 3). In both years, it was determined that all mixtures were superior to monoculture (LER>1.0) when the land equivalent (LER) ratios of mixed planting plots were examined. This suggests that plants utilize environmental factors more effectively in mixed cropping than in monoculture (Albayrak et al., 2004).

3.5. Aggressivity

Aggressivity is used to determine the interspecific competition in mixtures. If aggressivity=0, it is assumed that both species have the equal competitive ability. If the aggressivity value is positive, the plant is supposed to be the dominant species. If the aggressivity value is negative, the plant is considered the suppressed species (Dhima et al., 2007; Lithourgidis et al., 2011). In the first and second harvests of 2017, it was determined that in the 80%C+20%OG and 60%C+40%OG mixtures of chicory with sow thistle and in the 80%C+20%RC mixture of chicory with red clover, chicory was the suppressed species (Aother ≥ positive), while in other mixtures, chicory was the dominant species (Acichory ≥ positive). Aggressivity was not calculated in the third harvest of 2017 and in the first harvest of 2018 because there was no growth of orchard grass and red clover plants. In the second harvest of 2018, it was determined that in the 40%C+60%OG and 20%C+80%OG mixtures with orchard grass and the 20%C+80%RC mixture with red clover, chicory was the dominant species (Achicory ≥ positive), while in the other mixtures, the suppressed species was dominant (Aother ≥ positive). In the third harvest of the same year, it was found that chicory was the suppressed species in the 80%C+20%OG mixture with orchard grass, while it was the dominant species in the 20%C+80%RC mixture with red clover (Table 4).

3.6. Competitive Ratio

The competition ratio is a parameter that expresses how a species interacts with other species and how it uses ecological resources compared to other species, taking into account the planting rate and yield of a species in a mixture (Kızılşimşek and Erol, 2000).

Table 3. LER values of chicory, red clover, and orchard grass in different proportions

Treatments	2017 year cuttings			2018 year cuttings		
	1. cutting	2. cutting	Average	2. cutting	3. cutting	Average
80%C+20%OG	2.34	2.30	2.32	2.34[ab]	2.31	2.32
60%C+40%OG	2.54	2.36	2.45	2.74[a]	2.39	2.56
40%C+60%OG	2.35	2.28	2.32	2.18[ab]	2.48	2.33
20%C+80%OG	1.78	1.52	1.65	2.04[ab]	2.32	2.18
80%C+20%RC	2.14	2.22	2.18	2.44[ab]	2.60	2.52
60%C+40%RC	2.02	2.12	2.07	2.46[ab]	2.10	2.28
40%C+60%RC	1.96	2.32	2.14	1.59[b]	1.88	1.73
20%C+80%RC	1.68	2.30	1.99	1.54[b]	2.03	1.78
Average	2.10	2.18	2.14	2.16	2.26	2.21

*There is no difference at the level of 0.05 (P≤0.05) between the values indicated with the same letter in the same column. OG= orchardgrass, RC= red clover, C= chicory.

Table 4. Aggresivity values of chicory, red clover, and orchard grass in different proportions

Treatments	2017 Year				2018 Year			
	1. Cutting		2. Cutting		2. Cutting		3. Cutting	
	Chicory	Other	Chicory	Other	Chicory	Other	Chicory	Other
80%C+20%OG	-0.19[c]	0.19[a]	-0.06[c]	0.06[a]	-0.07[cd]	0.07[ab]	-0.051[d]	0.051[a]
60%C+40%OG	-0.03[bc]	0.03[ab]	-0.01[c]	0.01[a]	-0.01[bc]	0.01[bc]	0.002[c]	-0.003[b]
40%C+60%OG	0.01[bc]	-0.01[ab]	0.01[c]	-0.01[a]	0.01[b]	-0.01[c]	0.018[bc]	-0.018[bc]
20%C+80%OG	0.13[ab]	-0.13[bc]	0.15[ab]	-0.15[bc]	0.10[a]	-0.10[d]	0.118[a]	-0.118[d]
80%C+20%RC	-0.02[bc]	0.02[ab]	-0.03[c]	0.03[a]	-0.10[d]	0.10[a]	-0.057[d]	0.057[a]
60%C+40%RC	0.01[bc]	-0.01[ab]	0.01[c]	-0.01[a]	-0.02[bc]	0.02[bc]	-0.017[cd]	0.017[ab]
40%C+60%RC	0.04[b]	-0.04[b]	0.04[bc]	-0.04[ab]	-0.03[bcd]	0.03[abc]	-0.009[c]	0.009[b]
20%C+80%RC	0.24[a]	-0.24[c]	0.19[a]	-0.19[c]	0.03[ab]	-0.03[cd]	0.046[b]	-0.046[c]
Average	0.02	-0.02	0.04	-0.04	-0.01	0.01	0.006	-0.006

*There is no difference at the level of 0.05 (P≤0.05) between the values indicated with the same letter in the same column. OG= orchardgrass, RC= red clover, C= chicory.

Table 5. Competition index values of chicory, orchard grass, and red clover in different proportions

Treatments	2017 Year				2018 Year			
	1. Cutting		2. Cutting		2. Cutting		3. Cutting	
	Chicory	Other	Chicory	Other	Chicory	Other	Chicory	Other
80%C+20%OG	1.07[abc]	1.43[b]	0.51	0.78	0.60[b]	2.33[a]	3.80[a]	2.91[a]
60%C+40%OG	1.64[a]	0.87[b]	0.83	1.29	0.69[b]	1.51[ab]	3.36[a]	2.65[ab]
40%C+60%OG	1.51[ab]	0.71[b]	1.42	1.64	1.49[b]	0.83[b]	1.03[b]	1.21[bc]
20%C+80%OG	1.61[a]	0.76[b]	1.30	1.90	1.93[b]	0.90[b]	1.01[b]	1.22[bc]
80%C+20%RC	0.29[c]	5.98[a]	0.22	2.36	0.92[b]	1.38[ab]	0.57[b]	1.76[abc]
60%C+40%RC	0.38[bc]	2.84[b]	0.37	3.12	1.19[b]	0.96[b]	1.04[b]	1.00[c]
40%C+60%RC	0.03[c]	2.29[b]	0.58	3.90	0.71[b]	0.19[b]	0.44[b]	0.40[c]
20%C+80%RC	0.70[abc]	2.35[b]	1.00	5.31	8.47[a]	0.18[b]	0.40[b]	0.36[c]
Average	0.91	2.16	0.78	2.54	2.00	1.04	1.46	1.44

*There is no difference at the level of 0.05 (P≤0.05) between the values indicated with the same letter in the same column. OG= orcard grass, RC= red clover, C= chicory.

When the competition ratio values calculated for both chicory and other plants (red clover and orchard grass) are examined together in the first version of 2017, chicory has a negative effect (RI>1) in mixtures containing 40, 60 and 80% of orchard grass.

It was determined that chicory had a positive impact (RI<1) in all mixtures created with red clover. In other words, it is beneficial to grow chicory together with red clover. In the second cutting, chicory reached its highest competition ratio value in a mixture containing 60% orchard grass. In the second cutting conducted in 2018, chicory reached its highest competition ratio value in a mixture containing 80% red clover. In the third cutting conducted in 2018, chicory reached its highest competition ratio value in mixtures containing 20% and 40% orchard grass. To make a general evaluation for both 2017 and 2018, it can be said that chicory has a positive effect in mixtures with red clover (Table 5). However, considering that the red clover plants were negatively affected by drought during the summer months of 2017 and many plants died, more reliable interpretations regarding the competition ratio can be made based on the results of future studies.

4. Conclusion

The wild forms of chicory, which are very suitable for our country's ecology, are frequently encountered in every region. Considering the fact that chicory is rich in minerals and its preventive properties against swelling and parasite formation in animals, it can make a significant contribution to increase the yield and quality of artificial pasture mixes in our region and to spread the green fodder period over a wider period. According to the results obtained from this study, which was carried out for two years, the highest total fresh and hay yield was determined in the mixtures of 40%C+60%RC, 20%C+80%RC, and 80%C+ 20%RC. Considering the calculated area equivalence ratios (LER) of mixed planting plots in both years and in all forms, it was determined that all mixtures were superior to plain plantings (LER≥1). However, a red clover variety that can overcome the summer drought with the least damage in non-irrigated conditions should be selected. In order to reduce the quality roughage deficit and increase the yield and quality of pastures, especially in summer, the genotypes should be collected and examined in terms of forage yield and quality, and studies for the development of new varieties should be started as soon as possible.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	E.Ö.	İ.A.
C	50	50
D	100	
S		100
DCP	50	50
DAI	100	
L	50	50
W	70	30
CR	40	60
SR	60	40
PM	60	40
FA	50	50

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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Research Article
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NON-DESTRUCTIVE LEAF AREA MEASUREMENT USING MATHEMATICAL MODELING FOR PADDY VARIETIES

Fatih ÖNER[1]*, Mehmet Serhat ODABAŞ[2]

[1]*Ordu University, Faculty of Agriculture, Department of Field Crops, 52200, Ordu, Türkiye*
[2]*Ondokuz Mayis University, Bafra Vocational School, 55200, Samsun, Türkiye*

Abstract: Leaf area is considered an important parameter in fields such as plant phenotyping and plant breeding. In this study, leaf areas of different rice varieties were measured using a leaf area meter. Subsequently, a mathematical model was developed using leaf dimensions to estimate leaf area. Multiple regression analysis was used in the study to examine how leaf area is related to leaf dimensions. The results showed significant differences in leaf areas among different paddy varieties (Efe, Osmancık-97, Hamzadere, and Paşalı). Additionally, leaf dimensions were found to be a strong predictor for estimating leaf area. The equation of leaf area (LA= a + (b x L) + (c x W) + (d x L^2) + [e x (L x W)] for paddy varieties tested. The R^2 values for paddy varieties between 84% - 99%. The mathematical model is an important tool that can be used in plant phenotyping and plant breeding, and can be further utilized in future research in these fields.

Keywords: Paddy varieties, Leaf area, Modeling

***Corresponding author:** Ordu University, Faculty of Agriculture, Department of Field Crops, 52200, Ordu, Türkiye
E mail: fatihoner38@gmail.com (F. ÖNER)
Fatih ÖNER https://orcid.org/0000-0002-6264-3752
Mehmet Serhat ODABAŞ https://orcid.org/0000-0002-1863-7566

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1. Introduction

Paddy cultivation in the world is carried out using five cultivation systems based on water regime. These systems are grown as 45% irrigated, 30% rain fed, 11% deep-water, 10% upland, and 4% floating paddy, taking into account the cultivation area. In Türkiye, the paddy production system is grown using continuous irrigation, with the field kept underwater. Until20 days before harvesting, the field surface is covered with water. The water level is gradually increased depending on the development of the plants and kept around 15 cm during the maximum growth period (Sezer et al., 2012).

According to data from the Food and Agriculture Organization of the United Nations (FAO), rice is an important food crop that is grown on 164 million hectares of land worldwide, with a production of 760 million tons (FAO, 2020). Rice is such an important product that it is a significant component of food consumption for more than half of the world's population (Lopez et al., 2019). In Türkiye, rice is grown on 125,398 hectares of land, with a production of 980,000 tons and a yield of 782 kg per hectare (TMO, 2023). Rice is an annual crop with different varieties that vary in their sensitivity to day length and temperature. Rice grown between 45° North and 35° South latitude includes many varieties with different adaptation requirements (Fujino et al., 2012). Rice is the only grain that can germinate in water and benefit from dissolved oxygen in water for root growth (Uphoff, 2003).

The nutrients produced by plants are transmitted through the leaves to other parts of the plant that need to be fed and the plant uses this product as energy for growth (Albayrak and Yüksel, 2009). Light is an essential physical environmental factor for plants to grow and develop (Broge and Leblanc, 2001). The most important function of light is photosynthesis for green plants (Odabas et al., 2005). How much light energy can be captured by the leaves depends on the size of the leaf area (Rahman et al., 2012). Increasing leaf area is the main factor in plant growth due to its effect on the amount of photosynthetic radiation intercepted. Leaf area is particularly dependent on the number of leaves and leaf size in the plant (Uzun and Çelik, 1999). It may be possible to infer some aspects of the physiological status of a growing plant directly by analysis of allometric and other growth data (Kandiannan et al., 2002). This method has the advantage of being relatively simple and inexpensive (Causton and Venus, 1981). In this study, mathematical models that can be used to calculate the leaf area of different paddy varieties are proposed. With these models, leaf areas can be measured non-destructively.

2. Materials and Methods

In the research, four paddy varieties (Efe, Osmancık-97, Hamzadere and Paşalı) were used as plant materials. Before sowing, the seeds were completely soaked in water for 24 hours and then pre-germinated on a damp cloth for 24 hours. After the seeds were pre-germinated, 20 seeds were planted in each pot. As essential fertilization after planting, 500 g of 10-10-10 fertilizer was taken and dissolved in 18.5 liters of water and given to each pot as 100 ml.

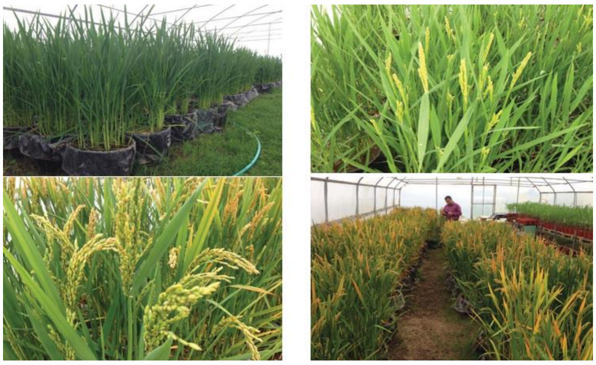

Figure 1. Paddy cultivars.

A mathematical method called curve fitting can be used to determine the functional connection between two or more variables in a dataset. To approximate the underlying mathematical function that produced the data, a series of data points must be fitted to a curve. For estimation, a variety of curve fitting methods can be applied, including the least squares approach, maximum likelihood method, nonlinear least squares method, splines, and genetic algorithms (Odabas et al., 2016). The type of data and the underlying mathematical function that produced it both influence the choice of curve fitting approach. To choose the best-fitting model, it is usual practice to employ a variety of methodologies and compare the outcomes.

3. Results and Discussion

Leaf area models using leaf length and width have been established in different studies in different plant species. Examples of these plant species are cucumber (*Cucumis sativus* L.), bean (*Phaseolus vulgaris* L.), grape (*Vitis vinifera* L.) and broad bean (*Vicia faba* L.) and in these studies, it has been stated that leaf area and leaf width and length have a very close relationship (Öner et al., 2012). In this study, the length and width of the leaf were considered independent variables in determining the leaf area. Leaf area was used as the dependent variable in the mathematical model. The R^2 value of the model is an important parameter that shows how high accuracy the leaf area can be estimated. Leaf area models of paddy varieties, coefficients of models, R^2, Adj. R^2, and RMSE values are shown in Table 1. RMSE stands for Root Mean Square Error. It is a measure of the difference between a predicted value and an actual value. It is commonly used in regression analysis to evaluate the accuracy of a model's predictions. The lower the RMSE, the better the model is at predicting values.

When these coefficients are substituted in the equation, mathematical models that calculate leaf area for the paddy varieties considered in the study are obtained. Accordingly, the mathematical model for the Efe variety is formed as (equation 1);

$$\text{Leaf Area} = (-14.93) + (2.47 \times L) + (3.78 \times W) - (0.02 \times L^2) - [0.21 \times (L \times W)] \quad (1)$$

Osmancık-97 variety is formed as (equation 2);

$$\text{Leaf Area} = (1.16) + (0.08 \times L) - (1.65 \times W) - (0.01 \times L^2) + [0.83 \times (L \times W)] \quad (2)$$

Hamzadere variety is formed as (equation 3);

$$\text{Leaf Area} = (-8.55) + (1.32 \times L) + (5.81 \times W) - (0.001 \times L^2) - [0.13 \times (L \times W)] \quad (3)$$

Paşalı variety is formed as (equation 4);

$$\text{Leaf Area} = (-2.78) + (1.06 \times L) - (2.54 \times W) - (0.001 \times L^2) + [0.28 \times (L \times W)] \quad (4)$$

Table 1. The equation of leaf area (LA= a + (b x L) + (c x W) + (d x L^2) + [e x (L x W)] for paddy cultivars tested

Paddy Cultivars	Coefficiencies					R^2	Adj. R^2	RMSE
	a	b	c	d	e			
Efe	-14.93	2.47	3.78	-0.02	-0.21	0.98	0.96	0.96
Osmancık-97	1.16	0.08	-1.65	-0.01	0.83	0.99	0.99	0.46
Hamzadere	-8.55	1.32	5.81	-0.001	-0.13	0.97	0.97	1.29
Paşalı	-2.78	1.06	-2.54	-0.01	0.28	0.84	0.84	3.03

a, b, c, d, and e are co-efficiencies.
LA= leaf area, L= leaf length, W= leaf width.
R^2 values are significant at P<0.001

R^2 values of these models are 0.98, 0.99, 0.97 and 0.84 respectively. The closer the R^2 value is to one, the higher the accuracy of the model. As a result of these models, the effect of leaf width and length on leaf area is graphically shown below for each variety.

Figure 2 shows that the leaf area is affected by the change in leaf width and length in each paddy variety. Especially the increase in leaf length affects the increase in leaf area positively, although slightly more than the increase in leaf width. The leaf area information obtained with these mathematical models is used to measure the capacity of the plant's leaves to photosynthesize. This measurement allows us to obtain information about plant growth and productivity. In addition, leaf area measurements in plants can also be used to assess the impact of environmental stressors such as plant diseases and pests. These data can help plant breeders to optimize plant growing (Gutierrez-Boem and Thomas, 2001).

Leaf area index (LAI) can be calculated using the leaf area and leaf width and length obtained with the mathematical model. LAI is the ratio of the area covering the leaf of a plant to the surface area of the plant relative to the soil.

The LAI is formulated as (equation 5);

$$LAI = \frac{1}{k}\ x\ ln(N/NO) \quad (5)$$

Where; k is the extinction coefficient of the canopy, N is the total number of leaves per unit ground area, N0 is the leaf number per unit ground area when the canopy is absent or fully transparent. This formula is based on the principle that the amount of light absorbed by a plant canopy is related to the LAI and the extinction coefficient, which represents the reduction in light intensity due to scattering and absorption by leaves in the canopy. By measuring the leaf number and using the extinction coefficient for a given canopy, you can use this formula to calculate the LAI (Myneni et al., 1997).

This ratio can provide information about the plant's photosynthetic capacity and overall growth. LAI can also be used to assess the impact of environmental stressors such as plant diseases and pests.

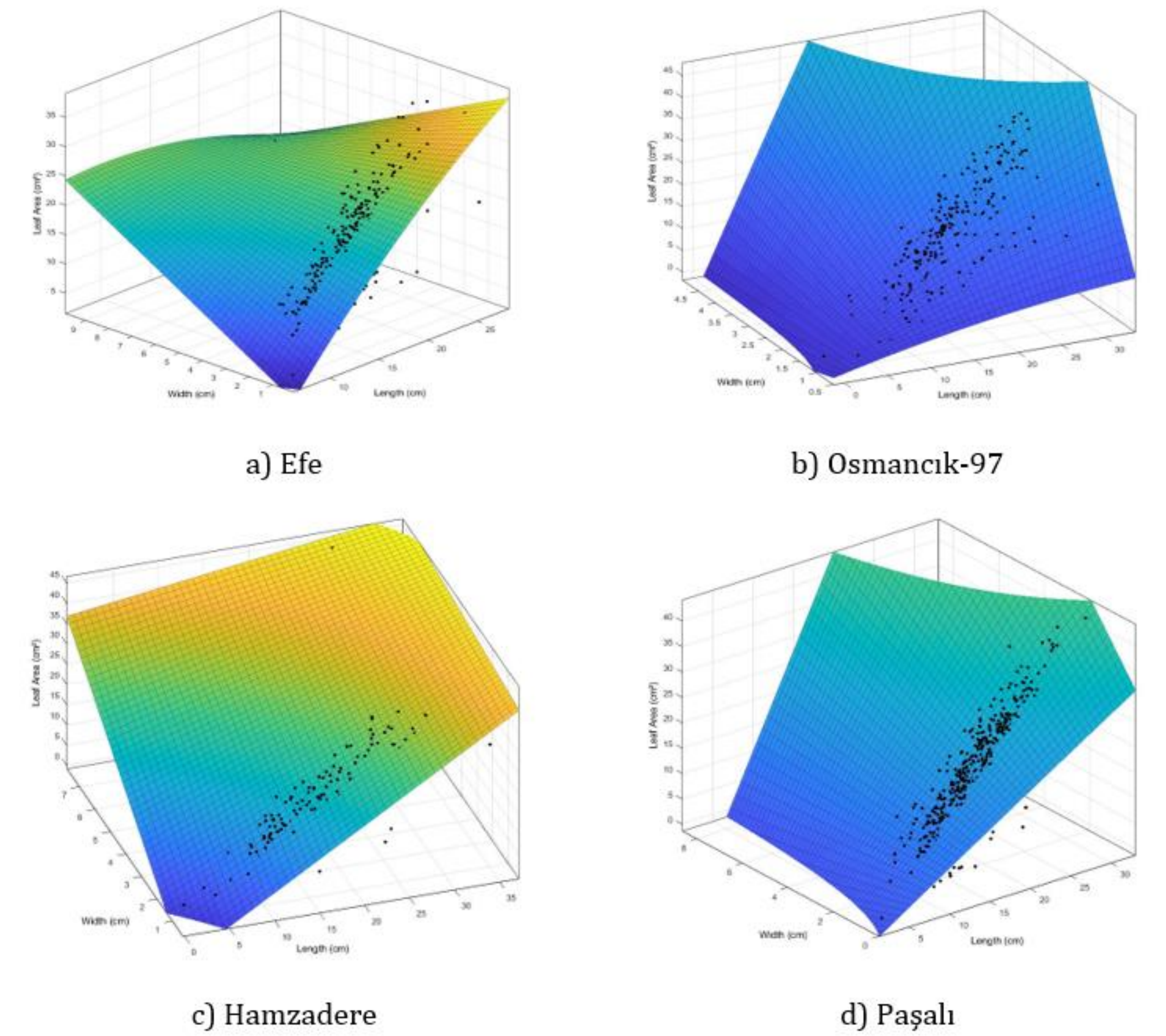

Figure 2. The effect of leaf width and length on leaf area based on mathematical models.

5. Conclusion

Simple, accurate and plant-safe methods for determining the leaf area of plants have an important place in plant physiology studies (Bozkurt and Sayılıkan Mansuroğlu, 2019). Non-destructively Leaf area measurement is important because they provide researchers with the opportunity to work on the same plant and leaf over and over again, thus potentially reducing the high coefficients of variation that can arise in trials. Furthermore, the ability to determine leaf area with simple linear measurements would eliminate the need for very expensive and complex leaf area measuring devices.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	F.Ö.	M.S.O.
C	50	50
D	100	
S		100
DCP	50	50
DAI		100
L	80	20
W	50	50
CR	60	40
SR	60	40
PM	80	20
FA	70	30

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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Research Article
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EVALUATION OF DIFFERENT SOYBEAN GENOTYPES IN TERMS OF ISOFLAVONES, ANTIOXIDANTS AND SOME QUALITY TRAITS

Nurgül ERGİN[1], Erdem GÜLÜMSER[1]*, Hanife MUT[1], Uğur BAŞARAN[2], Medine ÇOPUR DOĞRUSÖZ[2]

[1]*Bilecik Şeyh Edebali University, Faculty of Agriculture and Natural Science, Department of Field Crop, 112000, Bilecik, Türkiye*
[2]*Yozgat Bozok University, Faculty of Agriculture, Department of Field Crop, 66100, Yozgat, Türkiye*

Abstract: Soybean (*Glycine max* L.) varieties around the world have different quality characteristics that determine their use and nutritional value. In this study, the isoflavones (daidzein and genistein), isoflavone glycosides (daidzin and genistin), total flavonoid, total phenolic, free radical scavenging activity (DPPH), crude protein, crude fiber, fat, and condensed tannins contents of Turkish origin soybean genotypes were determined. The isoflavone contents were determined in the LC-MS/MS, antioxidants and condensed tannins content in the spectrophotometer, and other quality traits were determined in the NIRS device. The daidzein and genistein contents ranged between 0.035-0.446 and 0.308-1.188 ppm, respectively. The genistin content (0.254-8.906 ppm) was more variable than daidzin (0.388-1.006 ppm). Soybean genotypes exhibited high antioxidant characteristics. The crude protein contents were ranged from 36.127-40.603%. As a result, all genotypes examined were found to be rich in bioactive metabolites, therefore, high-quality raw materials for food production and human consumption.

Keywords: Soybean, Food, Protein, Secondary metabolite

***Corresponding author:** Bilecik Şeyh Edebali University, Faculty of Agriculture and Natural Science, Department of Field Crop, 112000, Bilecik, Türkiye
E mail: erdem.gulumser@bilecik.edu.tr (E. GÜLÜMSER)
Nurgül ERGİN https://orcid.org/0000-0003-3105-7504
Erdem GÜLÜMSER https://orcid.org/0000-0001-6291-3831
Hanife MUT https://orcid.org/0000-0002-5814-5275
Uğur BAŞARAN https://orcid.org/0000-0002-6644-5892
Medine ÇOPUR DOĞRUSÖZ https://orcid.org/0000-0002-9159-1699

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1. Introduction

Soybean (*Glycine max* L.) is native to Southeast Asia, widely grown for its edible seeds and young pods more than 3.000 years ago (Carter et al., 2004). Soybean consumption is increasing all over the world due to its high nutritional value and low cost. In 2019, world soybean cultivation was 128 million hectares, with 370 million tons of production, mostly in Brazil, the United States, and Argentina. In Türkiye, it is cultivated on 30 thousand hectares with an average yield of 4.44 tons of ha^{-1} grain (Anonymous, 2023).

Soybean is also rich in secondary metabolites such as furanocoumarins, isoflavonoids, and pterocarpan, as well as antioxidant substances that positively affect the health of humans and animals. These substances play a role both in the defense mechanism of the plant and they also have beneficial effects on human physiology and diseases. The amount of secondary metabolites is genotype-dependent and give the plant a distinctive odor (Li et al., 2010; Tantasawat et al., 2011). Besides, condensed tannins in soybean are mitigating the risk of diabetes risk in humans by decreasing blood sugar levels (Kumari and Jain, 2015).

A large number of soybean varieties are available worldwide and naturally, they vary secondary metabolites content. But the common feature of all is that it contains a high amount of protein and other essentials vitamins that play important role in our daily life (Chen et al., 2018). In this respect, the secondary metabolites, antioxidant traits, crude protein, crude fiber, and fat content in 12 different soybean genotypes were investigated in the current study.

2. Material and Methods

2.1. Materials

Soybean seeds, from eleven varieties (Altınay, Altınsoy, Arısoy, Atakişi, Atlas 3616, Cinsoy, Çetinbey, Umut 2002, Sarıgelin, Yemsoy and Yeşilsoy) and one local population, were used as plant material. Varieties were obtained from different institutions and private companies, and the local population was obtained from farmers.

2.2. Methods

2.2.1. Isoflavones (daidzein and genistein) and isoflavone glycosides analysis

Secondary metabolite analysis of the seed samples was determined with slight modification according to Carolina et al. (2021). Finely ground seed sample (2 g) was added to a glass vial (15 ml) containing 10 ml of methanol and 2 mL of aqueous 0.1 M HCl. The samples were sonicated for 3 minutes (×3) at room temperature.

Then, the samples were centrifuged at 5000 rpm for 5 minutes and the liquid on the collapsed samples was taken with the aid of a syringe. The finally, samples were adjusted to 2 mL of methanol and read on the LCMS/MS.

2.2.2. Total phenolic contents

The total phenolic contents of samples were determined with slight modification according to the Folin-Ciocalteu reagent (FCR) method of Singleton et al. (1999). Samples (200 μL) were mixed with diluted FCR (200 μL) and shaken vigorously for 3 min. Then, 200 μL sodium carbonate (Na_2CO_3) solutions (20%) were added. Then samples absorbance of each sample was measured at a spectrophotometer at the absorbance value of 760 nm after incubating in dark at room temperature for 2 h. The total phenolic contents were expressed as mg equivalents of gallic acid (GAE) g^{-1} dry weight (DW) according to the equation obtained from the standard gallic acid graph and calculated from the calibration curve (R^2= 0.9994).

2.2.3. Total flavonoid content

The total flavonoid content was determined by using Arvouet-Grand et al. (1994) with some modifications. Each sample (200 μL) was mixed with 100 μL of aluminum nitrate (10%) and 100 μL of potassium acetate (1 M). The total volume of the solution was adjusted to 5mL with ethanol. Similarly, a blank was prepared by adding methanol in place of the sample. Absorbance measurements were read at a spectrophotometer at the absorbance value of 417 nm after 40 min incubation at room temperature in dark conditions. Total flavonoid content was expressed as mg equivalents of quercetin (QE) g^{-1} DW according to the equation obtained from the standard quercetin graph and calculated from the calibration curve (R^2= 0.9994).

2.2.4. Free radical scavenging activity (DPPH)

The effect of each sample on 2,2-diphenyl-1-picryl-hydrazylhydrate (DPPH) radical was identified according to Gezer et al. (2006). One hundred microliters from each sample in methanol were added to 3.9 mL of 0.004% methanol solution of DPPH. The absorbance of each sample was read at a spectrophotometer at the absorbance value of 517 nm after 30 min incubation at room temperature in dark.

2.2.5. Total condensed tannin

A 6 ml of tannin solution was added to 0.01 g of ground seed then placed in a tube and mixed on a vortex. The tubes were tightly capped and kept at 100 ° C for 1 hour, and the samples were allowed to cool. Then, they were read at a spectrophotometer at the absorbance value of 550 nm (Bate-Smith, 1975). Condensed tannins were calculated by the following formula: Absorbance (550 nm x 156.5 x dilution factor)/Dry weight (%).

2.2.6. Crude protein, crude fiber and fat content

Finely powdered seed samples were subjected to crude protein (CP), crude Fiber (CF) and fat analysis by using Near Reflectance Spectroscopy (NIRS, 'Foss XDS') with the software package program 'IC-0904FE'. These analyses were made in Yozgat (Türkiye) Bozok University Faculty of Agriculture Field Crops Laboratory.

2.3. Statistical Analysis

The data was expressed as mean ± standard deviation and analyzed by analysis of variance (ANOVA). Duncan test was employed to draw the comparison between means and the significance was accepted at P<0.05. The correlations between examined parameters were determined by Pearson's correlation coefficient. The Biplot analysis was carried out with the help of the JMP package program.

3. Result and Discussion

Isoflavones (daidzein and genistein) and isoflavone glycosides (daidzin and genistin) contents of soybean genotypes were shown in Table 1. The genotype was significant (P<0.01) on daidzein, genistein, daidzin, and genistin contents. The highest daidzein and genistein content were determined in genotypes Yemsoy (0.446 ppm) and Çetinbey (1.188 ppm), respectively. Generally, the local population exhibited low isoflavone content compared to varieties. The daidzein and genistein are the most abundant isoflavone in soybean (Frank et al., 1999). These compounds are currently receiving more attention because of their potential benefit to human health especially in cancer treatment and prevention (Barnes, 2010; Bursaća et al., 2016). Wardlaw (2000) reported that consume half a cup of soybean a day is effective in cancer prevention. Previous studies showed that the daidzein and genistein content of soybean seed ranged between 0.08-2.35 mg g^{-1} and 0.02-0.83 mg g^{-1}, respectively (Malencic et al., 2012; Sumardi et al., 2017). The isoflavone contents of the soybean genotypes we studied were different from those reported in previous studies, which could be attributed to genetic variation.

The highest daidzin content was determined in the genotype of Altınay (1.006 ppm), while the lowest was genotype Yemsoy (0.395 ppm) and local population (0.388 ppm). Daidzin is an isoflavone glycoside that occurs naturally in soybean, it has antioxidant and anti-carcinogenic (Lu et al., 2009). Lojza et al. (2004) reported that daidzin content of soybean seed ranged between 0.249-0.534 mg g^{-1}. In the present study, the genistin content of soybean genotypes ranged between 0.254-8.906 ppm, and the highest genistin content was determined in the genotype Yeşilsoy. Choi et al. (2020) indicated that genistin is a popular ingredient with anti-adipogenic and anti-lipogenic properties. In other words, the genistin prevents excess weight by reducing fat accumulation in the body. Also, it is used to prevent weight gain after losing weight. Previous researchers indicated that genistin was the most abundant in soybean compared to the other isoflavone glycosides (Lee et al., 2005). These findings of the researchers were similar to our study, and genistin content of soybean seed was more than daidzin content (Table 1).

There were significant (P<0.01) differences in terms of total phenolic, total flavonoid, and DPPH-radical scavenging activity between genotypes (Table 2). With regards to total phenolic content, the genotype of

Çetinbey (20.469 mg GAE g^{-1}) showed the highest level, followed by the local population (18.177 mg GAE g^{-1}) and Cinsoy genotype (17.855 mg GAE g^{-1}). The phenolic compounds are important plant constituents with redox properties responsible for antioxidant activity, while antioxidants show positive effects on improving health (Soobrattee et al., 2005; Glenville, 2006). Dajanta et al. (2011) reported that soybean total phenolic content ranged between 27.67-37.29 mg GAE g^{-1}. In the present study, the total phenolic contents examined soybean seeds were different from the previous study due to differences in the genetic material used. Some researchers stated that genotype is significant on the total phenolic content in soybean and that the differences in total phenolic content may be reflect genotypic variability (Chung et al., 2008; Josipović et al., 2016). The highest total flavonoid content was determined in genotype Atakişi (6.738 mg QE g^{-1}), followed by genotype Atlas 3616 (6.062 mg QE g^{-1}) (Table 2). The flavonoids reduce blood lipid and glucose in humans, and they are are good for heart patients Josipović et al. (2016) found that the average flavonoid content of 33 soybean genotypes was 0.511 mg CAE g^{-1}. The highest DPPH was determined in the genotypes Yeşilsoy (30.440%) and Yemsoy (29.150%), while the lowest was in the local population (9.676%). DPPH is one of the most important methods to evaluate the antioxidant properties of plants and desirable to be high. Zamindar et al. (2017) reported that DPPH of soybean ranged from 6.79-36.55%.

Table 1. Isoflavon and isoflavone glycoside contents of soybean genotypes

Genotypes	Daidzein (ppm)**	Genistein (ppm)**	Daidzin (ppm)**	Genistin (ppm) **
Çetinbey	0.190 ± 0.014^{f}	1.188 ± 0.060^{a}	0.552 ± 0.003^{g}	5.421 ± 0.345^{c}
Arısoy	0.258 ± 0.021^{d}	0.147 ± 0.030^{i}	0.666 ± 0.015^{d}	0.427 ± 0.025^{g}
Sarıgelin	0.385 ± 0.024^{b}	0.381 ± 0.020^{g}	0.605 ± 0.004^{e}	0.254 ± 0.117^{g}
Atakişi	0.260 ± 0.007^{d}	0.066 ± 0.003^{j}	0.484 ± 0.010^{h}	7.762 ± 0.184^{b}
Altınsoy	0.114 ± 0.009^{g}	0.308 ± 0.015^{h}	0.574 ± 0.010^{f}	1.799 ± 0.037^{e}
Yemsoy	0.446 ± 0.021^{a}	0.558 ± 0.002^{e}	0.395 ± 0.009^{i}	5.469 ± 0.150^{c}
Umut 2002	0.039 ± 0.002^{h}	1.139 ± 0.048^{b}	0.747 ± 0.001^{b}	5.253 ± 0.092^{c}
Cinsoy	0.183 ± 0.004^{f}	0.234 ± 0.021^{i}	0.708 ± 0.008^{c}	3.983 ± 0.158^{d}
Yeşilsoy	0.019 ± 0.001^{h}	0.604 ± 0.030^{d}	0.578 ± 0.018^{f}	8.906 ± 0.111^{a}
Altınay	0.220 ± 0.009^{e}	0.672 ± 0.002^{c}	1.006 ± 0.003^{a}	4.174 ± 0.184^{d}
Atlas 3616	0.321 ± 0.020^{c}	0.497 ± 0.003^{f}	0.424 ± 0.007^{i}	0.348 ± 0.015^{g}
Local population	0.035 ± 0.002^{h}	0.380 ± 0.001^{g}	0.388 ± 0.008^{i}	0.976 ± 0.077^{f}

** P<0.01, There is no difference between the same letters in each column (P<0.05).

Table 2. Antioxidant properties of soybean genotypes

Genotypes	TP (mg GA/g)**	TF (mg QE/g)**	DPPH (%)**
Çetinbey	20.469 ± 0.296^{a}	5.709 ± 0.015^{de}	11.012 ± 0.729^{ef}
Arısoy	15.678 ± 0.027^{d}	5.312 ± 0.029^{f}	14.980 ± 3.077^{d}
Sarıgelin	16.711 ± 0.553^{c}	5.621 ± 0.014^{e}	11.336 ± 0.486^{ef}
Atakişi	9.513 ± 0.269^{g}	6.738 ± 0.014^{a}	12.672 ± 0.121^{e}
Altınsoy	15.335 ± 0.523^{d}	5.782 ± 0.000^{cde}	24.534 ± 1.214^{b}
Yemsoy	13.997 ± 0.348^{e}	4.047 ± 0.029^{i}	29.150 ± 0.405^{a}
Umut 2002	14.389 ± 1.092^{e}	5.915 ± 0.044^{bcd}	20.972 ± 1.052^{c}
Cinsoy	17.855 ± 0.660^{b}	6.003 ± 0.044^{bc}	11.417 ± 0.648^{ef}
Yeşilsoy	15.683 ± 0.175^{d}	5.944 ± 0.044^{bcd}	30.040 ± 0.485^{a}
Altınay	13.949 ± 0.594^{e}	4.356 ± 0.515^{h}	20.810 ± 0.162^{c}
Atlas 3616	12.075 ± 0.512^{f}	6.062 ± 0.014^{b}	12.429 ± 0.688^{e}
Local population	18.177 ± 0.027^{b}	5.003 ± 0.015^{g}	9.676 ± 0.445^{f}

** P<0.01, There is no difference between the same letters in each column (P<0.05). TP= total phenolic content; TF= total flavonoid; DPPH= free radical scavenging activity.

Crude protein, crude fiber, fat, and condensed tannin contents of soybean genotypes were given in Table 3. Among to genotypes, significant differences were detected (P<0.01) in terms of crude protein, crude fiber, fat contents, while condensed tannin was not significant. Among the genotypes, the rude protein content amongst was ranged from 36.127% (local population) to 40.603% (genotype Atakişi). The protein content of soybean is important for diabetics and cholesterol patients (Bhathena and Velasquez, 2002), and used to replace animal proteins in the diet (Lindsay and Claywell, 1998). It has been suggested that soybeans are low in saturated fat and cholesterol and consuming 5 grams of soybean protein per day may be beneficial for heart health (Bolla, 2015). Kulan et al. (2017) indicated that a high variation in soybean seed for protein contents, and ranged between 36-40%. The fiber content of genotype Altınsoy (4.977%), Yemsoy (5.477%), Yeşilsoy (5.217%), and local population (5.690%) was higher than other genotypes. Ciabotti et al. (2006) found that the fiber content of soybean ranged between 7.09-7.56%. Soybean seed is low in saturated fat and naturally cholesterol-free (Bolla, 2015). Besides, some researchers indicated that fiber of soybean decreases serum cholesterol in patients with high cholesterol levels (Shorey et al., 1985)

The fat content in studied genotypes was ranged between 17.440-22.337% and was less in the local population than varieties. Kulan et al. (2017) reported that the fat content of 13 different soybean genotypes ranged from 19.2% to 23.1%. Tannin is a polyphenol that possesses various medicinal properties, as well as acts as an antioxidant. Tannins are divided into two groups as condensed and hydrolyzable tannins. Condensed tannins are effective against asthma, hypersensitive pneumonitis, allergic rhinitis. Some researchers indicated that condensed tannins are anti-nutrients, but beneficial at low concentrations (2-3%) (Champ, 2002; Akindahunsi and Salawu, 2005). In this study, condensed tannins of soybean genotypes ranged from 0.219% (genotype Yeşilsoy) to 0.272% (genotype Umut 2002). El-Shemy et al. (2000) found an average of 0.029% concentrated tannin content in soybean seeds they examined. The correlations between the investigated traits in soybean genotypes are given in Table 4. The strong and negative correlations were noted between crude protein and crude fiber content (-0.676) followed by the correlations between total flavonoid and crude fiber (-0.592), total phenolic content and crude protein (-0.542), genistein and crude protein (-0.588). It was also determined that there was a negative correlation of daidzein with genistein, daidzin and genistin meaning that the increase in the daidzein content in soybean results the decrease in other isoflavones. On the other hand, there was a low and positive correlation of genistein with daidzin and genistin.

Table 3. Some quality traits of soybean genotypes

Genotypes	CP (%)**	CF (%)**	FAT (%)**	CT (%)
Çetinbey	36.173 ± 0.127^{e}	4.860 ± 0.167^{b-e}	20.150 ± 0.175^{cd}	0.263 ± 0.099
Arısoy	39.520 ± 0.315^{b}	4.297 ± 0.547^{de}	21.047 ± 0.076^{b}	0.257 ± 0.105
Sarıgelin	37.010 ± 0.760^{cde}	4.600 ± 0.668^{cde}	17.857 ± 0.087^{g}	0.237 ± 0.026
Atakişi	40.603 ± 0.411^{a}	4.047 ± 0.245^{e}	19.853 ± 0.176^{d}	0.254 ± 0.067
Altınsoy	36.640 ± 0.234^{de}	4.977 ± 0.240^{a-d}	18.910 ± 0.144^{f}	0.248 ± 0.096
Yemsoy	36.930 ± 0.520^{cde}	5.477 ± 0.405^{ab}	20.363 ± 0.110^{c}	0.248 ± 0.096
Umut 2002	37.303 ± 0.410^{cd}	4.417 ± 0.325^{cde}	19.873 ± 0.110^{d}	0.272 ± 0.090
Cinsoy	38.803 ± 1.037^{b}	4.857 ± 0.758^{b-e}	19.487 ± 0.092^{e}	0.257 ± 0.047
Yeşilsoy	37.653 ± 0.263^{c}	5.217 ± 0.359^{abc}	20.130 ± 0.308^{cd}	0.219 ± 0.067
Altınay	37.437 ± 0.603^{cd}	4.837 ± 0.498^{b-e}	19.257 ± 0.308^{e}	0.257 ± 0.088
Atlas 3616	37.217 ± 0.260^{cd}	4.560 ± 0.275^{cde}	22.377 ± 0.160^{a}	0.239 ± 0.081
Local population	36.127 ± 0.770^{e}	5.690 ± 0.785^{a}	17.440 ± 0.378^{h}	0.263 ± 0.076

** P<0.01, There is no difference between the same letters in each column (P<0.05). CP= crude protein, CF= crude fiber, CT= condensed tannin.

Table 4. The correlation values between quality traits in soybean genotypes

	Genistein	Daidzin	Genistin	TP	TF	DPPH	CP	CF	FAT	CT
Daidzein	-0.261	-0.185	-0.254	-0.295	-0.287	-0.109	0.157	-0.209	0.277	-0.170
Genistein		0.215	0.288	0.346	-0.153	0.183	-0.588*	0.137	0.111	0.271
Daidzin			0.071	0.048	-0.154	0.111	0.155	-0.306	-0.099	0.239
Genistin				-0.206	0.182	0.476	0.259	0.014	0.125	-0.129
TP					-0.196	-0.233	-0.542*	0.476	-0.395	0.177
TF						-0.347	0.432	-0.592*	0.173	-0.129
DPPH							-.0143	0.330	0.153	-0.394
CP								-0.676**	0.298	0.008
CF									-0.383	-0.155
FAT										-0.161

* P<0.05, ** P<0.01, There is no difference between the same letters in each column (P<0.05). TP= total phenolic; TF= total flavonoid; DPPH= free radical scavenging activity; CP= crude protein; CF= crude fiber; CT= condensed tannin.

The biplot graphic of the 12 soybean genotypes for investigated traits is present in Figure 1. PCA (Principle Component Analysis) shows the relationships between genotype and traits as a whole, and it has many advantages according to the correlation analysis which shows the relationship between two traits (Yan and Reid, 2008). The results of PCA revealed that the first l component (PCA 1) and the second (PCA 2) respectively exhibited 27.4% and 17.8% of the variation, a total of 45.2%. This analysis shows that what genotype/genotypes have higher values in terms of the quality traits and that these traits are in a positive or negative relationship with each other. According to the biplot, crude fiber and DPPH with genistein are in the same direction, while total phenolic and condensed tannin with daidzin are in the same direction. In addition to, 1 (Çetinbey) and 12 (Local population) genotypes exhibited a higher value in total phenolic content compared to the other genotypes (Figure 1).

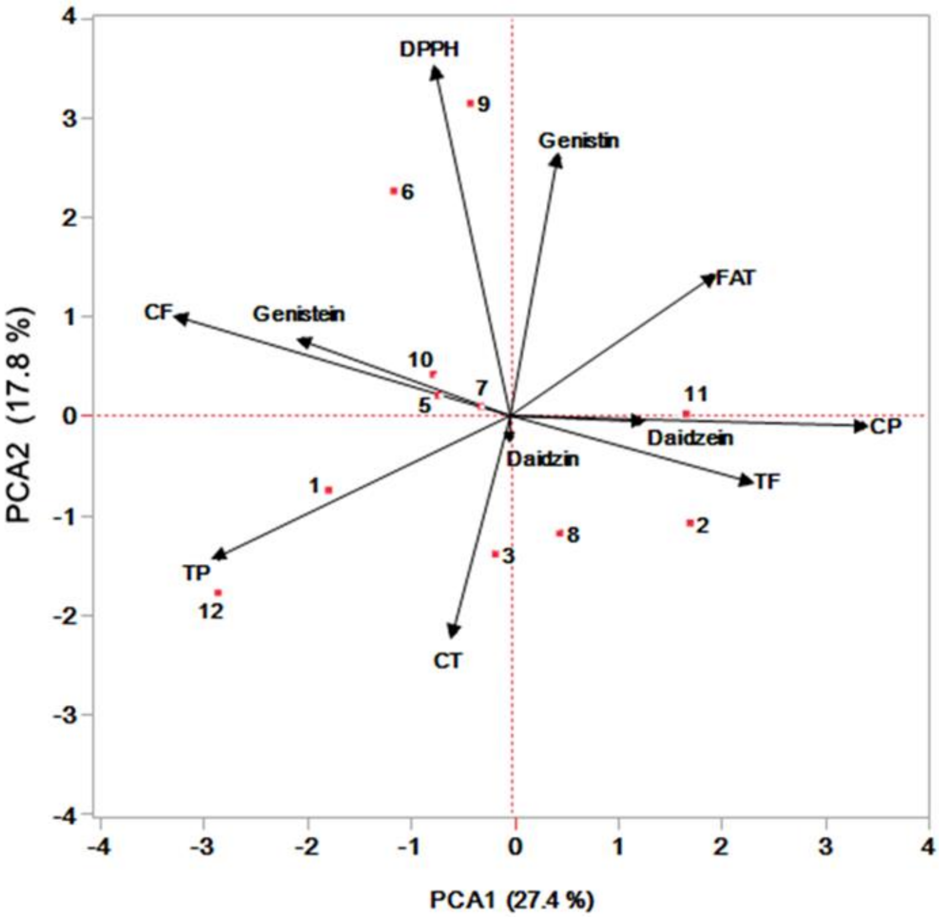

Figure 1. Principal component analysis of some quality traits of soybean genotypes. TP= total phenolic, TF= total flavonoid, DPPH= free radical scavenging activity, CP= crude protein, CF= crude fiber, CT= condensed tannin. G1= Çetinbey, G2= Arısoy, G3= Sarıgelin, G4= Atakişi, G5= Altınsoy, G6= Yemsoy, G7= Umut 2002, G8= Cinsoy, G9= Yeşilsoy, G10= Altınay, G11= Atlas 3616, G12= local population.

4. Conclusion

This study reveals the role of genotype selection in soybean in terms of healthy diets or the special demands of consumers. Isoflavonoids, antioxidants, and some quality traits in soybean seed were found to be different among the genotypes.

When isoflavonoid (daidzein, genistein) and isoflavone glycoside (daidzin and genistin) contents were compared, Yemsoy, Çetinbey, Altınay, and Yeşilsoy genotypes exhibited high value. Genotypes of Çetinbey, Atakişi, and Yeşilsoy antioxidant characteristics were more than other genotypes. On the other hand, all genotypes had sufficient nutritional value in terms of crude protein, crude fiber, fat, and condensed tannins contents. Within respect, all genotypes used in the current study constituted high-quality raw materials for human consumption and food production.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	N.E.	E.G.	H.M.	U.B.	M.Ç.D.
C	20	30	20	20	10
D	30	40	30		
S		50	50		
DCP	20	40	20	10	10
DAI		40	30	30	
L	20	20	20	20	20
W	10	30	30	30	20
CR	20	20	20	20	20
SR	10	30	30	30	0

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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DETERMINATION OF GRAIN YIELD AND AGRICULTURAL TRAITS OF SOME OAT CULTIVARS AT DIFFERENT LOCATIONS

Hüseyin GÜNGÖR[1]*, Mehmet Fatih ÇAKIR[2], Ziya DUMLUPINAR[3]

[1]Düzce University, Faculty of Agriculture, Department of Field Crops, 81620, Düzce, Türkiye
[2]Düzce University, Environment and Health Coordination, 81620, Düzce, Türkiye
[3]Kahramanmaraş Sütçü İmam University, Faculty of Agriculture, Department of Agricultural Biotechnology, 46100, Kahramanmaraş, Türkiye

Abstract: This research was carried out during the 2016-2017 and 2017-2018 growing seasons at Edirne, Kırklareli, and Tekirdağ locations with the aim of determining some agricultural and quality traits of nine registered oat cultivars. The experiments were arranged in a randomized complete block design with four replications. According to the results of the examined traits, plant height ranged from 101.5 to 132.4 cm, vegetative period from 125.1 to 138.9 days, thousand kernel weight from 26.6 to 40.0 g, test weight from 46.2 to 53.2 kg hl^{-1}, protein content from 12.5% to 15.1%, and grain yield from 4011 to 5321 kg ha^{-1}. According to the biplot analysis, PC1 and PC2 (accounting for 69.3% and 18.3% of the total variation, respectively) constituted 87.6% of the total variation. The angle value between the vectors of grain yield and protein content, thousand kernel weight, and test weight was narrow, indicating a high positive relationship between these traits, whereas the angle between the vectors of grain yield and plant height and vegetative period was wide, indicating a negative relationship between these traits. According to the correlation analysis, grain yield had a positive and significant relationship with test weight (r=0.594**), protein content (r=0.431**), and thousand kernel weight (r=0.350**), and a negative and significant relationship with a vegetative period (r=-0.360**) and plant height (r=-0.047**). According to the biplot analysis, cultivars Kahraman, Kırklar, Kehlibar and Somun Yıldızı were found outstanding genotypes in terms of grain yield.

Keywords: Oat, Grain yield, Yield components, Principal Component Analysis, Correlation Analysis

***Corresponding author:** Düzce University, Faculty of Agriculture, Department of Field Crops, 81620, Düzce, Türkiye
E mail: hgungor78@hotmail.com (H. GÜNGÖR)
Hüseyin GÜNGÖR https://orcid.org/0000-0001-6708-6337
Mehmet Fatih ÇAKIR https://orcid.org/0000-0003-1354-9476
Ziya DUMLUPINAR https://orcid.org/0000-0003-3119-6926

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1. Introduction

Oat (*Avena sativa* L.) is an important crop used mainly as animal feed but also utilized in the human food, pharmaceutical and cosmetic industries. There are three species of oats cultivated worldwide: *Avena sativa* L., *Avena byzantina* Koch. and *Avena nuda* L. (Hoffmann, 1995; Batalova et al., 2016). In 2021, oat cultivation area was 9.4 million ha, with a production of 23.5 million tons and an average yield of 2360 kg ha^{-1} worldwide, while in Türkiye, oat cultivation area was 136 thousand ha, with a production of 276 tons and an average yield of 2080 kg ha^{-1} (FAO, 2023; TUIK, 2023). In recent years, there has been an increasing demand for oat cultivation in Türkiye. One of the factors that hinder the desired level of oat production in the country is the lack of sufficient commercial varieties. Therefore, it is crucial to develop appropriate varieties for each region to achieve the desired level of oat cultivation (Halil and Uzun, 2019). Oat is rich in β-glucan, protein, vitamins, minerals, dietary fiber, fat, fatty acids, and some antioxidants. With the recent studies demonstrating the benefits of oats in the food and health sectors, oat has gained more importance in human nutrition (Butt et al., 2008; Jing and Hu, 2012; Finnan et al., 2019). The goal of plant breeders is to develop superior varieties that are adaptable to different ecological conditions and have desired traits. GGE Biplot is a combined analysis method that visually evaluates the two basic components, genotype (G) and G×E (interaction), on the same graph, thus providing plant breeders with a two-way evaluation of the data. The GGE Biplot analysis method is considered an innovative approach in plant breeding because it allows for the simultaneous visualization of many traits and influences success in selection (Yan and Tinker, 2006). Correlation analysis is significant in developing high-yielding and quality varieties by determining the level of binary relationships between the examined traits and is used by many researchers (Albayrak and Ekiz, 2004; Erol and Carpici, 2020).

The aim of this study was to investigate some agronomic and quality traits of nine registered oat cultivars at Edirne, Kırklareli, and Tekirdağ locations and determine the relationships between these traits to identify oat cultivars that hopeful for grain yield and quality.

2. Materials and Methods

The study was carried out with nine registered oat cultivars (Table 1) at Edirne, Kırklareli, and Tekirdağ locations in the 2016-2017 and 2017-2018 growing seasons according to the randomized complete blocks experimental design with four replications. The seeds were sown between the end of October and the first week of November in both growing seasons, with 500 seeds per square meter density in 6 m^2 plots. Weed control was done manually in the trials, and no application was made for pests. 50 kg ha^{-1} of nitrogen and 50 kg ha^{-1} of phosphorus (20-20-0) were applied at sowing, and the top dressing was split into two with 90 kg ha^{-1} (46% Urea) of nitrogen applied during the tillering stage and 60 kg ha^{-1} (26% Ammonium Nitrat) of nitrogen applied during the heading stage. Harvest was done in the first week of July in both growing seasons.

In the study, plant height (PH), vegetative period (VP), thousand kernel weight (TKW - Williams et al., 1988), test weight (TW – Vasiljevic and Banasic, 1980), protein content (PR-NIR), and grain yield (GY) were evaluated. According to the results of the homogeneity test, there was no significant difference between the years ($p>0.05$), and therefore, the analysis of variance was conducted by combining the years (Levene, 1960). Principal component analysis was performed using JMP software (JMP 15.1 SAS Institute Inc., 2020).

Table 1. The oat cultivars used in the experiment, owner company/institute and registration years and amounts of precipitation of environments

Cultivars	Owner Companies / Institutes	Registration Year	Environments	Precipitation (mm)	
				2016-2017	2017-2018
Kehlibar	SM	2018	Edirne	408.0	799.6
Somun Yıldızı	SM	2020	Kırklareli	366.3	699.3
Kahraman	TARI	2014	Tekirdağ	451.7	633.0
Kırklar	TARI	2014			
Yeniçeri	BDIARI	2013			
Faikbey	BDIARI	2004			
Seydişehir	BDIARI	2004			
Checota	TZARI	1986			
Sebat	TASC	2011			

SM= Som Un Seed company, TARI= Trakya Agricultural Research Institute, BDIARI= Bahri Dagdas International Agrıcultural Research Institute, TZARI= Transitional Zone Agricultural Research Institute, TASC= Trakya Agriculture Seed company

3. Results and Discussion

According to the statistical analysis made for plant height, years were found to be insignificant, while genotypes and locations were found significant at the level of 5%. The plant height of the examined oat cultivars varied between 101.5-132.4 cm. The longest plant height was measured in the cultivar Seydişehir (132.4 cm), and the shortest plant height was in the cultivar Somun Yıldızı (101.5 cm). Plant height was measured as 113.9 cm in the first year of the experiment and 114.8 cm in the second year. As for the locations, plant height was determined as 115.8 cm at Kırklareli, 114.2 cm at Tekirdağ, and 113.0 cm at Edirne (Table 2). In other studies, plant height was found to vary between 82.5-172.5 cm (Sari and Imamoglu, 2011; Naneli and Sakin, 2017; Kahraman et al., 2021). Plant height is influenced by cultivation techniques, environmental conditions, and genetic structure. Researchers focused on short and non-lodging genotypes in oat breeding studies (Kara et al., 2007; Dumlupinar et al., 2016; Kahraman et al., 2022).

In terms of vegetative period, years were statistically insignificant, while genotypes and locations were found to be significant at the level of 1%. The average vegetative period of oat cultivars ranged from 125.1 to 138.9 days. The cultivar Faikbey had the longest vegetative period, while cultivars Kahraman and Kırklar had the shortest vegetative period. Tekirdağ had the longest vegetative period (136.3 days), while Edirne had the shortest (132.0 days) among the trial locations (Table 2). In studies conducted in different ecologies, the vegetative period was reported to vary between 141-183 days (Dumlupinar et al., 2016; Dumlupinar et al., 2017; Naneli and Sakin, 2017). Although the duration of the vegetative period in oats is largely influenced by genetic structure (Locatelli et al., 2008; Dumlupinar et al., 2016; Naneli and Sakin, 2017), it is also affected by environmental conditions (Gautam et al., 2006).

As for thousand kernel weight, years, genotypes, and locations were found to be statistically significant at the level of 1%. Thousand kernel weight was determined as 34.7 g in the first year and 34.3 g in the second year of the experiment. The thousand kernel weight of the cultivars included in the trial varied between 26.0-40.0 g, and the lowest thousand kernel weight was obtained from the cultivar Sebat (26.6 g), while the highest thousand kernel weight was from the cultivar Kahraman (40.0 g). As for the locations, thousand kernel weight was determined as 35.1 g at Edirne, 34.0 g at Kırklareli, and 34.4 g at Tekirdağ (Table 2). In similar studies, thousand kernel weight was found to vary between 13.5-51.0 g (Sari and Imamoglu, 2011; Dumlupinar et al., 2016; Naneli and Sakin, 2017; Sahin et al., 2019).

The years, genotypes, and locations were found statistically significant in terms of test weight. The lowest test weight was observed in the cultivar Seydişehir (42.1 kg hl^{-1}), while the highest was in the cultivar Kahraman. The test weight was 45.3 kg hl^{-1} in the first year and 49.0 kg hl^{-1} in the second year. Previous studies have reported test weights ranging from 36.6 to 59.8 kg hl^{-1} (Naneli and Sakin, 2017; Sahin et al., 2019; Kahraman et al., 2021; Hocaoglu et al., 2022). The shape and size of oat grains can affect test weight, along with genetic and environmental factors (Dumlupinar et al., 2016; Sahin et al., 2019).

In terms of protein content, genotypes and locations were statistically significant, while years were not. The protein content was 13.77% in the first year and 13.79% in the second year. The study found that protein content ranged from 12.56% to 15.10%, with the highest protein content observed in the cultivar Kahraman and the lowest in the cultivar Sebat. The Kırklareli (13.83%) and Edirne (13.81%) locations had statistically similar protein content, while the Tekirdağ location (13.70%) had the lowest protein content (Table 2). Previous studies have reported protein content ranging from 11.71% to 13.34% (Naneli and Sakin, 2017), 10.59% to 20.85% (Sahin et al., 2019), and 12.40% to 13.47% (Kececioglu et al., 2021). Protein content is an important quality factor in oats, and high protein content is desirable. Oat grains typically have protein content ranging from 11% to 15% (Dumlupinar et al., 2011; Rodehutscord et al., 2016).

In terms of grain yield, years were not significant, while genotypes and locations were statistically significant. The highest grain yield was obtained from the cultivars Somun Yıldızı (5321 kg ha^{-1}), Kahraman (5222 kg ha^{-1}), and Kehlibar (5065 kg ha^{-1}), while the lowest grain yield was obtained from the cultivars Sebat (4011 kg ha^{-1}) and Checota (4037 kg ha^{-1}). When locations were examined, the highest grain yield was obtained from the Tekirdağ (4744 kg ha^{-1}) location, while the lowest grain yield was obtained from the Edirne (4514 kg ha^{-1}) location (Table 2). Previous studies have reported grain yields ranging from 2336 to 4481 kg ha^{-1} (Naneli and Sakin, 2017), 2150 to 5810 kg ha^{-1} (Mut et al., 2018), 5696 to 8127 kg ha^{-1} (Hocaoglu et al., 2022), and 4136 to 8104 kg ha^{-1} (Kahraman et al., 2021). Oat grain yield can vary significantly depending on the variety's genetic potential, cultural practices, and climatic and soil conditions (Dumlupinar et al., 2016; Gungor et al., 2017).

Table 2. Average data belong to plant height (PH), vegetative period (VP), and thousand kernel weight (TKW), test weight (TW) protein ratio (PR) and grain yield (GY)

		PH (cm)	VP (days)	TKW (g)	TW (kg hl^{-1})	PR (%)	GY (kg ha^{-1})
		ns	ns	**	**	ns	ns
Years	2016-2017	113.9	133.8	34.7 a	45.3 b	13.77	4658
	2017-2018	114.8	133.7	34.3 b	49.0 a	13.79	4608
		*	**	**	**	**	**
Cultivars	Kehlibar	105.6 d	133.3 d	34.6 d	49.6 c	14.18 c	5065 a
	Somun Yıldızı	101.5 e	136.3 c	34.0 e	48.6 d	14.17 c	5321 a
	Kahraman	105.5 d	125.1 e	40.0 a	53.2 a	15.10 a	5222 a
	Kırklar	108.6 d	125.3 e	38.3 b	50.8 b	14.43 b	4743 b
	Yeniçeri	120.5 c	132.9 d	33.0 f	45.4 f	13.60 d	4612 bc
	Faikbey	128.1 b	138.9 a	37.5 c	43.2 g	12.97 f	4335 d
	Checota	120.3 c	136.2 c	34.2 e	45.1 f	13.25 e	4037 e
	Seydişehir	132.4 a	138.3 ab	32.4 g	42.1 h	13.76 d	4353 cd
	Sebat	106.5 d	137.6 b	26.6 h	46.2 e	12.56 g	4011 e
		*	**	**	**	**	*
Locations	Kırklareli	115.8 a	133.0 b	34.0 c	48.0 a	13.83 a	4636 ab
	Tekirdağ	114.2 ab	136.3 a	34.4 b	46.1 c	13.70 b	4744 a
	Edirne	113.0 b	132.0 c	35.1 a	47.2 b	13.81 a	4514 b
	Mean	114.3	133.8	34.5	47.1	13.7	4633
	CV (%)	3.7	0.6	1.2	1.5	1.3	10.0
Year x Genotype		*	**	**	**	**	*
Year x Location		*	**	**	**	**	**
Genotype x Location		*	**	**	**	**	**
Year x Genotype x Location		*	**	**	**	**	ns

** Significant at 1%, * Significant at 5% and ns: not significant

3.1. Principal Components (PCA) and Correlation Analysis

The biplot analysis of the principal components allows for a visual representation of the relationships among the genotypes and the studied traits, providing ease in evaluating the relationships among both the genotypes and the traits (Yan and Kang, 2003). According to the biplot analysis, PC 1 (69.3%) and PC 2 (18.3%) explained 87.6% of the total variation (Figure 1). Grain yield, thousand kernel weight, test weight, and protein content had a positive correlation, while plant height and vegetative period had a negative correlation. A positive correlation was found between plant height and vegetative period. The cultivars Somun Yıldızı, Kahraman, Kehlibar, and Kırklar stood out in terms of grain yield, protein content, and test weight, while cultivars Seydişehir and Faikbey were determined to be the leading cultivars in terms of plant height and vegetative period. Hocaoglu et al. (2022) reported a positive relationship between grain yield and thousand kernel weight. The correlation coefficients for the studied traits are provided in Figure 2. Grain yield had a positive and significant correlation with test weight (r=0.594**), protein content (r=0.431**), and thousand kernel weight (r=0.350**), and a negative and significant correlation with vegetative period (r=-0.360**) and plant height (r=-0.047**). A positive and significant correlation (r=0.410**) was found between plant height and vegetative period. Dumlupinar et al. (2012) reported a positive correlation between grain yield and thousand kernel weight but a negative correlation between grain yield and plant height. Sari and Unay (2015) found a positive and significant relationship between grain yield and test weight and thousand kernel weight. Gungor et al. (2017) reported a positive but insignificant relationship between grain yield and vegetative period and a negative and significant relationship between grain yield and plant height.

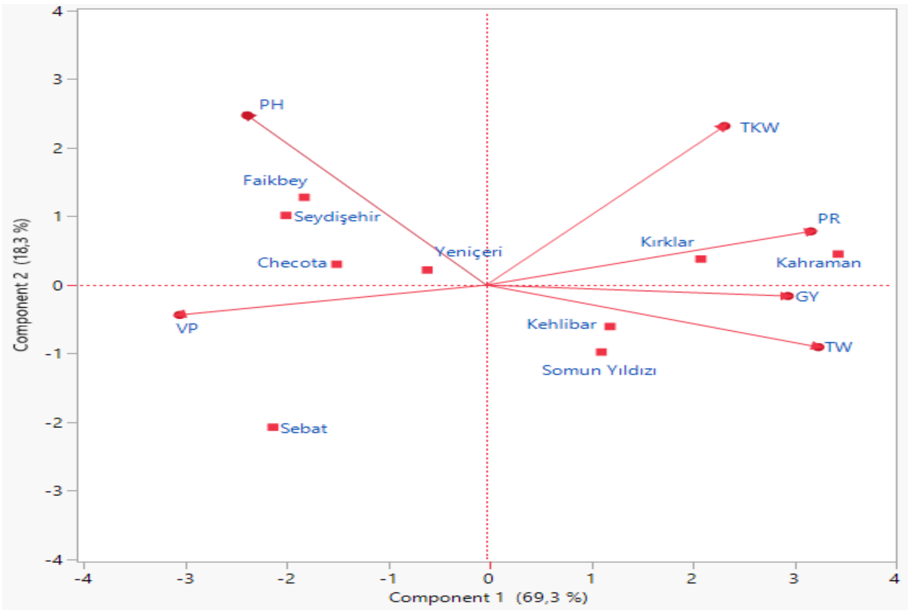

Figure 1. Relationships among cultivars and traits according to principal components biplot analysis.

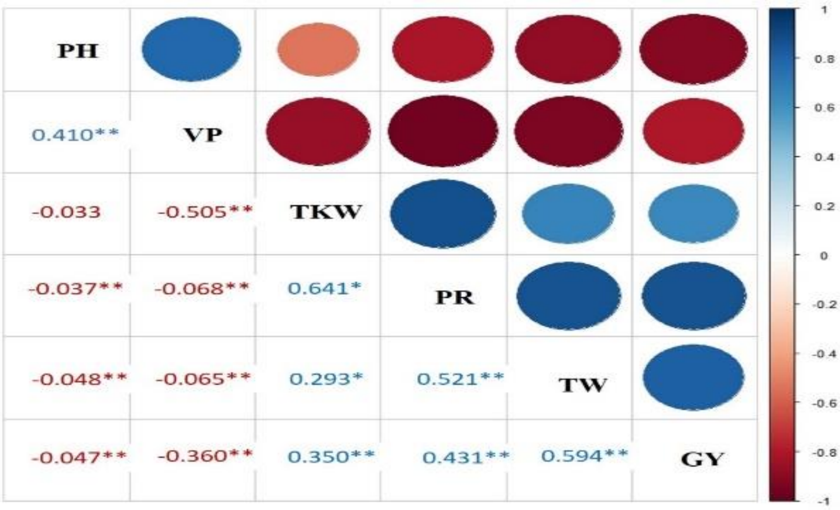

Figure 2. Relationships among investigated traits.

4. Conclusion

The study was conducted out for two years at Edirne, Kırklareli, and Tekirdağ locations to examine the agronomic and quality characteristics of nine different oat cultivars. The results of the principal component biplot analysis and correlation analysis showed that there was a positive relationship between grain yield and thousand kernel weight, test weight, and protein content. Tekirdağ location had a higher grain yield compared to Edirne and Kırklareli locations. According to biplot graph, cultivars Kahraman, Kırklar, Kehlibar, and Somun Yıldızı were found prominent for grain yield.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	H.G.	M.F.C.	Z.D.
C	40	30	30
D	40	30	30
S	40	30	30
DCP	40	30	30
DAI	40	30	30
L	40	30	30
W	40	30	30
CR	40	30	30
SR	40	30	30
PM	40	30	30
FA	40	30	30

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans

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POST-HARVEST TECHNOLOGY ADOPTION AND INCOME PATTERNS OF TOMATO FARMERS IN NEPAL

Salina MAHARJAN[1]*, Tikaram DHAKAL[1]

[1]*Tribhuvan University, Institute of Agriculture and Animal Science, 44600, Kathmandu, Nepal*

Abstract: A study was conducted in the Kavrepalanchok district of Nepal to analyze the post-harvest technology adoption among open field and plastic house tomato growers and assess the factors of tomato production determining the income of the farmers. Altogether fifty-six tomato growers were selected randomly following the Simple Random Sampling technique for the household survey. Primary data were collected using pre-tested interviews with tomato farmers. Data were analyzed using SPSS and Ms. Excel 2010. Descriptive statistics were used to estimate the adoption level of post-harvest technologies and a multiple linear regression model was carried out to estimate the factors of tomato production affecting the household income. Analysis of the post-harvest practices of farmers suggested that 53.85% of plastic house growers and 33.33% of open field growers harvested tomatoes in the yellow stage; 44.64% of farmers practiced grading; 88.5% plastic house tomatoes and 80.0% open field tomatoes were packed in plastic crates; only 26.49% practiced processing; more than half of the farmers had access to collection centers; the majority had a medium level of knowledge regarding different post-harvest management technologies. Among various factors, Nova variety was estimated to increase household income by 71% followed by production per unit area (48%), cost of cultivation (37%), access to processing industries (10%), and direct selling to consumers (9%). In wholesome, though NARC has recommended many post-harvest technologies, the adoption level is unsatisfactory. The unavailability of a sufficient quantity of quality fertilizers, lack of rural infrastructure facilities including roads, and inadequate technological extension were the factors hindering the adoption of post-harvest technologies in the study area.

Keywords: Post-harvest technology, Open fields, Plastic house, Household income, *Solanum lycopersicum* L., Adoption

***Corresponding author:** Tribhuvan University, Institute of Agriculture and Animal Science, 44600, Kathmandu, Nepal
E mail: salinamaharjan82@yahoo.com (S. MAHARJAN)
Salina MAHARJAN https://orcid.org/0000-0001-7519-3255
Tikaram DHAKAL https://orcid.org/0000-0002-6443-6482

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1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most consumed fresh and processed vegetable also used as an ingredient in many cooked dishes (Esguerra and Rolle, 2018) in the world which belongs to the Solanaceae family of plant genera. Tomato cultivation is one of the lucrative enterprises with high market potentialities in Nepal grown throughout the years. Open-field tomato farming is popular in the Terai region (up to 200 masl), inner Terai, and foothills (200-700 masl) during Autumn-Winter; however, off-season production in plastic houses during Summer-Rainy season is being admired in the hills which are fetching higher prices in the plains of Nepal and developing comparative advantage for income generation and livelihood improvement (Ghimire et al., 2018). It is an important contributor to agricultural GDP with figures of 16.36% in the fiscal year 2021/22. In the year 2020/21, fresh vegetables were cultivated in an area of 284,121 ha with a total production of 3,993,167 Metric tonnes and a yield of 14.05 Metric tonnes per ha. Among the fresh vegetables, the tomato was under cultivation in an area of 22,600 ha, with a total production of 432,616 Mt and a yield recorded at 19.14 Mt/ha. Kavrepalanchowk is one of the leading districts in tomato production that occupied an area of 2,639 ha producing 50,290 Metric tonnes of fresh tomatoes with a yield of 19.01 Metric tonnes per ha (MoALD, 2022).

Tomato is commonly used in a variety of dishes as raw, cooked, or processed products (Weldeslassie, 2007) ranging from ketchup, sauce, juice, puree, pasta sauce, salsa, tomato-based powders, sundried tomatoes, curries, to ready-to-eat products (Ghimire et al., 2018). The processed products are even exported to international markets at high prices. It was reported that 385,452 liters of unfermented tomato juice were exported worth 21530 thousand rupees in the fiscal year 2020/21 (MoALD, 2022). Nepal produces tonnes of tomatoes; however, a significant amount of tomatoes get lost before reaching the end consumers. The post-harvest loss in tomatoes is the result of improper handling, packaging, grading, off-road situation, use of low-level technology, lack of basic equipment and facilities at collection centers, improper marketing, and lack of qualified workers. Reducing post-harvest loss can save money, can feed more people, improve health and nutrition, and reduce pressure on natural resources (Acedo et al., 2016). Several postharvest handling techniques such as harvesting index, harvesting time, method, grading standards, and packaging materials have been developed for tomatoes in Nepal. The study of post-harvest technology adoption covers many aspects such as the nature of the commodities, their profitability and turnover aspect, availability, actors involved in marketing structure, sociocultural factors, and value chain actors' awareness about technologies. Therefore, this study covers multiple dimensions of the post-harvest chain of tomatoes. The purpose of this paper, therefore, is to identify the available post-harvest technologies; spot the gaps for the adoption of improved technologies, and rank the constraints of technology adoption.

2. Materials and Methods

2.1. Study Area

This study took place in the Kavrepalanchok district of Nepal chosen purposively (Figure 1). It is among the seventy-seven districts of Nepal located in Bagmati Province at latitude 27°33′06.48″ North and longitude 85°38′38.04″ East. It is a leading tomato producer in Nepal both seasonal and off-season.

Figure 1. Study site location map.

2.2. Research Design and Data Collection Methods

This study employed a cross-sectional research design. It uses both primary and secondary sources of data. Structured questionnaires were used to collect data to evaluate the farmers' knowledge, perception, and practices on available postharvest technology; the constraints; and opportunities of adoption from the households growing tomatoes in open-field and plastic houses. A pilot study was conducted before conducting the main survey to track the study sites and minimize the limitations.

Furthermore, the secondary source of information was gathered through an intensive desk review of research reports and articles of Ministry of Agriculture and Livestock Development (MoALD, 2022), books and book sections of different organizations such as Food and Agriculture Organization of the United Nations (Esguerra and Rolle, 2018), newsletters and bulletins from different websites, relevant research articles from different scientific journals.

2.3. Sampling and Data Analysis

Sampling units were the households engaged in tomato production in open fields and plastic houses in the study area, whereby the head of the household or his/her representative was picked as the respondent. A total of 56 tomato farmers from the Kavrepalanchok district, 30 open-field growers, and 26 plastic house growers were selected randomly following lottery method of Simple Random Sampling techniques (Elder, 2009).

The collected data was analyzed using Microsoft Excel 2010 and Statistical Package for Social Science (SPSS) version 25. The descriptive statistics involved analysis of frequencies, percentages, means, and standard deviations based on (Aidoo-Mensah, 2018) to compute the socio-demographic characteristics of respondents, their practices and perception, constraints of post-harvest technology adoption, etc.

A functional analysis was carried out to examine the determinants of household income from tomato production using ordinary least squares (OLS) method as adopted by (Aidoo-Mensah, 2018). The Model (Equation 1) as shown below expressed household income as a function of the following independent variables – Variety Nova (X_1), Productivity(X_2), Cost of cultivation (X_3), Processing industries (X_4), and Marketing method (X_5).

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\varepsilon_i \quad (1)$$

where,

Y= Household income from tomato

X_1= Variety Nova which takes the value '1' if the variety is cultivated and value '0' otherwise

X_2= Productivity (kg/ha)

X_3= Cost of cultivation (in USD ($))

X_4= Processing industries which take the value '1' if access to processing industries and value '0' otherwise

X_5= Marketing method which takes the value '1' if direct selling of tomato without the involvement of middlemen and value '0' otherwise

β_0= intercept

β_1, β_2, β_3, β_4, β_5 = Coefficients of the respective variable

ε_i =Random-error

3. Results

3.1. Demographics of Respondents

3.1.1. Age

The survey results showed that the mean age of farmers was 40.39 years, suggesting that most of the farmers were in the active age group. Further the age was categorized into three different age groups as seen in Table 1. The results of the age distribution of the respondents indicate the modal age group was the 30-65 years age bracket for both plastic houses (88.46%) and open fields (86.67%). Since the majority of the respondents are in their middle age, income from tomato production is potentially high for the area (Aidoo-Mensah, 2018).

3.1.2. Household size

The household size affects productivity as the possibility of more family labor available for the timely operation of farm activities. The research area appeared to be mildly populated since the average size of the family was 5.2 people per household, with the highest household size of 4-6 persons for both the plastic house (61.54%) and open field (73.33%) (Table 1). This family size is more as compared to the national average as indicated by the annual household survey 2015/16 in Nepal. Larger the household size, the larger the available labor pool for farm operations (Aidoo-Mensah, 2018).

3.1.3. Education

The average year of schooling was found to be 6.95 years which means the tomato-growing farmers were mostly illiterate; education helps to build a good and confident relationship with development agents thus maximizing production. The majority of the respondents had a secondary level of education for both plastic houses (57.69%) and open fields (36.67%) as shown in Table 1.

3.1.4. Farm size and livestock

The average farm holding for the plastic house growers was 7.87 ha which is less in comparison to 9.18 ha for open fields. Interestingly the area under tomato cultivation in plastic houses was more than that in an open field with figures 5.96 ha and 3.19 ha respectively. There was no big difference between them for livestock ownership (Table 2).

3.1.5. Household income

The annual household income was interestingly higher for plastic house growers (5957.2 USD) as compared to an open field (4724.3 USD). Similarly, the income from tomato cultivation was also higher for plastic tunnel growers (2779.61 USD) than for open field growers (1466.50 USD). This indicates that growing tomatoes under a plastic tunnel is more profitable than in an open field as shown in Table 2.

Table 1. Demographics of the respondents in the survey area conducted in Kavrepalanchok district in 2019

	Plastic House		Open field	
	Number	Percent	Number	Percent
1. Age category				
<30	3	11.54	4.00	13.33
30-65	23	88.46	26.00	86.67
>65	0	0	0	0
2. Household size				
<=3	5	19.23	3	10.00
4-6	16	61.54	22	73.33
7-9	3	11.54	4	13.33
>9	2	7.69	1	3.33
3. Education level				
No education	5	19.23	8	26.67
Basic education (1-8)	5	19.23	8	26.67
Secondary education (9-12)	15	57.69	11	36.67
Higher secondary education(>12)	1	3.85	3	10.00

Table 2. Means and standard deviations of farm sizes and household income as USD in the survey conducted in Kavrepalanchok district in 2019

	Plastic house (N=26)				Open field(N=30)			
	Minimum	Maximum	Mean	Std. Dev.	Minimum	Maximum	Mean	Std. Dev.
Land owned	0.5	25	7.87	6.27	0.5	70	9.18	12.89
Area under cultivation	2	48	10.12	9.21	1	68	8.16	12.13
Area under tomato cultivation	1	35	5.96	6.77	0.25	40	3.19	7.14
Livestock owned	0	1	0.81	0.40	0	1	0.90	0.31
Total income	776.72	39520.00	5957.29	7801.50	228.00	19000.00	4724.31	4817.61
Income from agriculture	760.00	18240.00	3849.75	4076.71	228.00	19000.00	2666.28	3804.24
Income from tomato	380.00	13680.00	2779.61	3445.76	76.00	19000.00	1466.50	3376.87

3.2. Farmer's Practices and Perception of Post-Harvest Management Technologies

3.2.1. Harvesting maturity

Harvesting of tomatoes depends upon factors like market, demand, and purpose. Farmers growing tomatoes in the study area were found to harvest tomatoes at four stages viz., green, yellow, light red, and red ripe stage with a majority at the yellow stage in both plastic houses i.e., 53.85%, and open fields i.e., 33.33%. For polyhouse growers, it was followed by the green and ripe stage with 19.23% each and very few i.e., 7.69% harvested at the red stage. While for open field cultivators, it was a red stage with 30.00% then a ripe stage i.e., 20.00%, and a green stage i.e., 16.67% as shown in Table 3. The result revealed that the bulk of tomatoes, i.e., nearly half of the production is sent to the distant market by picking at the yellow stage.

3.2.2. Time of harvesting

The combination of harvesting time following the harvesting stage is a determining factor for post-harvest life. The majority (30.77%) of the plastic house growers were observed to harvest tomatoes early morning before 10 am whereas 36.67% of open field growers harvested late morning between 10 am to 12 am. The harvest time is followed by late morning harvest (26.92%), harvest based on demand (23.08%), and then mid-day harvest (19.23%) in the case of the plastic house whereas, in case of the open field late morning harvest is followed by early morning harvest (30.00%), mid-day harvest (23.33%) and harvest based on demand (10.00%) (Table 3). The possible logic behind harvesting in the early morning is to sell maximum produce on the same day.

3.2.3. Harvesting practices

The method of harvesting plays a crucial role in reducing post-harvest loss. Different harvesting practices adopted by farmers were studied as shown in Table 3. Nearly half of the farmers, 50.00% plastic house and 40.00% open field growers were found to harvest tomatoes even if there is rain. This may have been because of demand even during rainy days. All of the farmers were revealed to harvest the tomato fruits with peduncles attached to the fruits. Farmers were observed to be aware of the necessity of peduncle at post-harvest life to reduce losses. Very few plastic house growers (7.69%) were found to practice pre-cooling activities while more than a quarter (26.67%) open field cultivators performed it. Similarly, even fewer (11.54% plastic house and 16.67% open field growers) cleaned the fruits before marketing. Farmers were somewhat aware of health issues related to the unsafe use of pesticides and thus 46.15% of polyhouse growers and 33.33% of open field growers used gloves; 38.46% of polyhouse growers and 40.00% of open field growers washed hands before, after harvesting (Table 3).

3.2.4. Sorting/grading practices

Sorting and grading of tomatoes are practiced only in big marts. However, these practices are a must in the Nepalese context due to the uneven shapes and sizes of the fruits. More than half of the farmers (55.36%) in the study area didn't appear to practice grading the fruits. Results showed that the most popular way of grading the tomato fruits in the study area was based on insect pest attacks for both open-field tomato growers (26.67%) and plastic house growers (19.23%) (Figure 2). These results are in line with (Khatun and Khandoker, 2014) where the authors discussed about majority of farmers sorting their tomatoes based on size of the fruit and disease infected.

Table 3. Harvesting practices of tomatoes at farmers' field in the survey conducted in Kavrepalanchok district in 2019

S.N.	Harvesting Practices	Plastic House		Open field	
		Frequency	Percent	Frequency	Percent
1	Harvesting stages				
	Green	5	19.23	5	16.67
	Yellow	14	53.85	10	33.33
	Red	2	7.69	9	30.00
	Ripe	5	19.23	6	20.00
2	Harvesting time of day				
	Early morning (before 10 am)	8	30.77	9	30.00
	Late morning (10 am to 12 noon)	7	26.92	11	36.67
	Mid-day (12 noon to 3 pm)	5	19.23	7	23.33
	Any time based on demand	6	23.08	3	10.00
3	Harvest During Rain	13	50.00	12	40.00
4	Harvesting with Peduncle	26	100.00	30	100.00
5	Pre-cooling practices	2	7.69	8	26.67
6	Cleaning practices	3	11.54	5	16.67
7	Use Gloves	12	46.15	10	33.33
8	Wash hands before and after harvesting	10	38.46	12	40.00

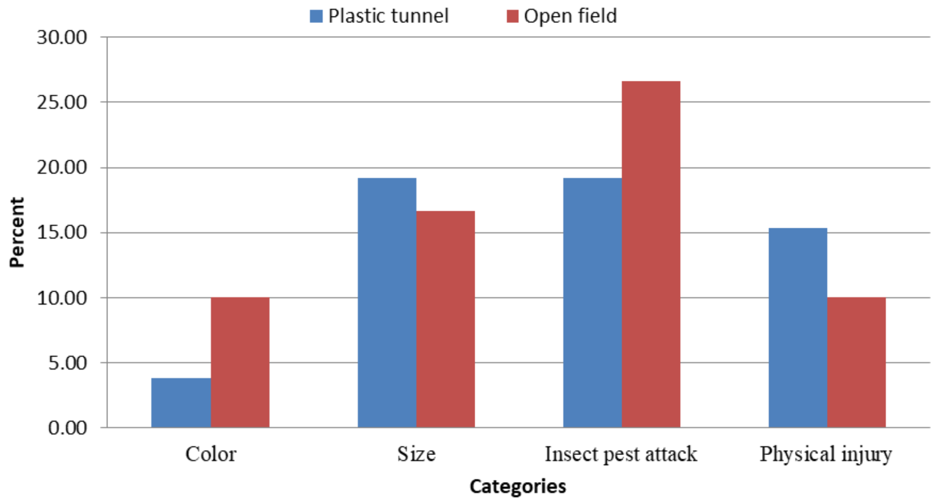

Figure 2. Sorting and grading practices in tomato.

3.2.5. Packaging practices

Doko, a locally woven bamboo basket is the most widely used packing material in rural regions of Nepal. However, its use is not limited to rural areas. The research identified that plastic crates are the most used packaging material by both plastic house growers (88.5%) and open field growers (80.0%). A negligible number of farmers was identified to pack their harvest in doko and polythene bags as shown in Table 4. Farmers of the study area were found to adopt the improved technologies by prioritizing plastic crates for ensuring damage-free fruits. Plastic crates are among the common packaging materials used in most developing countries (Paltrinieri, 2017). The use of plastic crates is recommended due to less damage. These findings are in parallel with (Bhattarai, 2018).

Different aspects of packaging practice largely determine the probability of damage during transportation. Farmers in the study area were observed to lag in practicing those aspects. More than half of the farmers, 61.5% plastic house farmers, and 46.7% open field farmers practiced packaging to full level, increasing the chances of damage. However, more open-field growers (33.3%) were found to put something at the base compared to plastic house growers (11.5%). Similarly, only 11.5% of plastic house growers compared to 16.7% of open field growers practiced cleaning the packaging materials as shown in Table 4. A wholesome majority of farmers to some aspect did know about packaging practices.

3.2.6. Management of the leftover tomatoes

Waste tomatoes with poor quality are either sold at lower prices if consumers wish to buy them or used for processing, or thrown away. The study on the management of waste tomatoes showed that the majority of the farmers 73.1% plastic house growing farmers and 86.7% open field farmers threw the unsold tomatoes in open pits. Very few, around 10% of farmers were found to bury in pits and a negligible number were identified to sell at a low price (Figure 3). Burying the waste products in pits is a time-consuming task; furthermore selling at a low price still needs transportation facilities which may lead to loss. Thus, farmers may have preferred to throw the waste in open pits.

3.2.7. Processing practices

Farmers in the study area were tested for their knowledge of processing practices. Only 26.79% of the producers practiced processing the tomatoes, remaining 73.21% did no processing practices. Some processed products; ketchup, sauce, pickle, and dry tomatoes were the parameters of the study. In the case of plastic house tomato growers, they were found to know very well about picking practices (34.6%) compared to drying (15.4%), ketchup (3.8%), and sauce (3.8%). Interestingly open field farmers also had good knowledge of pickling (30.0%) compared to drying (13.3%), sauce (10.0%), and ketchup (6.7%) (Figure 4). The results suggest that farmers in the study area were well-known about pickling and drying as these practices are traditional ones common among almost all farmers.

Table 4. Packing practices for tomato fruits in the field survey conducted in Kavrepalanchok district in 2019

S.N.	Packing Practices	Plastic House	Open field
1	Packaging materials		
	Doko	3(11.5)	5(16.7)
	Plastic crates	23(88.5)	24(80.0)
	Polythene bag	0(0.0)	1(3.3)
2	Mixed damage with good quality	5(19.2)	4(13.3)
3	Pack to the full level	16(61.5)	14(46.7)
4	Put something at the base	3(11.5)	10(33.3)
6	Cleaning packing materials before packing	3(11.5)	5(16.7)

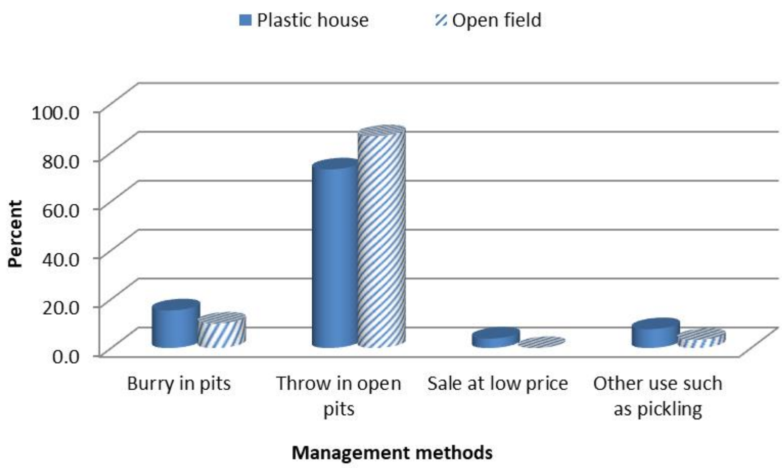

Figure 3. Management of leftover tomatoes.

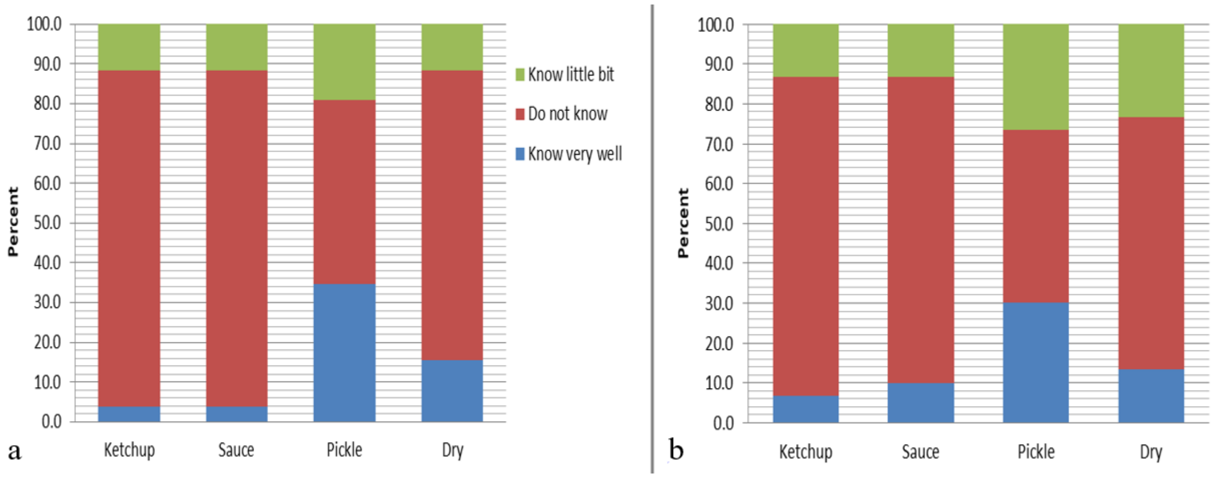

Figure 4. Level of processing knowledge: a) Plastic house and b) Open field.

3.2.8. Post-harvest management infrastructures

The study investigated if there was an involvement of middlemen in the supply chain of tomatoes. Interestingly, more than half of the producers; 73.1% and 60.0% plastic house producers and open field producers used to sell their produce to the middlemen. This lessens the net return of producers. The availability of infrastructures such as cold stores and collection centers minimizes post-harvest loss. Table 5 shows the frequency of tomato growers with access to such infrastructures. A few farmers, 11.5% and 13.3% plastic house and open field farmers, respevtively, had access to the cold store. Similarly, half (50.0%) of the plastic house producers and slightly more than half (60.0%) open field producers sent their products to the collection center. The majority of plastic house producers (61.5%) and open field producers (53.3%) had access to the good road for transporting tomatoes; 30.8% and 30.0% to poor roads; and the remaining 7.7% and 16.7% to the poor road. Wholesome the study area had good roads for transportation.

Farmers were investigated for their level of knowledge of different post-harvest management technologies (Table 6). The level of knowledge was categorized into high, medium, and low. The majority of plastic house farmers were found to have a medium level of knowledge about all three technologies i.e., high-yielding varieties (38.46%), production package (46.15%), and insect pest management (50.00%) except machinery equipment for which they had very low knowledge (53.85%). These findings are in parallel with the open field farmers, maximum of whom also had a medium level of knowledge about high-yielding variety (66.67%), production package (63.33%), and insect pest management (63.33%) except machinery equipment (33.33%). For both field conditions, a high level of knowledge was revealed in the production package. Adoption of machinery for cultivation seemed to be lagging in the areas as none had a high level of knowledge about the use of machinery; more than half (53.85% of plastic house growers and 66.67% open field growers) were found to have a low level of knowledge. Results show that farmers had more knowledge about methods of production compared to other post-harvest management technologies.

Table 5. Post-harvest management infrastructures in Kavrepalanchok district in 2019

S.N.	Infrastructures	Plastic House	Open field
1	Marketing method		
	Middlemen	19 (73.1%)	18 (60.0%)
	Direct selling	7 (26.9%)	12 (40.0%)
2	Cold store availability	3 (11.5%)	4 (13.3%)
3	Collection center	13 (50.0%)	18 (60.0%)
4	Condition of Road		
	Fair	2 (7.7%)	5 (16.7%)
	Poor	8 (30.8%)	9 (30.0%)
	Good	16 (61.5%)	16 (53.3%)

Table 6. Post-harvest management technologies in Kavrepalanchok district in 2019

	Level of knowledge					
	Plastic House			Open field		
Post-harvest management technologies	High	Medium	Low	High	Medium	Low
High yielding variety	34.62%	38.46%	26.92%	13.33%	66.67%	20.00%
Production package	46.15%	46.15%	7.69%	33.33%	63.33%	3.33%
Machinery equipment	0	46.15%	53.85%	0	33.33%	66.67%
Insect pest management	19.23%	50.00%	30.77%	3.33%	63.33%	33.33%

Table 7. Income pattern model

S.N.	Explanatory Factors	Standard Coefficients Beta	Std. Error	t	Sig.	95.0% Confidence Interval for B	
						Lower Bound	Upper Bound
	(Constant)		0.270	1.038	0.300	-0.262	0.824
1	Variety Nova (yes =1 otherwise 0)	0.71	1.510	15.921	0.000***	21.012	27.080
2	Production per unit area	0.478	0.000	10.579	0.000***	0.000	0.000
3	Cost of cultivation	0.366	0.001	7.937	0.000***	0.006	0.010
4	Access to processing industries (yes =1 otherwise 0)	0.101	0.910	2.213	0.030**	0.186	3.841
5	Marketing method (direct selling=1, otherwise 0)	0.097	0.424	2.176	0.030**	0.071	1.776

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1017.309	5	203.462	91.89	.000
2	Residual	110.709	50	2.214		
	Total	1128.018	55			

***=significant at 1%, **=significant at 5%, *=significant at 10%.

3.3. Determinants of Household Income from Tomato

The model (Table 7) represents a relationship between various factors of tomato production and household income. The study showed a positive and significant relationship between income and the Nova variety as a 1% increase in the use of the Nova variety increases the income of the household by 71%. Similarly, production per unit area and cost of cultivation increase the income by 48 and 37 times respectively. The farmers who had access to processing industries tended to earn 10% more than those without access. Processing is one of the value-added activities which enhance the ways of utilization of farm products. The farmers who sold their products directly to the consumers earned 10 times more than those selling via middlemen.

3.4. Constraints of Post-Harvest Technology Adoption at Farm Level

The adoption of post-harvest technologies is still lagging among Nepalese farmers; possible causes for this were studied. Farmers were asked to rank a list of factors that may have affected the rate of adoption of technologies. The results suggested that nearly three-quarters of the farmers (69.64%) agreed with the unavailability of fertilizers being the foremost constraint. Whereas, nearly half (44.64% and 41.07%) agreed that poor topography and poor extension visit affected the technology adoption. About 30% of the respondents said that small-scale production, unavailability of seeds, and loans were the reasons; while around 20% felt a lack of training, incentive and support, social networking, and irrigation as the ones. Few, 12.5%, and 17.86% expressed that lack of information and unavailability of chemical pesticides influenced the adoption respectively as shown in Table 8. The study revealed that the untimely availability of fertilizers is the major constraint that is affecting the farmers to keep pace with the improved post-harvest technologies.

Table 8. Constraints of post-harvest technology adoption at the farm level in Kavrepalanchok district in 2019

S.N.	Status of technology adoption factors	Degree of response*
1	Poor Extension visit	23(41.07)
2	No training taken in the relevant field	12(21.43)
3	No Incentive and support	15(26.79)
4	Not able to get Information about the Usefulness of information	7(12.5)
5	No Social Networking	12(21.43)
6	Small Scale of production of less than 5 ropani	18(32.14)
7	Poor Topography or off-road	25(44.64)
8	Unavailability of inputs	(0)
	Seed	17(30.36)
	Fertilizer	39(69.64)
	Chemical Pesticides	10(17.86)
	Irrigation	16(28.57)
	Loan	17(30.36)

*If yes 1 otherwise 0.

4. Discussion

Post-harvest loss, both qualitative and quantitative occurs at all the stages in the supply chain of perishables from harvesting, through handling, packing, storage and transportation to final delivery of the fresh produce to the consumer (Paltrinieri, 2017). Post-harvest technologies lengthen the time period that a commodity can be put on use. Harvesting at right stage largely determines the post-harvest life of a fruit. However, harvesting of tomato fruits largely depends upon the purpose of fruit utilization and market distance. The fruit is harvested at the green stage if the market is distant and at pink stage if the market is near. (JICA, 2016) suggested that the ripe stage in which the majority of the fruit surface is red is suitable for home or table use while the full ripen stage, where the fruit develops maximum color and turns soft, is best for processing. Farmers in the study area were found to harvest mostly at yellow stage targeting the distant market. Thus, it can be suggested that both green and yellow stages are fine for distant market.

Serrano and Rolle (2018) in one of the studies has discussed that harvesting of the tomato needs to be carried out in dry weather and cool temperatures, hence in the early morning. This aligns with the present study where the farmers were observed to harvest at early morning. It is not wise to harvest at the time of rain and after immediate rain but the farmers in the study area were found to do so which needs an attention. Harvesting should be done with peduncle for long durability. Cent percent of farmers were found to follow this in the study area.

Balemi et al. (2005) found that the tomatoes must be picked with clean hands and twisted gently off a plant and not be squeezed or damaged by fingernails. Tomatoes must be gently placed in the container and not thrown in or dropped. Containers must be clean nylon net bags, plastic buckets, or wood/plastic crates. These findings are in parallel with the present study where majority of farmers are using plastic crates.

Tomato can be graded according to shape, color and texture separating the damaged, rotten, burst tomatoes. Ghimire et al. (2018) mentioned that good quality tomatoes are generally preferred by buyers, thus sorting/grading is a necessary operation and grading based on size i.e. small and large is highly recommended. In contrast, the present study concluded that grading based on insect pest attacks is the most popular one in the Kavrepalanchok district.

According to Paltrinieri (2017), packaging is one of the important aspects of reducing post-harvest loss as it protects the product from mechanical injuries, tampering, and contamination from physical, chemical, and biological sources. Some common packaging materials used in most of the developing countries include plastic crates, wooden crates, cardboard boxes, nylon sacks, bamboo basket, woven palm baskets, jute sacks, and polythene bags. In rural Nepal, bamboo woven doko and dhaki are still popular in rural Nepal but plastic crates and locally available wrapping/cushion materials likes newspaper, paddy straw are recommended due to less damage (Bhattarai, 2018). The findings of present study match with the recommendations. The majority of farmers are replacing traditional doko and dhaki with plastic crates. Bhattarai (2018) also mentioned that the crates must not be filled with the fruits completely, some space must be left from the surface such that something can be placed in the surface to avoid bruising and damage. In parallel to these findings, very few farmers were found to pack to full level.

The tomato can be processed into different forms like ketchup, sauce, juice, paste, and puree. Very few farmers of the study area practiced processing the tomatoes into ketchup, sauce, pickle and dry tomatoes. The present study shows that access to processing industries directly affects the household income of the tomato growers. Thus, there must be a good communication between the industry and the producers (USAID, 2014).

Adhikari (2006) mentioned that as tomato can be produced all year round due to diversity in the climate, long time storage is not practiced in Nepal. Small growers and retailers can store for 5-10 days in zero energy storage. Free movement of fresh air needs to be maintained which helps to remove ethylene gas. During storage, temperature and relative humidity management are vital. The current findings show that very few cold store and collection center are available for storage in the study area.

The household income is catalysed by a number of factors. Among various factors, variety of the tomato, production per unit area, cost of cultivation, access to processing industries, and marketing method were revealed to determine the income of a household from tomato cultivation in the study area. Though some researches such as (Aidoo-Mensah, 2018) have been done for knowing the extent of impact of various factors on household income, yet there are rooms for more researches especially in case of Nepal.

5. Conclusion

Tomato is a year-round vegetable crop in Nepal gaining popularity because of its flexibility in its use. Keeping an eye upon the high demand for tomatoes all months around, off-season production under plastic houses has gained fame in hilly regions of Nepal. Plastic house production is one of the foremost examples of technology adoption by farmers. Farmers are slowly adopting improved technologies whether during cultivation or after cultivation i.e., during the post-harvest life of tomatoes. The study shows that income generation through tomato cultivation in plastic houses is more profitable than in the open field. Among the various factors determining the income from tomatoes; the variety of tomatoes, production per unit area, cost of cultivation, access to processing industries, and marketing method had a positive and significant relationship. This indicates that considering these factors can significantly increase the income of a household. Overviewing the constraints of technology adoption, unavailability of fertilizers, poor topography, and poor extension visits are the top three factors determining the extent of technology use.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	S.M.	T.D.
C	50	50
D	50	50
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50

C=Concept, D= design, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

The research was done under the supervision and monitoring of the Department of Horticulture at Tribhuvan University. The study was approved by Tribhuvan University (protocol code: 2019/15 and date: March 15, 2019).

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DETERMINATION OF YIELD AND YIELD COMPONENTS OF SOME SWEET FENNEL POPULATIONS

Seyhan GÜNDOGMUŞ ÇETİNKAYA[1], Hülya DOĞAN[2]*

[1]*Yozgat Bozok University, Faculty of Agriculture, Department of Field Crops, 66100, Yozgat, Türkiye*
[2]*Yozgat Bozok University, Hemp Research Institute, Department of Agriculture and Food, 66100, Yozgat, Türkiye*

Abstract: This research was carried out to determine the yield and yield characteristics of some sweet fennel (*Foeniculum vulgare* Mill. var. *dulce*) populations obtained from different regions in Yozgat ecological conditions. The experiment was established in Yozgat Bozok University, Faculty of Agriculture, Research and Application Area in the vegetation period of 2019, according to the random blocks trial pattern with 3 replications. In the study, the emergence of four different sweet fennel populations, biological yield (kg/da), plant height (cm), number of branches per plant (pieces/plant), number of umbellets per plant (pieces/plant), number of small umbellets per plant (pieces/plant), number of seed per plant (pieces) /plant), seed yield per plant (g/plant), seed yield (kg/da), 1000 seed weight (g), essential oil content (%), essential oil yield (L/da) were investigated. According to the results, the plant height of sweet fennel is 48.33-59.56 cm, the number of branches in the plant is 5.00-5.96, seed yield is 8.52-13.60 g per plant; one thousand seed weight is 3.82-7.435 g biological yield 708.70-1972.00 kg/da seed yield, 67.96-198.43 kg/da essential oil ratio 3- 4.20% essential oil yield 5.35-15.06 L/da was observed. Consequently, it has been concluded that the population of Tokat was found to have outstanding characteristics in terms of seed yield and essential oil yield.

Keywords: Sweet fennel, Populations, Essential oil, Seed yield

***Corresponding author:** Yozgat Bozok University, Hemp Research Institute, Department of Agriculture and Food, 66100, Yozgat, Türkiye
E mail: hulya.dogan@bozok.edu.tr (H. DOĞAN)
Seyhan GÜNDOGMUŞ ÇETİNKAYA https://orcid.org/0000-0003-2092-6794
Hülya DOĞAN https://orcid.org/0000-0003-1970-4123
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1. Introduction

Medicinal and aromatic plants are used in fields such as herbal tea, essential oil, especially medicine, due to their pleasant smell, spices and flavors (Baydar, 2005). *Foeniculum vulgare* L. (fennel), belonging to the Umbelliferae (Apiaceae) family, is a medicinal and aromatic plant of Mediterranean origin that has been used by humans since ancient times. Although Fennel (*Foeniculum vulgare* Mill.) is natural plant of the Mediterranean climate zone, it has emerged and has been cultivated in many regions (Damjanovic et al., 2005). *F. vulgare* Mill. is one of 300 genera in the Apiaceae family (Davis, 1984). There are two subspecies and three varieties of the fennel plant. Of these, sweet fennel (*Foeniculum vulgare* Mill. var. *dulce*) is cultivated and *Foeniculum vulgare* var. *vulgare* generally spreads naturally in natüre (Ceylan, 1997; Baydar, 2013). Today, fennel, which is cultivated in some countries such as Egypt, China, India, Italy, Germany, Bulgaria and Romania, is cultivated in the northern, southern and western regions of Türkiye in the provinces of Istanbul, Zonguldak, Kastamonu, Artvin, Bursa, Çanakkale, Kırklareli, Kocaeli, Samsun, Sinop, Trabzon and Hatay province in the south Anatolia (Davis, 1984; Koru, 2019).
All parts of fennel are used. Especially the leaves and fruits are used in the production of essential oil (Erberk et al., 2019). Fennel has a rich content of essential oil components. It has been reported that anethole and other compounds in the fennel essential oil contain galactagogue, which causes the secretion of breast milk (Rosti et al., 1998). Fennel is used as an antiseptic in medicine. Compared to other plants in the Umbelliferae family, fennel is known to have a more relaxing and stimulating effect. Its use as a carminative is increasing in low-level digestive system disorders (Erberk et al., 2019). The genetic variability of medicinal plants with natural evolution increases the importance of these plants as a gene source in breeding studies, as well as the diversity of their usage areas. Fennel production in Türkiye is mostly sweet fennel (*Foeniculum vulgare* var. *dulce*). However, in some regions, it is collected and used in fennel, which spreads naturally. The effect of ecological factors on yield and quality is important in medicinal and aromatic plants than in the other cultivated plants. Thus, it is important to find high-quality and high-yielding varieties that are adapted to different ecologies. In this study, it was aimed to determine the yield and yield components of some sweet fennel (*Foeniculum vulgare* Mill.var. *dulce*) populations in Yozgat ecological conditions.

2. Materials and Methods

2.1. Material

The research was carried out in the spring of 2019. Sweet fennel (*Foeniculum vulgare* Mill. var. *dulce*) populations obtained from the provinces of Isparta, Konya and Tokat were used as material in the study. One of the fennel populations was obtained from the Central Black Sea Transition Zone Agricultural Research Institute (Tokat), the other from Süleyman Demirel University Faculty of Agriculture (Isparta) and the other two populations from local producers in Konya province. The research was carried out in Yozgat Bozok University, Faculty of Agriculture, Topçu Application and Research Area, in May-September 2019. Topçu site has an altitude of 1165 m and is located 17 km south of Yozgat province.

2.2. Methods

The trial was established according to the Random Blocks Trial Design with three replications. Each plot is 12 m^2, each block is 48 m^2 and the total area covered by the experiment is 144 m^2. Weed hoeing was done on 05.07.2019 as maintenance work. No fertilizer was used in the experiment. The soil characteristics of the area where the experiment was conducted are given in Table 1.

Table 1. Experimental field soil analysis results

Variant	Measurement Values	
Clay (g/kg)	476	-
Silt (g/kg)	138	-
Sand (g/kg)	386	-
Ph	7.09	C
Salt (%)	0.178	Neutral
CaCO3 (%)	7.15	Lightly salted
Organic matter e (%)	2.49	Medium chalky
Total N (%)	0.15	Medium
P (µg/g)	78	Sufficient
K (µg/g)	728	Much
Ca (µg/g)	7060	Much
Mg (µg/g)	5604	Too much
Fe (µg/g)	8.08	Much
Cu (µg/g)	2.84	Sufficient
Zn (µg/g)	0.62	Little
Mn (µg/g)	4.07	Little

The searched phenological observations included: Sowing – Emergence Time (days), Emergence – Branching Time (days), Emergence – Flowering Time (days), Emergence – Fruit Setting Time (days), Sowing – Ripening Time (days). Morphological and Yield Related Characteristics were included: Biological Yield (kg/da), Plant Height (cm), Number of Branches Per Plant (pieces/plant), Number of Umbellets Per Plant (pieces/plant), Number of Small Umbellets Per Plant (pieces/plant), Number of Seed Per Plant (pieces) /plant), Seed Yield per Plant (g/plant), Seed Yield (kg/da), 1000 Seed Weight (g), Essential oil content (%), Essential oil yield (L/da) (Kalkan (2015, Özyılmaz (2015), Karataylı (2020)). The abbreviations used in Principal Components Analysis are: BB: Plant height, BDS: Number of branches per plant, BBSS: Number of umbellats per plant, BBSMS: Number of small umbellats per plant, BBMS: Number of seed per plant, BBMV: Seed yield per plant, BMA: 1000 seed weight, BVER: Biological yield, MVER: Seed yield, UYAGOR: Essential oil rate, UYAGVER: Essential oil yield.

2.3. Statistical Analysis

The data obtained from the examined features were analyzed using the SAS 9.1 package program according to the randomized blocks experimental design. When a significant difference emerged as a result of the statistical analysis, the LSD multiple comparison test was applied at a significance level of $P \le 0.05$ to compare the means. The data of the yield characteristics of the populations were subjected to Principal component analysis (TBA) and Biplot analysis in the XLSTAT 2020 (Addinsoft, New York, USA) statistical program (SAS, 1998).

3. Results and Discussion

3.1. Phenological Observations

The sowing of fennel populations was done on 02 May 2019. The seed emergency and ripening time of populations are given in Table 2.

Table 2. Phenological observations

Phenological Observations	Day	Date
Sowing – Emergence Time (days),	19	21 May 2019
Emergence – Branching Time (days)	28	18 June 2019
Emergence – Flowering Time (days)	60	19 July 2019
Emergence – Fruit Setting Time (days)	78	6 August 2019
Sowing – Ripening Time (days)	128	07 September 2019

3.2. Yield and yield components

In this study, which was carried out to determine the yield characteristics of some sweet fennel populations. The biological yield (kg/da), plant height (cm), number of branches per plant (pieces/plant), number of umbellets per plant (pieces/plant), number of small umbellets per plant (pieces/plant), number of seed per plant (pieces) /plant), seed yield per plant (g/plant), seed yield (kg/da), 1000 seed weight (g), essential oil content (%), essential oil yield (L/da) were investigated. According to Table 3, it was observed that the biological yield values varied between 708.70-1972.00 kg/da. The highest value was observed in the Tokat population with 1972.00 kg/da, and the lowest value was observed in the Isparta population with 708.70 kg/da. When our study was compared with other studies, Karataylı (2020) found that the average of biological yields in his study in Kahramanmaraş ecological conditions changed between 2310.10-3035.40 kg/da. According to another study, it was determined that the biological yield was between 484.00-2663.90 kg/da in Tokat conditions and similar results were obtained with our data (1517.47 kg/da) (Özyılmaz, 2015). The highest plant height was determined from the Tokat population with 59.56 cm, followed by the Isparta population with 53.33 cm and the Konya 1 population with 49.80 cm. The shortest plant height was obtained in Konya 2 population with 48.33 cm (Table 2). In the study conducted by Karataylı (2020) in Kahramanmaraş, the plant height was found as between 79.73-89.66 cm. According to similar studies, the plant height of the fennel plant was found to be 55.57-76.23 cm (Cosge et al., 2007), 73.1-79.2 cm (Özyılmaz, 2007) and 51-64 cm (Yıldırım et al., 2008). When our data is compared with other studies, it is thought that these differences are affected by climate, genotype and growing times. According to Table 2, in the data of the sweet fennel populations in the study, the lowest value in the number of branches per plant was found in the Isparta population with 5.00, while the highest value was the Tokat population with 5.96 branches. Number of umbellate per plant was found to be 14 in the Tokat population, followed by 10.83 in the Isparta population. The lowest values were obtained as 10.66 in Konya 2 population and 8.96 in Konya 1 population, respectively. While the number of small umbellate per plant was obtained from the Tokat population (163.83), the lowest values were determined as 110.47 in the Isparta population, 108.30 in the Konya 2 population and 81.33 in the Konya 1 population, respectively (Table 3). According to other studies conducted with sweet fennel, the number of branches per plant is 7.56-12.26 according to the study conducted in Kahramanmaraş conditions (Karataylı, 2020), the number of branches in the study conducted under Tokat conditions is 3.4-5.7 (Özyılmaz, 2007), the number of branches in the study conducted in Tokat conditions is 9.7 number/plant (Dirican, 2013) The number of branches obtained in Erzurum climatic conditions was found to be 5.0-6.5 (Çoban et al., 2019). Mahfouz and Eldin (2007) stated that the number of branches is 6.20-8.11 in his study to determine the difference between organic and mineral fertilizers. Looking at other studies, Tunçtürk et al. (2011) found that the average number of umbellate between years was 10.55-8.66 in the study of the effect of different nitrogen and phosphorus doses on yield and quality in Van conditions. Uzun et al. (2011) Considering the characteristics of fennel populations in Central Black Sea conditions, the number of umbellate was stated as 4.61-9.59. When we look at these studies, the effects of fertilization applied to the plant and different climates on plant growth have been observed. In the study conducted by Karataylı (2020) in Kahramanmaraş conditions, the number of umbellate per plant was determined as 112.70-143.33. It is similar to our data. However, in the study conducted by Özyılmaz (2015) in Tokat conditions, the average number of umbellate was stated as 188.41.

Table 3. Some morphological characteristics of fennel populations

Population	Biological yield (kg/da)	Plant height (cm)	Number of branches per plant	Number of umbellats per plant	Number of small umbellats per plant
Konya 1	1299	49.80ab	5.33	8.96b	81.33b
Konya2	1242	48.33b	5.20	10.66b	108.30b
Isparta	709	53.33ab	5.00	10.83ab	110.47b
Tokat	1972	59.56a	5.96	14.00a	163.83a
CV:	38.05	6.78	13.77	9.65	11.81
LSD:	1504.10	10.83	2.241	3.2493	41.49

CV= coefficient of variation, LSD= least significant difference

According to Table 4, the highest number of seeds per plant was obtained from the Tokat population with 967.37, followed by the Isparta population with 888.80 and the Konya 2 population with 796.50. The lowest value was obtained in Konya 1 population as 741.07. In addition, the highest seed yield per plant was obtained from Konya 1 population with 13.60 g, while the lowest values were determined as 9.63 g in Tokat population, 8.69 g in Konya 2 population and 8.52 g in Isparta population, respectively. According to the study conducted by Özyılmaz (2015), the average number of seeds per plant was determined as 993.27 and it is seen to be compatible with our data. However, according to the study conducted by Yıldırım and Kan (2006) in Konya ecological conditions, the number of seeds per plant was determined as 98-194. According to the literature, in the study of Karataylı (2020) in Kahramanmaraş conditions, seed yield per plant was 16.66-35.13 g, and Coşge et al. (2007) reported 5.04-11.21 g in their study in Ankara conditions, 0.8-1.7 g in Yıldırım and Kan (2006)'s study in Konya conditions, and 2.87-4.67 g in Özkan and Gürbüz (2000)'s studies in Ankara conditions.

When we look at Table 4, the 1000 seed weight of the sweet fennel plant was determined by the Konya 1 population at the most, 7.34 g, while the least weight was obtained from the Konya 2 (4.06 g), Tokat (3.98 g) and

Isparta (3.82 g) populations, respectively. In addition, the highest seed yield was determined as 198.43 kg in Tokat population per decare. In the second place, the highest seed yield was obtained from Konya 1 population (115.00 kg/da), while the lowest yield was determined from Konya 2 (76.70 kg/da) and Isparta (67.96 kg/da) populations, respectively. Karataylı (2020) stated that the 1000 seed weight was 5.93-7.85 g in their study, while Çoban et al. (2019) in Erzurum ecological conditions, it was determined that it was 8.31 g in different water levels, and Ayritman (2015) found that the 1000 seed weight was 5.82 g in his study at different nitrogen levels. Kalkan (2015) found that the 1000 seed weight was 8.52 g (different row spacings) in Erzurum conditions, Ehsanipour et al. (2012) stated that the 1000 seed weight in Iran was 3.79-4.01 g. When we look at these studies, we can conclude that maintenance studies (irrigation, fertilization, etc.), genetic characteristics of plants, climate and environmental factors may have effects on 1000 seed weight. Ghanbari-Odivi et al. (2013) stated that the yield was between 474-1019 kg/da in the study where fennel was carried out at different planting times, whereas Malik et al. (2009) found the seed yield to be lower (202.4-215.00 kg/da) in his study in India. In addition, Kırıcı et al. (2010) stated that the seed yield was 43-331 kg/da in their study in Adana ecological conditions. Nakhaei et al. (2012) examined the effects of different nitrogen applications and planting frequency on the yield characteristics of fennel plants in Iranian ecological conditions, and they stated that the effect of planting distances and nitrogen doses were important in all data.

In Table4, the lowest essential oil ratio was obtained from Konya 2 population with 3.64%, while the highest was found in Konya 1 population with 4.14%. Also, the highest yield of essential oil was obtained from Tokat population with 15.06 L, followed by Konya 1 population with 9.49 L/da, and the lowest yield was Konya 2 (5.61 L/da) and Isparta populations (5.35 L/da), respectively (Table 4). Environmental factors (temperature, precipitation, duration and intensity of lighting, altitude, direction, drought, salinity, soil texture and nutrients, etc.) affect the synthesis and accumulation of the active substance. The alkaloid and essential oil contents of medicinal and aromatic plants grown in hot and arid regions are higher than those grown in cool and rainy regions (Baydar, 2020). Karayel (2019) obtained 1.83% essential oil in Kütahya conditions, and Karataylı (2020) found 1.60-2.00% essential oil in Kahramanmaraş conditions. In the study conducted by Şahin (2013) in Konya conditions, it was stated that the essential oil ratio was between 2.4-4.2% and Doğan (2020) was between 2.37-3.24%. According to other studies, the essential oil yield of fennel was determined as 6.24-14.65 L/da in Karayel (2020) and 3.65 L/da in Özyılmaz (2015).

Table4. Yield, yield component, essential oil percentage and yield characteristics of fennel populations

Population	The number of seed per plant	Seed yield per plant (g/plant)	1000seed weight (g)	Seed yield (kg/da)	Essential oil percentage (%)	Essential oil yield (L/da)
Konya 1	741.07b	13.60a	7.34a	115.00b	4.14	9.49 b
Konya2	796.50ab	8.69b	4.06b	76.70c	3.64	5.61 c
Isparta	888.80ab	8.52b	3.82b	67.96c	3.96	5.35 c
Tokat	967.37a	9.63b	3.98b	198.43a	3.80	15.06 a
CV:	7.21	7.98	2.49	3.53	12.09	8.30
LSD:	185.41	2.45	0.36	12.27	1.42	2.23

CV= coefficient of variation, LSD= least significant difference

3.3. Principal Component Analysis of Yield Characteristics

Principal components analysis (PCA), which is a dimension reduction method, was performed using the yield characteristics data set and 100% of the total variation was obtained from the 3 principal component axes (Table 5). The amounts, percent variances and percent cumulative values of the principal components are given in Table 3. The first component (TB1) represents 61.817% of the total variation. In the first component, BBSEMS, BBSS, BB, BDS, BBMS, MVER, UYAGVER and BVER had the highest coefficients, respectively. In the second component (TB2), 30.015 % of all variation was explained. In this component, BBMV, BMA, UYAGOR, UYAGVER, MVER, BVER, BDS and BB showed the highest coefficients. The third component (TB3) explained 8.168% of the total variation. In this component, UYAGOR, BB, BBMS, BBSS, BBSEMS, BBMV and UYAGVER had the highest coefficients, respectively. In principal component analysis, the fact that the eigenvalues of the principal component weight are greater than 1 indicates that the values are in the reliable range.

3.4. Biplot Analysis of Yield Characteristics

A biplot plot showing the relationship with 11 traits examined in sweet fennel populations is given in Figure 1. The biplot plot, where 61.82% of the represented variation is represented by principal component 1 (First major component) and 30.02% by principal component 2 (Second main component), explains 91.84% of the total variation (Figure 1, Table 5).

According to Principal Component Analysis results, the distribution of traits is between 0 and 1 and between 0 and -1, and the distribution of populations is between 0 and 4; It ranged from 0 to -2. It shows the closeness of the features as the angle of the vectors gets narrower, and the weaker the relationship between the features as it gets wider.

Biplot plot shows that sweet fennel populations are located in three different regions (Figure 1). It has been determined that the vector that affects TB1 the most is BBSEMS, and the vector that affects TB2 the most is BBMV (Figure 1). BBŞEMS vector showed positive correlation with BBMS, BBSS, BB, MVER, UYAGVER and BVER vectors. On the other hand, in the region where Konya 1 population is located, it was determined that BBMV vector showed a positive relationship with BMA and UYAGOR properties. The vectors MVER, BVER, BDS, UYAGVER showed a partially negative correlation with the BBMV trait (Table 5, Figure 1). It is seen that the Tokat population has a close positive relationship with the characteristics of BBMS, BBSS, BB, MVER, UYAGVER and BVER. Konya 2 and Isparta populations were found to be negatively correlated with all characteristics. It can be said that genotypes located in the same direction and in the same circle have values close to each other. In this study, populations with high yield and quality in terms of some agricultural characteristics were tried to be determined.

Table 5. Principal component analysis of the yield traits studied

Yield characteristic	PC1	PC2	PC3
BB	0.348	0.031	0.438
BDS	0.338	0.242	-0.185
BBSS	0.373	-0.124	0.031
BBSEMS	0.375	-0.114	0.024
BBMS	0.332	-0.186	0.389
BBMV	-0.121	0.522	0.004
BMA	-0.188	0.479	-0.030
BVER	0.303	0.255	-0.422
MVER	0.330	0.279	-0.039
UYAGOR	-0.159	0.362	0.664
UYAGVER	0.313	0.318	0.003
Eigen value	6.800	3.302	0.898
Variance (%)	61.817	30.015	8.168
Cumulative (%)	61.817	91.832	100.000

BB= plant height, BDS= number of branches per plant, BBSS= number of umbellets per plant, BBSMS= number of small umbellets per plant, BBMS= number of seed per plant, BBMV= seed yield per plant, BMA= 1000 seed weight, BVER= biological yield, MVER= seed yield, UYAGOR= essential oil rate, UYAGVER= essential oil yield

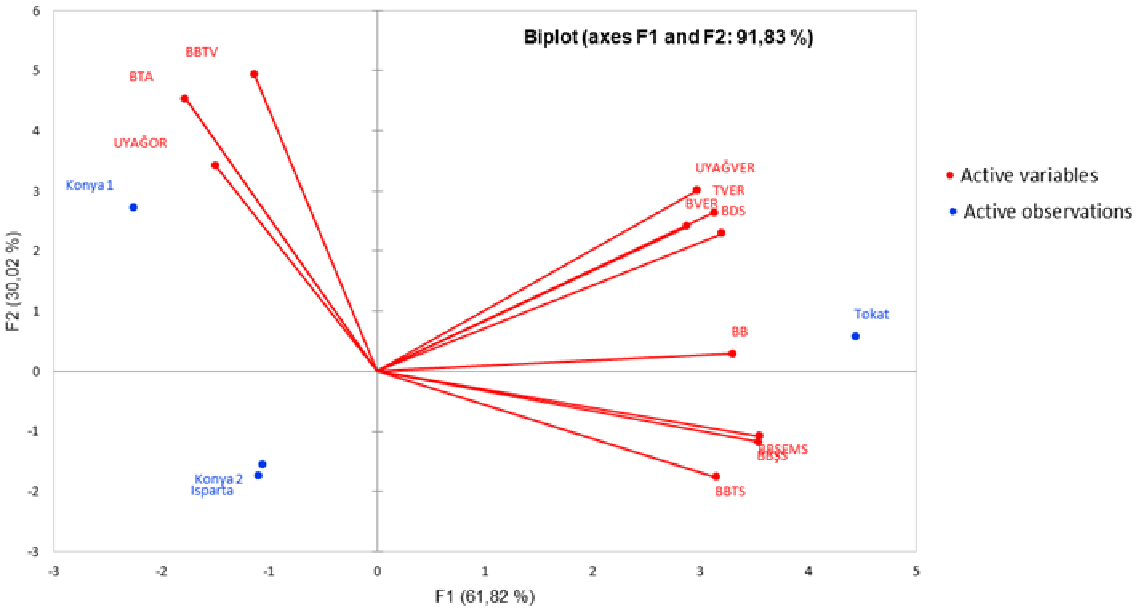

Figure 1. Principal COMPONENT ANALYSIS. BB= plant height, BDS= number of branches per plant, BBSS= number of umbellets per plant, BBSMS= number of small umbellets per plant, BBMS= number of seed per plant, BBMV= seed yield per plant, BMA= 1000 seed weight, BVER= biological yield, MVER= seed yield, UYAGOR= essential oil rate, UYAGVER= essential oil yield.

4. Conclusion

According to the results of this study on some yield characteristics of sweet fennel, it is thought that sweet fennel can be grown in Yozgat conditions. When this study and the studies in the literature were compared, it was observed that there were similarities and differences. The reason for these differences is thought to be due to factors such as climate, irrigation, fertilization, planting frequency and differences between genotypes. According to principal component analysis, Tokat population has a close positive relationship with the characteristics of BBMS, BBSS, BB, MVER, UYAGVER and BVER. Konya 2 and Isparta populations were found to be negatively correlated with all characteristics.

Considering the examined characteristics,it is thought that the populations that are found to be important can be used for production purposes in future studies and can be evaluated as materials in breeding studies. The prominent population in this study was the Tokat population.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	S.G.Ç	H.D.
C	50	50
D	100	
S		100
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50
FA	50	50

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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SOME SOYBEAN [*Glycine max*. L. (Merill)] VARIETIES DETERMINATION OF CULTIVATION POSSIBILITIES OF AS MAIN CROP

Mehtap ANDIRMAN[1], Nurettin BARAN[2]*

[1]*Batman University, Sason Vocational School, Department of Plant and Animal Production, Organic Agriculture Program, 72000, Batman, Türkiye*
[2]*Muş Alparslan University, Faculty of Applied Sciences, Department of Plant Production and Technologies, 49000, Muş, Türkiye*

Abstract: This research was carried out at Batman University West Raman experimental area with 3 replications in order to determine the yield and yield components of some soybean varieties as the main crop under Batman conditions in the 2018 production year. In the study, 7 different soybean varieties (Umut-2002, Nova, Bravo, Asya, Ataem, Atakişi, Blaze) were used as plant materials. In the study, plant height, number of branches, first pod height, number of pods per plant, yield per decare and oil content were investigated. As a result of the study, the plant height is 64.90-72.47 cm, the number of branches is 4.83-9.23 pieces/plant, the first pod height is 10.70-15.20 cm, the number of pods per plant is 31.27- 49.23 pieces, the seed yield was determined as 244.05-554.44 kg/da and the oil content was between 17.82-24.83%. In addition, it was determined that the results of the heat map clustering, PCA and DARwin plots and the grouping of the relationships between cultivars, traits and cultivar*traits were confirmed.

Keywords: Soybean, *Glycine max*. L. (Merill), Yield, Oil content

***Corresponding author:** Muş Alparslan University, Faculty of Applied Sciences, Department of Plant Production and Technologies, 49000, Muş, Türkiye
E mail: n.baran@alparslan.edu.tr (N. BARAN)
Mehtap ANDIRMAN https://orcid.org/0000-0001-8566-3388
Nurettin BARAN https://orcid.org/0000-0003-2212-3274

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1. Introduction

Due to the rapid increase in the human population in Türkiye, the need for basic nutrients is also increasing (Ozturk et al., 2000). For this reason, the importance of vegetable and animal origin oils, which also have an important place in food consumption, is gaining interest among consumers. However, due to the extremely high cost of animal oils and the lack of adequate production, a large proportion of the oils that people need are supplied from vegetable oils (Kolsaraci et al., 2015). The importance of oil plants in human and animal nutrition is increasing in terms of the fat, protein, carbohydrate, vitamin and mineral substances they contain. Although a healthy individual needs 2500-3000 calories to carry out his daily vital activities, it is known that 30-35% of these calories come from fats. In this case, each individual should consume approximately 23 kg of fat per year.

Oilseed plants are grown both as annuals and perennials. Annual plants; are soybean, rapeseed, peanut, sunflower, safflower, flax, oil turnip, camelina, sesame, castor oil and crambe, while perennial plants are trees such as olive, coconut, avocado, cocoa, palm and jojoba (Baydar and Erbas, 2014).

While 58% of the world's oilseed demands come from the production of soybean plants, 53% Türkiye's of oilseed demands come from sunflower production. However, the amount of oil consumption is increasing as a result of the continuous increase in the population, and the oil deficit is increasing day by day because the demand for the amount of vegetable oil produced in Türkiye cannot be met. The oil shortage, which is increasing due to the insufficient cultivation of oil crops, is mitigated through the import of seeds and crude oil. For these reasons, there is a serious foreign exchange loss in Türkiye. By increasing the current agricultural potentials of oilseed plants, which are as strategic as cereals, both the oil needs of Türkiye will be demands and the capacities of oil factories will increase and great contributions will be made to the oil sector (Arioglu et al., 2010). Approximately 3.4 million hectares of land (TUIK, 2019) in Türkiye are used as a fallow land and cannot be utilized for alternative oil crops and oilseed meal, which is needed for the development of livestock sector.

Soybean, which has 130 million hectares of cultivation area, 381 million tons of production and an average yield of 293 kg/da in the world, has a cultivation area of 135 thousand hectares and a production value of 150 thousand tons in Türkiye (USDA, 2022; TUIK, 2022). Although soybean has the potential to be successfully grown as a second product after wheat harvest in the Aegean, Mediterranean and Southeastern Anatolia regions of Türkiye, cultivation area and production are quite insufficient (Figure 1). An average of 3,000,000-3,200,000 tons of soybean products are needed annually and approximately 97% of this product is imported from abroad (TURKIYEM-BIR, 2022) (Figure 1).

More than 90% of soybean production in Türkiye comes from the provinces in the Mediterranean Region. The country that produces the most soybeans in the world is the USA. This country is followed by Brazil, Argentina and China (TUIK, 2022; USDA, 2022). Although soybean is the primary product among oilseeds in many countries around the world and constitutes approximately 50% of the total oilseed production, this rate is only 4% in Türkiye. The most important feature of soybean is that it provides more and cheaper protein per unit area than other plant and animal feed sources. Soybean protein is the closest protein to animal protein and has a very high biological value. For this reason, soybean skim flour is used as a protein source, especially in the rations of poultry and ovine animals; as well as dairy cattle and beef cattle. Soybean is mostly consumed as animal feed in Türkiye (TEPGE, 2015).

The soybean plant (*Glycine max* L.) belongs to the legume family and is an annual, summer plant. It contains 36-40% protein, 26% carbohydrates, 18-24% oil and 8% mineral substances and vitamins in its seeds. It has different usage areas because it contains important amino acids (Bellaloui et al., 2013; Bohn et al., 2014). Although it is the plant that produces the most protein per unit area, it is considered as an excellent plant for animal feed, especially in the nutrition of poultry, since it contains a remarkable protein in the pulp that remains after the oil is removed from the seeds (Okcu et al., 2007; Yilmaz and Efe, 1998).

Türkiye has suitable climatic features for the cultivation of oil crops with different characteristics. Researching and identifying oilseed plants that can be grown in different climate factors in order to close the existing oil deficit in Türkiye and initiating production incentive programs by increasing agricultural supports will contribute to closing the oil deficit. As in all plants, the most important factor affecting yield and yield characteristics in soybean is the determination of the appropriate variety (Tuncturk et al., 2020). With the provision of irrigation facilities of the Southeastern Anatolia Project and the expansion of soybean cultivation areas, there will be a parallel increase in production. After this situation, it is thought that it will be used as both the main product and the second product and the rate in oilseed production will increase day by day. The aim of this study is to determine the potential of different soybean varieties to be grown under Batman conditions as the main product.

2. Materials and Methods

The research was carried out in the trial area at Batman University West Raman Campus in the 2018 growing season. In the study, 7 different soybean varieties (Umut-2002, Nova, Bravo, Asya, Ataem, Atakişi, Blaze) were used as plant materials. The coordinates of the experiment are: 37°78' 73 20'' North latitude and 41°06' 27 30'' East longitude. The annual total precipitation amount of the long-year average (UYO) in the growing season of the region where the research was conducted is 40.63 mm, the average temperature is 16.38ºC, and the average relative humidity is 41.3%. The total rainfall in the growing season of 2018 was 30.70 mm, the average temperature was 24.50 °C, and the average relative humidity was 42.53% (Anonymous, 2018). The 7 different soybean varieties included in the study were obtained from Çukurova University, Faculty of Agriculture, Department of Field Crops.

This study was carried out in a randomized block design with three replications. Each plot consisted of four rows with a width of 2.8 m and a length of 5.0 m. Sowing was done by hand with 70 cm row spacing and 10 cm intra-row spacing. 20 kg/da of 18-46-0 DAP (Diamonyumfosfat) fertilizer was given to all parcels as a spread and mixed into the soil with a rake. Due to insufficient rainfall in June, July and August, the water needed by the plant was met with irrigation water. Irrigation was applied 6 times using of drip method.

Figure 1. Distribution of soybean production by provinces in Türkiye.

In the harvest, the remaining 2 rows were harvested by removing the one row at the edge of the parcel and the 0.5 m section at the ends as the edge effect. In statistical analysis, the values obtained from the trial results were subjected to analysis of variance using the JMP (13.0) pro package program according to the randomized blocks trial design. The differences in the obtained data were grouped by the LSD test. In addition, principal component analysis (Principal Component Analysis, PCA) (XLSTAT, 2021) was applied to the examined cultivars and their characteristics. Heat map clustering (ClustVis) and the DARwin-6 program were used to visualize and differentiate the examined varieties and traits and to determine the correlation between them.

3. Results and Discussion

3.1. Plant Height (cm)

According to the results of the variance analysis of the plant height values obtained from the 7 different soybean varieties included in the experiment, they were found to be statistically significant. According to the results of the study, it was determined that the plant height values varied between 64.90-72.47 cm. The highest plant height was obtained from the Umut-2002 variety with 72.47 and the lowest value was obtained from the Atakişi variety with 64.90 cm (Table 1). The findings of plant height in this study; are compatible with other findings from other researchers including Ekinci (2019), 37.27-98.67 cm; Cetin and Ozturk (2012), 58.4-66.8 cm; Yildirim (2017), 63-94.85 cm; Gumus and Beyyavas (2020) show that 41.20-104.83 cm. However, for plant height, the obtained results was lower than the findings by Erdogmus et al. (2007), 82.0-107.9 cm; Karaaslan (2011), 108.7-138.8 cm; Bakal et al. (2016), 89.9-131.5 cm; Altinyuzuk (2017), 74.1-113.1 cm.

It was expected that the results to be obtained will differ from each other due to the fact that the studies are carried out in different ecological conditions and using varieties with different characteristics.

3.2. Number of Branches (pieces/plant)

It has been shown that there is a significant variation in the number of branches among the cultivars included in the experiment. According to the results of the study, it was determined that the number of branches varied between 4.83-9.23 pieces/plant. The highest number of branches was obtained from the Umut-2002 variety with 9.23 pieces/plant and the lowest value was obtained from the Asya variety with 4.83 pieces/plant (Table 1).

Other researchers obtained similar results; for the number of branches such as Cetin and Ozturk (2012), 4.8-6.9 pieces/plant; and even lower numbers such as Acar (2015), 1.17-3.80 pieces/plant and Altinyuzuk (2017) who obtained the number of branches varying between 1.9 and 3.9 pieces/plant.

3.3. First Pod Height (cm)

According to the results of the variance analysis of the first pod height values obtained from the 7 different the soybean varieties included in the experiment, they were found to be statistically significant. According to the results of the study, it was determined that the first pod height values varied between 10.70-15.20 cm. The maximum height of the first pod was obtained from the Atakişi variety with 15.20 cm and the lowest value was obtained from the Nova variety with 10.70 cm (Table 1).

Findings of the first pod height obtained from the study was in the range of data obtained by; Karaaslan et al. (1999), 10.0-12.9 cm; Karaaslan (2011), 9.2-15.4 cm; Sabanci (2013), 12.68-18.13 cm in Aydin. However, Tunçtürk (2020) determined that 15.6-21.2 cm is lower than the findings obtained.

3.4. Number of Pods per Plant (pieces)

According to the results of the variance analysis of the pod number values obtained from the 7 different soybean varieties included in the experiment, they were found to be statistically significant. According to the results of the study, it was determined that the number of pods per plant varied between 31.27-49.23 pieces The highest number of pods per plant was obtained from the Asya variety with 49.23 pieces and the lowest value was obtained from the Ataem variety with 31.27 pieces (Table 1).

In the studies conducted with the number of pods per plant, Karaaslan (2011), 51.2-70.6 pieces; Acar (2015), 32.17-72.10 pieces; Altinyuzuk (2017) determined that it varies between 45.7-94.9 pieces.

Table 1. Sources of variance and significance levels for the analyzed features

Variety	Plant height (cm)	Number of branches (pieces/plant)	First pod height (cm)	Number of pods per plant (pieces)	Number of seeds per pod (pieces/plant)	Seed yield (kg/da)	Oil content (%)
Asya (G1)	69.27^{b}	4.83^{c}	11.76^{bc}	49.23^{a}	27.2^{a}	554.44^{a}	20.88^{b}
Blaze (G2)	68.77^{bc}	6.57^{b}	11.8^{bc}	41.20^{b}	25.77^{abc}	534.23	19.40^{bc}
Bravo (G3)	65.86^{cd}	4.87^{c}	14.2^{a}	35.37^{c}	26.4^{ab}	467.79	24.83^{a}
Ataem (G4)	65.37^{d}	4.93^{c}	12.77^{b}	31.26^{d}	24.47^{c}	464.87	23.73^{a}
Atakişi (G5)	64.90^{d}	8.93^{a}	15.2^{a}	36.97^{c}	26.07^{ab}	425.51	21.19^{b}
Nova (G6)	67.23^{bcd}	7.43^{b}	10.70^{c}	36.87^{c}	25.30^{bc}	349.04	17.82^{c}
Umut-2002 (G7)	72.47^{a}	9.23^{a}	14.9^{a}	36.93^{c}	26.06^{ab}	244.05	19.40^{bc}
CV (%)	2.64**	8.1**	5.53**	3.12**	3.11*	5.87**	6.52**

**P<0.01; *P<0.05.

3.5. Number of Seeds per Pod (pieces/plant)

The number of seeds in the pod obtained from the 7 different soybean varieties included in the experiment was found to be statistically significant according to the results of the analysis of variance. According to the results of the research, it was determined that the number of seeds in the pod varied between 24.47-27.2 pieces/plant. The highest number of seeds per pod was obtained from the Asya variety with 27.2 pieces/plant, and the lowest value was obtained from the Ataem variety with 24.47 pieces/plant (Table 1).

3.6. Seed Yield (kg/da)

According to the results of the variance analysis of the seed yield values obtained from the 7 different soybean varieties included in the experiment, they were found to be statistically significant. According to the results of the study, it was determined that the seed yield values varied between 244.053-554.44 kg/da. The highest seed yield was obtained from the Asya variety with 554.44 kg/da and the lowest value was obtained from the Umut-2002 variety with 244.053 kg/da (Table 1).

One of the most important conditions for the sustainable and economical production of oilseed plants is a high seed yield per unit area. Because there are two important goals in the production of oilseed plants. In the first place, the oil yield per unit area must be high as possible, and in the second place a very high pulp yield per unit area must be obtained. In order to achieve these goals, the most important condition is to obtain a very high seed yield per unit area (Gecit et al., 2009).

Other researchers, in their studies on seed yield obtained varying results as follow; Tayyar and Gul (2007), 189.0-330.2 kg/da in Canakkale conditions; Karaaslan (2011), 187.1-287.1 kg/da; Arioglu et al. (2012), 275.2-367.4 kg/da; Cetin and Ozturk (2012), 192-251 kg/da in Konya conditions; Acar (2015), 128-239 kg/da in Bingöl conditions; Bakal et al. (2016), 321-463 kg/da; Altinyuzuk and Ozturk (2017), 395-489.9 kg/da in Çukurova conditions; Ozturk (2019), in the study conducted in Sirnak ecological conditions, 232.57-376.25 kg/da; Tuncturk et al. (2020), 170.51-214.15 kg/da; Sengoz and Arslan (2022) determined that it varies between 206.22-269.41 kg/da in Sanliurfa ecological conditions.

While the seed yield values obtained from this study were in line with the data obtained by some researchers above, they were found to be inconsistent with other findings.

New varieties that are superior in terms of yield and agricultural characteristics are developed through breeding studies (Nyirahabimana et al., 2022). It is known that the new lines or varieties developed give different results in different ecological conditions. Therefore, regional adaptation studies are especially important for new varieties or lines.

3.7. Oil Content (%)

According to the results of the analysis of variance of the oil ratio values obtained from the 7 different soybean varieties included in the experiment, they were found to be statistically significant. According to the results of the study, it was determined that the fat content values varied between 17.82-24.83 %. The highest oil content was obtained from Bravo variety with 24.83 % and the lowest value was obtained from Nova variety with 17.82% (Table 1). While the oil content values obtained from this study were in line with the data obtained by Ozturk (2019), 19.90-21.23% and Ozturk et al. (2021), between 18.29-24.81%, whereas the fat ratio values by Bakal et al. (2021), were found to be inconsistent with the findings of 16.8-17.4%

The reason why the parameter values examined in the study are different from the findings of Bakal et al. (2021), is that different varieties and lines, were grown using different agricultural practices during the cultivation period. As well as the climatic factors were different and laboratory conditions of the analyzed materials varied.

3.8. PCA Graph of Heatmap Clustering and Examined Parameters

In the research, a heat map graph was created to interpret the relationships between parameters, applications and similarity between parameters. It has been determined that the investigated parameters occur in two different main clusters and subgroups occur in each main cluster.

In the first main cluster these parameters were included; SY (Seed yield), PH (Plant height), NP (Number of pods) and NGP (Number of grains per pod). In the second main cluster, parameters such as; OR (Oil content), NB (Number of branches), and FPH (First pod height) were included (Figure 2). According to the heatmap clustering and PCA plot, the subgroups show a high level of correlation (Figure 2 and 3).

Also, the variation between traits explained 36.13% of PC1; and 29.21% of PC2. According to the PCA analysis, Umut-2002 (G7) cultivar is the most ideal variety in terms of features in the first group (NB), and Asya (G1) is the best variety in terms of features in the second group (NP, OR and NGP). In addition, it is understood that Blaze (G2) and Atakişi (G5) cultivars did not stand out in terms of any traits examined in the study, while Nova (G6), Ataem (G4) and Bravo (G3) cultivars gave values close to the trial average in all traits (Figure 3).

The DARwin analysis graph confirmed the results of the heat map clustering and it was determined that there were 2 different main groups (A and B) in terms of varieties. The main group A; contains Asya (G1), Blaze (G2), Bravo (G3), Ataem (G4) and Atakişi (G5), while in the main group B; Nova (G6) and Umut-2002 (G7) varieties were included. In addition, main group A formed 2 subgroups. In the subgroup AI; it consisted of Asya (G1) and Ataem (G4) cultivars, and in subgroup AII, consisted of Blaze (G2), Bravo (G3) and Atakişi (G5) cultivars (Figure 4). The main purpose of the DARwin analysis program was to determine the morphological relationship between the varieties.

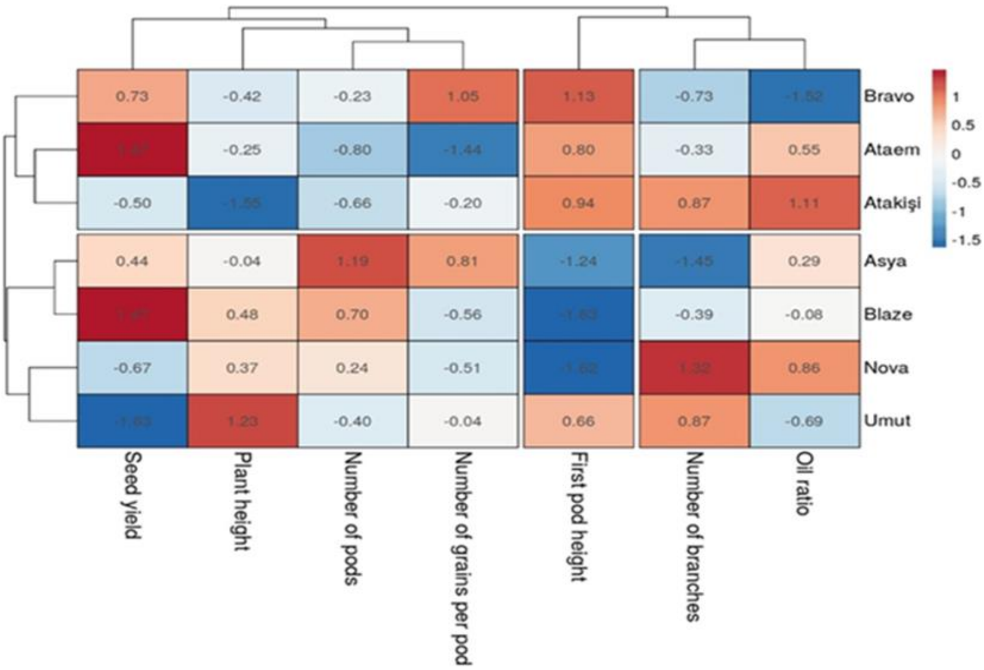

Figure 2. Clustering of soybean cultivars by heat map of investigated traits.

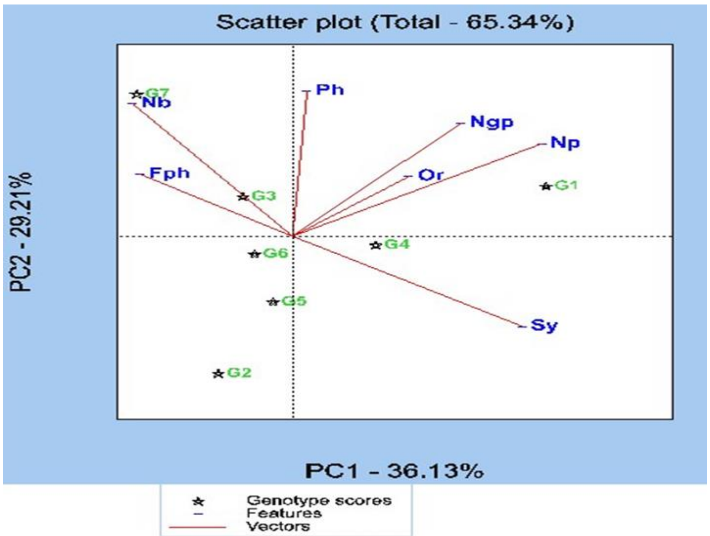

Figure 3. Principal component analysis (PCA) of soybean varieties.

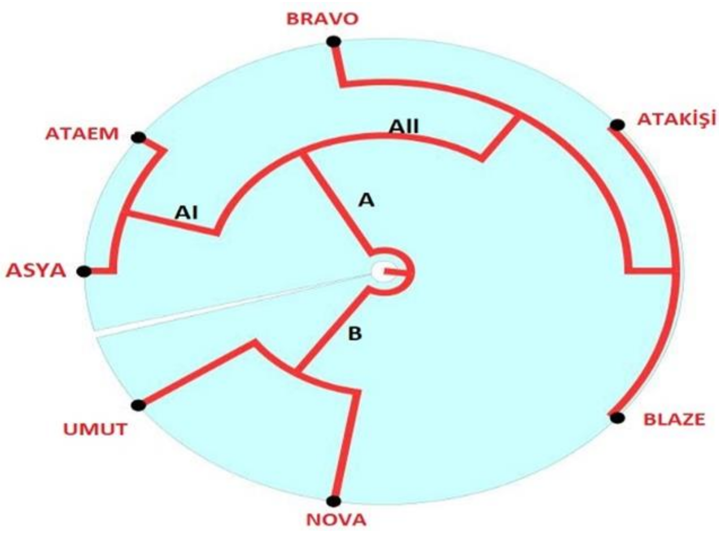

Figure 4. Morphological association of varieties with DARwin program.

4. Conclusion

In order to increase the production and cultivation area of the soybean plant, which is of great importance to meet the vegetable oil requirement in Türkiye, it is necessary to determine the ecologies in which the improved varieties can provide the best adaptation in terms of yield. Each variety in different climatic conditions (humidity, temperature, precipitation, etc.). Ecological conditions affect the adaptation of varieties and seed yield. For this reason, in order to obtain high seed yield, it is necessary to determine the varieties that are least affected by climatic factors during the year and to pay attention to these varieties.

With the researches carried out in the Southeastern Anatolia Region recently, the soybean plant has been tried to be introduced and popularized in this region. In this study, which was carried out in order to determine the suitability of the soybean plant for cultivation as the main product in irrigable agricultural lands in Batman province and to determine the variety; It has been determined that soybean can be successfully grown as the main product in Batman province, ''Asya'' in terms of seed yield and ''Bravo'' varieties in terms of oil content are among the varieties that can be recommended for local conditions with both high seed yield and high oil rate.

Considering that the world soybean yield is 293 kg/da it is an indication that soybean farming can be done in Batman since we have soybean varieties that can reach approximately twice the world average in terms of yield. For this reason, it has been concluded that the soybean varieties used in the research can be successfully grown as the main product in Batman Province conditions in terms of growing time and yield values and the ''Asya'' variety is the most suitable variety. In addition, it was determined that the results of the heatmap clustering, PCA and DARwin plots and the grouping of the relationships between cultivars, traits and cultivars*traits were confirmed.

Soybean plant is from the legumes family and it contributes to the yield of plants such as wheat, cotton and corn that will be planted after it, since it transforms the free nitrogen in the air into useful soil.

It is estimated that this study will shed light on other research to be carried out in Batman and the soybean agriculture that is expected to develop in the region. As a result of the repetition of similar studies in larger areas in the coming years, it will be possible to mobilize the people of the region for soybean production if the use of varieties determined to be productive and of high quality is encouraged.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	M.A.	N.B.
C	50	50
D	50	50
S	50	50
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50
FA	50	50

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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ROOT CAUSE ANALYSIS OF RECURRENT IRRIGATION SYSTEM DESTRUCTION IN JOWHAR DISTRICT, MIDDLE SHABELLE REGION, SOMALIA

Mohamed Mohamud ABDI[1], Bashir Ahmed MAOW[2]*

[1]Department of Irrigation and Agrometeorology, Ministry of Agriculture and Irrigation, Mogadishu, Somalia
[2]Department of Water and Environmental Engineering, Odoros Research Center, Mogadishu, Somalia

Abstract: Governments have historically considered irrigated agriculture as a way to stabilize rural communities, increase rural incomes, and meet the growing population's requirements for food and fiber. In Somalia, irrigation development started during the Italian colonization era of 1920s for the purpose of banana cultivation. The majority of these infrastructural investments were made in Middle Shabelle. The central government's fall in 1991 left the Somali government become weak financially and unable to finance the maintenance and operation of the irrigation infrastructure. The main objective of this research is to identify the root causes of recurrent irrigation system destruction after their rehabilitation in the Jowhar district of the Middle Shabelle Region, Somalia. Two sub-objectives of the study were to assess how insufficient institutional capacity and financing affected the failure of irrigation canals in the Jowhar District. In the study, 28 participants participated. A mixed-methods strategy was used to conduct the research, which included surveys, field observations, and interviews. The questionnaire is divided into three sections, each of which has a question about management, design, and financing. The final section investigates how inadequate institutional capability contributes to canals failure. This study examined the relationship between finance availability and institutional capacity with regard to canal failures and concluded that finance availability is positively correlated to the failure of irrigation canal and also low institutional capacity have moderately positive correlation with failures of irrigation canal.

Keywords: Irrigation, Canals, Jawhar, Middle Shabelle, Somalia

***Corresponding author:** Department of Water and Environmental Engineering, Odoros Research Center, Mogadishu, Somalia
E mail: Qaalla49@gmail.com (B. A. MAOW)
Mohamed Mohamud ABDI https://orcid.org/0000-0002-8809-3840
Bashir Ahmed MAOW https://orcid.org/0000-0002-5717-7232

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1. Introduction

Governments have historically considered irrigated agriculture as a way to address the growing population's requirements for food and fiber, boost rural incomes, and stabilize rural populations (Malano and Robertson, 2003). According to FAO data, the world's net cultivable area rose by 12% between 1961 and 2009, primarily at the expense of wetlands, grasslands, and forests. At the same time, the world's irrigated area doubled (FAO, 2011). Earth's agricultural land area has grown by 159 Mha since 1961. However, throughout the same time span, more land has been put under cultivation while less previously used land has been taken out of use. Irrigated cropping was responsible for the whole net gain in the cultivated area over the past 50 years, while rainfed systems exhibited a very minor drop (FAO, 2011).

According to a study by (Omar et al., 2019), evaporation, seepage through canal bunds, overtopping the bunds, overflow losses, and overwatering are the most common ways irrigation water is lost from canals and canal bunds, with an average field application efficiency of 25% and an average conveyance efficiency of 30%. When these considerations are taken into account, the scheme's calculated irrigation efficiency is 7.5%, which is low for surface irrigation, which is the prevalent method in the research area.

In Somalia, irrigation development started during the Italian colonization era of the 1920s for the purpose of banana cultivation when they constructed barrages in the Middle Shabelle region to divert more water for banana cultivation (Mbara et al., 2007). Middle Shabelle is the region that received the majority of these infrastructure investments. Major irrigation infrastructure was still being built and established by the Somali government after colonization in the 1960s, but it was abandoned after the central government was overthrown in 1991(Mbara et al., 2007).

Since the fall of the central government in 1991, the Somali government has deteriorated financially and in terms of its administrative capabilities (World Bank, 2018). Since 2000, the country has been recovering from protracted periods of government inefficiency. The government has been unable to support the operation and maintenance of the irrigation system because the security situation prevents it from leaving the cities and accessing the rural areas where the irrigation system is located.

Following the civil war (1998–1999), the United Nations' humanitarian agencies started to step in and take over the government's responsibilities. They also started projects to support Somalia's national food security system, which included the rehabilitation of the country's main irrigation canals. In the past ten years, the irrigation system that had been restored by the humanitarian organization with the help of foreign partners once more failed. The purpose of this study is to improve our knowledge of the main factors that lead to irrigation canal failures that occur repeatedly and to learn more about the factors that influence the success—or lack thereof—of irrigation canals in the Jowhar district in the middle Shebelle region.

This study is very significant as the Somali government, especially the Ministry of Agriculture and Irrigation, will benefit from the research output as it will contribute to the knowledge and information level of the government at both national and state levels regarding irrigation systems, and how to support more efficient and sustainable services for the people. It will also benefit the humanitarian organizations that collect the funds for the rehabilitation of these infrastructures to know the tangible causes of the recurrent destruction of these canals to not go back to the works completed earlier. This will contribute to the improvement of functionality and sustainability while reducing duplication of efforts.

The target audiences of this research were both levels of government (national and state levels), civil society organizations, farmer cooperatives, international non-governmental organizations, and their local non-governmental organizations and implementation partners.

2. Materials and Methods

2.1. Participants

Participants in the study were the irrigation committee of the Jowhar district, lower Shabelle Region, where selected committee members were used as information sources on the main causes of irrigation canal failures in the Jowhar area. 28 members of the irrigation committee responded to the survey. In the Jowhar district, the researcher also did field observations and conducted 20 interviews with local residents in order to learn more about the irrigation system there.

2.2. Instruments of Data Collection

The study combined field observations, a structured interview, and a questionnaire. Members of the irrigation committee of Jowhar were asked to fill out questionnaires that the researchers had prepared. The main purpose of the questionnaire was to collect information on major factors leading to the destruction of irrigation canals in the Jowhar area. There are three sections included in the questionnaire. All responses were rated using Likert scales: (1) strongly disagree (2) disagree (3) neither agree nor disagree (4) strongly agree (5) agree. The structured interview and field observations were conducted in order to obtain additional information in support of the data collected within the questionnaire. During the interview, the researcher raised open issues related to the causes of irrigation canal failure at Jowhar. During the observation process, the researcher also observed the status and physical condition of the irrigation canals.

2.3. Data Collection

The questionnaire was distributed to the members of the irrigation committee in Jowhar. The respondents were given an explanation of the questionnaire so that they could comprehend the goal of the study. This was done to prevent arousing suspicion, as well as to enable the researchers to provide impartial feedback on the questions asked. In addition, the researcher conducted interviews with other irrigation specialists, discussed the primary causes of canal failure, and observed the canals' current status and physical condition.

2.4. Data Analysis

The gathered data were statistically evaluated using Statistical Package for Social Sciences (SPSS version 20) software. To simplify and expedite data interpretation, tables were utilized, and responses were reported as percentages and evaluated for consistency. The obtained data were encoded for use with the Statistical Package for the Social Sciences (SPSS) because this is the most efficient way to identify, compare, and describe relative frequencies, means, and standard deviations. Using this strategy, accurate and reliable data will be gathered and a conclusion will be reached. Using a Pearson correlation coefficient, the relationship between the two variables was also determined.

2.5. Research Limitations

Due to the existence of Covid-19, the study was completed in a short timeframe of four months. As a result of the pandemic, the movement of the irrigation canal committee was hampered by the spread of the virus, and the researcher and a number of key knowledge figures perished.

Due to the scarcity of Somalia-specific irrigation literature, the majority of this study's references came from outside of the country. Due to the lack of clarity in the irrigation canal committee organization and the inability to establish it effectively, as well as the presence of Covid-19, the sample size was extremely small.

Due to the instability in Somalia, security is a key concern, as the project location is located outside of secure zones, the researcher was only permitted to move within the safe zones in the Jowhar area of the middle Shabelle region.

2.6. Data Interpretation

The Table 1 shows the data interpretation values used during the study.

Table 1. Data Interpretation of the values

Mean Range	Interpretation
1-1.8	Agree
1.9- 2.6	Strongly agree
2.7-3.4	Neither Agree nor Disagree
3.5-4.2	Disagree
4.3-5.0	Strongly disagree

3. Results

3.1. Demographic Information of the Participants

Table 2 outlines the demographic characteristics of the respondents. Within the sample size of 28 respondents, males dominated the respondents compared to females. 4 respondents were female, with a percentage of 14.3%, while 85.7% were men. This can be due to the reason that there are more male workers in the irrigation sector than female workers in Somalia. Additionally, the study showed that 46.4% of respondents had nonformal education, while 25% of the respondents had primary school qualifications, and other 25% of the respondents had graduate-level qualifications from an agricultural university which illustrates the fact that farmers lack qualified personnel to carry out the day-to-day activities of the sector.

With regard to the marital status of the respondents, the study found that most of the respondents, 89.3%, were married. In contrast, 7.1 % were single and 1 was divorced. This indicates that the percentage of respondents who are married is high. According to the age distribution of respondents, 39.3% of respondents are between 41-50 years old, 21.4% are between 31-40 years old, 17.9% are between 20-30 years old, 14.3% are between 51-60 years old, and 7.1% are over 60 years old.

Table 2. Demographic Information

Gender of Respondents	n	%
Male	24	85.7
Female	4	14.3
Total	28	100.0
Qualification of respondents		
Non-formal	13	46.4
Primary	7	25.0
Secondary	2	7.1
Graduate	6	21.4
Total	28	100.0
Marital status		
Single	2	7.1
Married	25	89.3
Divorced	1	3.6
Age		
20-30	5	17.9
31-40	6	21.4
41-50	11	39.3
51-60	4	14.3
>60	2	7.1

3.2. Descriptive Analysis to Measure Factors Causing the Failure of Irrigation Canals

Tables 2 and 3 illustrate the descriptive study of how independent variables (institutional capacity and financial availability) affect the dependent variables (canal failure) as the relationship between these variables was measured in the study. Both the independent and dependent variables contained nine and five questions, respectively. For each question, a Likert scale was utilized: strongly disagree, disagree, uncertain, agree, and strongly agree.

Table 3. Descriptive analysis of measures of the canal failure factors

Items	n	Mean	Std. Deviation	Interpretation
A Financing availability	28	1.57	0.573	Agree
Technical support	28	1.75	0.928	Agree
Low market access to the farm products	28	1.79	1.101	Agree
Low farm production	28	1.54	0.881	Agree
B Week institutional capacity	28	2.36	1.420	Strongly agree
Availability of Irrigation policy and regulation	28	1.82	1.090	Agree
Flood diversion/ projection mechanism	28	1.50	0.745	Agree
Availability of adequate irrigation expertise	28	1.79	1.197	Agree
Irrigation research center/institute and extension services	28	1.54	0.576	Agree
Availability of adequate irrigation expertise	28	1.79	1.197	Agree
Irrigation research center/institute and extension services	28	1.54	0.576	Agree

Table 4. Descriptive analysis measures of canal failure

Items	n	Mean	Std. Deviation	Interpretation
Management	28	2.61	1.166	Strongly agree
Poor design	28	1.86	1.079	Strongly agree
Seepage and leakage	28	1.82	1.124	Agree
Erosion and siltation	28	1.64	0.989	Agree
Frequency overtopping	28	1.64	1.062	Agree

The study interpreted the results of both variables using the mean and standard deviation for each question using SPSS (Tables 3 and 4).

Table 4 illustrates how the lack of management, poor design and related variables are causing the canal failures in Jowhar. The table shows that lack of management and poor design during canal rehabilitation was the most causing factors followed by seepage and leakage, Erosion and siltation and frequency overtopping.

3.3. Correlation Coefficient

In this study, the Pearson correlation was used to examine the relationship between finance availability and institutional capacity for canal failure. According to Table 5, there is a significant correlation between finance availability and canal failure (r=0.437*, P=0.02). However, institution capacity was moderately correlated with canal failure (r=0.355, P=0.064).

Table 5. Pearson's correlation of canal failure factors

Pearson's correlation		Canal failure
Finance availability	Pearson Correlation	0.437*
	Sig. (2-tailed)	0.020
Institutional capacity	Pearson Correlation	0.355
	Sig. (2-tailed)	0.064

*= correlation is significant at the 0.05 level (2-tailed).

3.4. Interview and Filed Observation

The study interviewed 20 respondents in Jowhar districts who had experience in the irrigation system in Jowhar. It was discussed in the study what the respondents perceived as the major causes of the recurrent failure of the irrigation system in Jowhar, what can be done to prevent the recurrent destruction of irrigation canals, the frequency of operation and maintenance, and finally, who is responsible for the operation and maintenance of irrigation canals? Despite their differences, the study grouped their responses and analyzed their responses to determine a common outcome. After collecting the answers from 20 respondents, the responses of the respondents were summarized below.

Operations and maintenance of the established or rehabilitated canals is a must to continue the work of the canals, Respondents that there is a lack of operation and maintenance of the canals is the main cause of the destruction of the canals in Jawhar district as the farmers and the irrigation committees do not have enough finance the maintenance and operations of the canals. On the other hand, respondents also noted that recurrent Shabelle River flooding during the wet season is another adding cause to the destruction of the canals (Figure 1). As the governments also struggle with financial problems, they do not have the budget to support these operations. Poor management of the canals is also another factor in the destruction of the canals.

As the factors that are contributing to the destruction of the canals were identified, respondents were also asked their perspectives regarding the solutions they are recommending to avoid the recurrent destruction of the canals (Figure 2). The respondents recommended that continues rehabilitation of the canals was the best option to keep the functioning of the canal, according to respondents, Management and monitoring of the canals are also crucial to avoid destruction of the canals. In addition, continuous improvements in the functionality of irrigation committees through capacity building and technical support and increasing the availability of financial support for canal rehabilitation projects are also part of the recommended solutions.

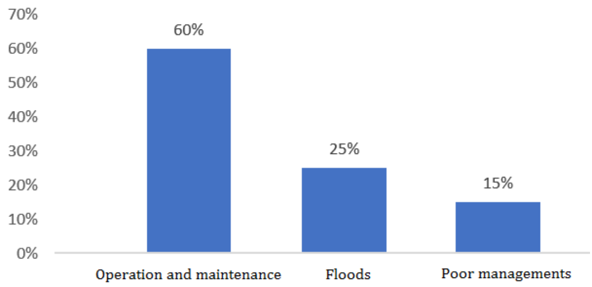

Figure 1. Analysis of the factors causing the failure of the irrigation canals.

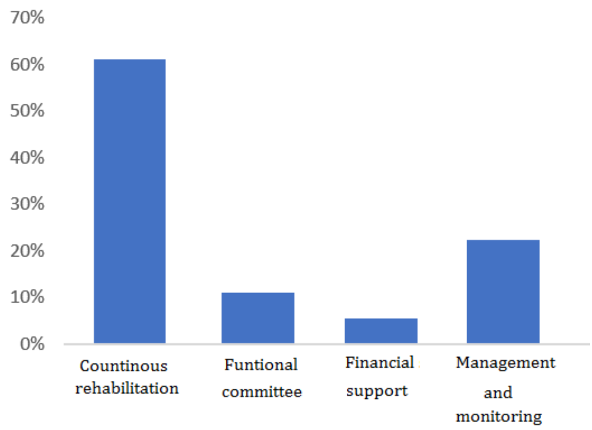

Figure 2. Proposed solutions for the destruction of the irrigation canals.

As continuous operation and maintenance was the most solution recommended by the respondents, the frequency of the maintenance was asked. 65% of the respondents suggested conducting the operation and maintenance of the irrigation canal twice a year while 35% recommended conducting the operation and maintenance once a year (Figure 3).

Most of the time, Government establishes new canals or rehabilitates the existing canals, but as these projects are finalized the maintenance of the operation of the canals is a must. For that reason, we asked the respondents who should take responsibility for the newly established or rehabilitated canals regarding their operation and maintenance after the project is finalized and the respondents indicated that Irrigation committees and farmers are mostly responsible for the operations and maintenance of the canals, although some of the canals are maintained with the support of local and International NGOs (Figure 4). They stated that the government's role is the initial establishment or rehabilitation of the canals but canal operations are for the farmers themselves.

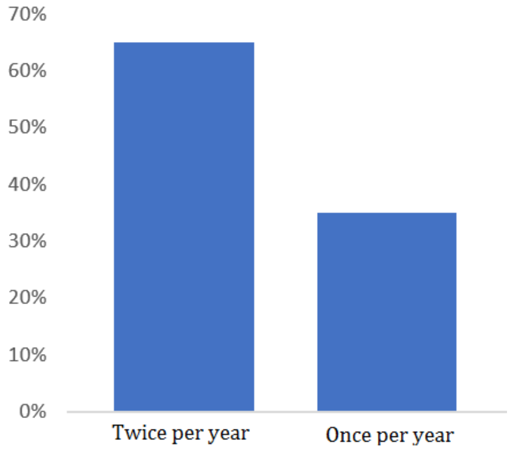

Figure 3. Recommended operation and maintenance intervals.

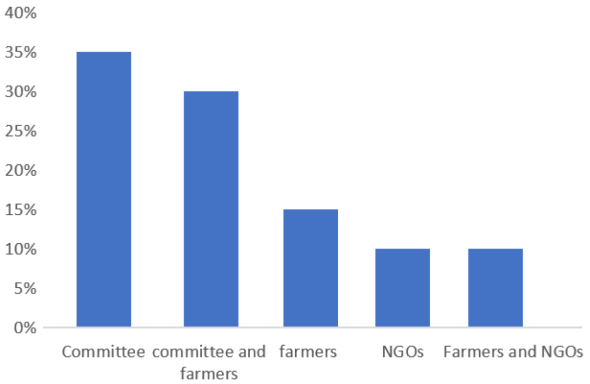

Figure 4. Recommended operation and maintainance intervals and the responsiblity of the operation and maintainance of the canals.

4. Discussion and Conclusion

Since the collapse of the central government in 1991, the Somali government's financial and administrative capabilities have worsened. As a result, the government has been unable to fund the irrigation system's management and maintenance, but humanitarian organizations have begun to step in and take over the government's responsibilities. They also began programs to help Somalia's national food security system, such as the rehabilitation of the country's primary irrigation canals. In the last ten years, the humanitarian organization's irrigation system, which had been rehabilitated with the assistance of foreign partners, has once again failed. This study was conducted to examine the major factors that cause irrigation canal failures in Jowhar and concluded that finance availability is positively correlated to irrigation canal failures and that low institutional capacity has a moderately positive correlation with irrigation canal failures, implying that if there is a gap in finance available for canal rehabilitation, the irrigation canal will not function due to a gap in operation and maintenance.

5. Recommendations

Since the study found that a lack of funding, a lack of policy and regulations, gaps in expertise, and the ineffectiveness of irrigation committees were the main causes contributing to the deterioration of repaired canals, the study suggests the following:

- Allocation of additional funds for the rehabilitation and operation and maintenance of irrigation canal systems: The government, humanitarian organizations, and farmers themselves must allocate funds for restoration at an early stage to avoid deterioration of the system. This will contribute to increased food security and farm income.
- Increase institutional capacity at both the government and farmer levels including capacity injection, awareness raising, and local knowledge enhancement through capacity building and field demonstrations of how the irrigation system is effectively administered and maintained. This will result in the irrigation system's sustainability and a reduction in recurring irrigation system failures.
- Improve agricultural water management policy and regulation, which can have a significant impact on water production and ultimately serve as a solution to lower water costs.
- Establishment of a nationwide agricultural water management platform that collects information for end users and provides it to government institutions to help with decision-making and to help researchers base their analyses.
- Increasing the number of studies addressing the irrigation sector and agriculture in general to understand the gaps and solutions to the difficulties faced by farmers.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	M.M.A.	B.A.M.
C	90	10
D	70	30
S	60	40
DCP	80	20
DAI	60	40
L	70	30
W	70	30
CR	50	50
SR	20	80
PM	60	40

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

A permission letter was obtained from the regional office of the Ministry of Agriculture and Irrigation, Somalia (date: May 10, 2021 and protocol code: 2021/013).

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THE EFFECTS OF DIFFERENT EXTRACTION METHODS AND SOLVENTS ON ANTIOXIDANT PROPERTIES OF PROPOLIS

Seda UFUK[1], Memnune SENGUL[2]*

[1]Artvin Directorate of Provincial Agriculture and Forestry, 08000, Artvin, Türkiye
[2]Ataturk University, Faculty of Agriculture, Department of Food Engineering, 25420 Erzurum, Türkiye

Abstract: Propolis is a complex sticky substance produced by the honey bees (*Apis mellifera*) from the resinous materials they collect from various parts of plant and used by the bees to defend their hives from pathogenic microorganisms. This research aimed to compare the antioxidant properties of propolis extracts produced by using different solvents and extraction methods. The method used in the extraction stage is of great importance as the amount and quality of the bioactive components in the final product are directly affected by the extraction method applied. To obtain propolis extracts, both classical and ultrasonic extraction methods were used with distilled water and 20% propylene glycol-distilled water as solvents. Folin-Ciocalteau method was used to record the total phenolic content of propolis extracts. In this study, to measure the antioxidant activity of extracts, three methods were used that are FRAP, DPPH, and ABTS. Moreover, the aluminum chloride colorimetric method was used for total flavonoid content analysis. According to analysis, brix values recorded between 14.90-27.50 for classic method and 14.40-16.50 for ultrasonic method. The total phenolic content calculated as 721.31-14419.46 mg GAE/L for classic method, and 1212.32-33621.70 mg GAE/L in ultrasonic method. Also, the total amount of flavonoid content was measured as 1137.52-24884.70 mg QE/L extract in ultrasonic method, and 2144.77-74021.42 mg QE/L extract in classic method. DPPH radical scavenging activity of the samples were calculated as 0.46-15.21 IC_{50} µl/ml in classic method, and 1.36-31.86 IC_{50} µl/ml in ultrasonic method, ABTS+ values changed from 0.09-2.71 IC_{50} µl/ml in classic method, and 0.21-4.64 IC_{50} µl/ml in ultrasonic method, and FRAP values measured between 29.22-639.43 µM TE/g in ultrasonic method, and 54.72-1783.02 µM TE/g in classic method. More studies and analysis are needed to investigate the effects of solvents and extraction methods on propolis extracts, as well as on the antioxidant properties of these extracts.

Keywords: Propolis, Extraction methods, Flavonoid, Antioxidant activity

***Corresponding author:** Ataturk University, Faculty of Agriculture, Department of Food Engineering, 25420 Erzurum, Türkiye
E mail: memnune@atauni.edu.tr (M. SENGUL)
Seda UFUK https://orcid.org/0000-0001-6250-6670
Memnune SENGUL https://orcid.org/0000-0003-3909-2523

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1. Introduction

Propolis is a natural bee product collected from diverse parts of different plant sources by honey bees (*Apis mellifera L.*) and mixed with materials resulting from bees' metabolism (Freitas et al., 2022; Kegode et al., 2022). Propolis is a gummy, sticky, lipophilic, and balsamic product, comes from two different Greek words 'pro' meaning in defense, and 'polis' meaning the city (Belmehdi et al., 2022; Hossain et al., 2022). Honeybees use propolis to coat openings in the hive and to prevent predators from entering the hives. Also, propolis is used by honey bees to maintain a constant internal temperature in the hive, and to contribute to the creation of an aseptic environment, and generally protect the hive from common microbial infections caused by bacteria, fungi, and yeast (Dogan and Hayoglu, 2012; Tumbarski et al., 2022; Abd Rashid. et al., 2022).

Propolis, one of the most interesting substances produced by honey bees, draws attention in many areas in the field of health. Throughout history, natural products such as propolis have been widely used to alleviate and prevent diseases, also to increase body resistance (Acun and Gul, 2020). Propolis has been used for many years and is used today in various formations such as personal products, handmade medicines, functional food ingredients, food supplements, and over-the-counter products (Freitas et al., 2022; Tumbarski et al., 2022). Along with in vivo and in vitro studies, it has been reported that propolis has many biological activities. Various biological properties of propolis such as antiviral, antioxidant, antiallergic, anti-inflammatory, antibacterial, hepatoprotective, antiparasitic, antiulcerogenic, anticancer, antidiabetic, and other therapeutic effects have been evaluated with various studies (Belmehdi et al., 2022).

The health properties of propolis are attributed to components such as polyphenols, phenolic aldehydes, sesquiterpene-quinones, coumarins, amino acids, steroids, and inorganic compounds (Sagdic et al., 2020). The composition of propolis, which has a characteristic smell and taste, varies according to the conditions of the region where it is collected, the time of collection, and the plant variety from which it is produced. In addition, the diversity in beeswax also affects the chemical composition of crude propolis (Dogan and Hayoglu, 2012). Generally, propolis consists of 50% resin and herbal balm, 30% bee wax, 5% pollen, and 10% essential and aromatic oils, and more than 420 components have been identified in its content (Gumus and Kizil, 2022; Escriche and Juan-Borrás, 2018). The main components of propolis include aromatic acids (cinnamic acid, caffeic acid, ferulic acid), aromatic esters (cinnamic and caffeic acid ethyl esters), volatile compounds (geraniol, nerol, farnesol, β-eudesmol), aromatic compounds (vanillin), hydrocarbons (eicosan, trichosan, pentacosan), steroids (cholinasterol, fucosterol, stigmasterol), flavonoids (pinocembrin, chrysin, galangin, apigenin, kaempferol), acids (palmitic acid, melisic acid, serotic acids), minerals (calcium, potassium, magnesium, sodium, zinc, chlorine, iron), vitamins (vitamins A, B1, B2, B3, B5, B6, B7, C and E) and essential oils (Gumus and Kizil, 2022; Ożarowski and Karpiński, 2023; Yildiz and Unal, 2022). Moreover, propolis contains enzymes such as succinic dehydrogenase, glucose-6-phosphatase, adenosine triphosphatase, and acid phosphatase (Dogan and Hayoglu, 2012).

Propolis is commercially available in different formulations such as capsules, mouthwash solutions, cosmetics, powders, shampoos, lotions, lipsticks, nail polishes, beverages, and foods. There are also chewable capsules and tablets such as throat lozenges, chewing gum, and candy (Irigoiti et al., 2021; Dogan and Hayoglu, 2012; Anjum et al., 2019). Propolis cannot be consumed directly as it is taken from the hive. In the first process, the raw wax and foreign materials in propolis must be removed, and then it is made ready for consumption by extraction. The method used in the extraction stage is of great importance because the amount and quality of the bioactive components in the final product are directly affected by the extraction method applied. Today, more efficient extraction methods such as ultrasonic-assisted extraction, microwave-assisted extraction, supercritical extraction, and classical extraction have been developed and used (Sagdic et al., 2020).

Even though many solvents are utilized in the extraction of propolis, merely water, ethanol, olive oil, propylene glycol, and glycerol (glycerin) are included in the legislation. Propylene glycol, which is chemically in the diol class; is miscible with many solvents such as water, chloroform, and acetone (Bakkaloglu and Arici, 2019). Yet, although propolis is appropriate for usage in different areas, there is concern about the solvents used for extraction processes in the food sector. Solvents that do not pose a threat to health should be used in propolis extracts offered for people's consumption. The usage of ethanol as a solvent in the extraction of propolis poses problems, mainly for pregnant women and consumers with halal/haram sensitivity (Bakkaloglu and Arici, 2019). On the other hand, the negative consequences of alcohol (sensory problems in the final product, limited use in cosmetic and pharmaceutical products, inability to use in children and pregnant women) led to the development of non-alcoholic extraction methods (Sagdic et al., 2020). Therefore, to decrease the usage of alcohol as a solvent for extraction of propolis, other types of solvents can be available including distilled water, oils and glycerol. Distilled water, one of the solvents in the legislation, is not preferred because it cannot dissolve the bioactive components in propolis at a sufficient rate (Bakkaloglu and Arici, 2019). For this reason, to increase the extraction efficiency of distilled water during propolis extraction, some tensoactive compounds can be added to the distilled water, such as sodium lauryl sulfate, propylene glycol, polysorbates and polyethylene glycol (Yeo et al., 2015).

Propylene glycol (propane-1, 2-diol) is a colorless, odorless and tasteless substance that is used in foods, drugs and cosmetic products due to its ability to dissolve hydrophobic compounds and water retention, and has a slightly viscous behavior at room conditions, soluble in water, ethanol and acetone. It is a synthetic substance with a density of 1.035 g/mL. Propylene glycol is unstable to sunlight, air, oxidizing agents, acid, base and high temperature and can oxidize (Karadag et al., 2022). Propane-1,2-diol is approved as a food additive (E 1520) in the European Union consistent with Regulation (EC No:1333/2008) on food additives and in the Turkish Food Codex Regulation on Food Additives dated 30/06/2013 (No:28693) (Aggett et al., 2018).

Since the properties of solvents used in propolis extraction are different, different results are found in determining the properties of propolis such as total phenolic substance content, and antioxidant capacity (Galeotti et al., 2018). Therefore, in this study, the effects of the extraction of propolis by different solvents and extraction methods on the amount of soluble solid matter, total phenolic content, antioxidant capacity, the total amount of flavonoid substances of the extracts were examined.

2. Materials and Methods

2.1. Materials

In this study, crude propolis was produced from different types of plants such as poplar, filbert etc. by *Apis mellifera Caucasica* and this propolis was obtained directly from honey producers in Ardanuç-Artvin in Türkiye. The fresh propolis was stored at refrigerator temperature (4-6°C) until the utilization of analysis.

2.2. Propolis Extraction Procedures

For propolis extraction, classic and ultrasonic extraction procedures were utilized, and propolis samples were extracted with distilled water and propylene glycol (20%) solvents (Juodeikaitė et al., 2022; Rodiahwati et al., 2019). For extraction, 25 g crushed propolis samples were macerated in 250 ml distilled water and also 250 ml %20 propylene glycol. The extraction process was prepared according to the propolis/solvent ratio of 1:10 (Keskin, 2018).

In the classic extraction method, 25 g propolis-distilled water (PKS) and 25 g propolis-propylene glycol (20%) (PKPG) samples were agitated in the shaking water bath (JSR, JSSB-30T, Korea) in dark-colored flasks at 40℃ with 90 rpm for 20 hours (Topdas and Sengul, 2021). The extracts were centrifuged at 4500 rpm at 4℃ for 15 minutes and filtered two times with Whatman No:2 and Whatman No:42, respectively. Then, the filtered supernatants were evaporated at 40°C with 150 rpm. After evaporation, the extracts were stored at -20 °C until utilization. Since the evaporation temperature of propylene glycol is high (188°C), and the structural property of propolis will deteriorate after the solvent is evaporated above 50°C, it was not processed in the vacuum evaporator for propylene glycol, however distilled water solution was evaporated and propolis extracts were obtained with the classic extraction method (Arslan et al., 2010).

In the ultrasonic extraction method, 25 g propolis-distilled water (PUS) and 25 g propolis-propylene glycol (20%) (PUPG) samples were agitated in an ultrasonic bath (Bandelin Sonorex Super RK 103 H) at 40 °C, 35 kHz frequency for 20 minutes with four times minutes (Topdas and Sengul, 2021). The extracts were centrifuged at 4500 rpm at 4°C for 15 minutes and filtered two times with Whatman No:2 and Whatman No:42, respectively. Then, the filtered supernatants were evaporated at 40°C with 150 rpm. After evaporation, the extracts were stored at -20 °C until utilization. Also, for ultrasonic extraction method, solution with propylene glycol was not removed by evaporation because it has a high evaporation temperature (Arslan et al., 2010).

2.3. Experiments

2.3.1. Soluble solids content

An Abbe refractometer device (Carl Zeiss) was used to determine the % dissolved solids of propolis extracts. The values measured using a refractometer were expressed as the propolis extract° Brix value (Cemeroglu, 2013).

2.3.2. Total flavonoid content

The aluminum chloride colorimetric method was used for flavonoid analysis. Quercetin (QE) at different concentrations (0.4; 0.3; 0.25; 0.2; 0.16; 0.12, 0.08, and 0.04 mg/L) was used as a standard in the assays. The absorbance of the tubes against distilled water at 415 nm was recorded 40 minutes after the pipetting process was completed. The standard was plotted with the recorded absorbance values versus the concentration. The total flavonoid substance content of propolis extracts was calculated according to the standard graph and the total flavonoid amount was expressed as Quercetin equivalent/L propolis extract (Meda et al., 2005).

2.3.3. Total phenolic content

The total phenolic content of propolis extracts was determined using the Folin-Ciocalteau method. A calibration chart using the Gallic acid (GA) standard was prepared using solutions of Gallic acid at different concentrations (10; 25; 50; 75; 100; 150; 200 and 250 mg/L) and results were expressed as mg GAE/L propolis extract in Gallic acid equivalents (Cemeroglu, 2013). The absorbance results were measured at 760 nm after incubation for 30 minutes at room temperature (Asem et al., 2020; Meda et al., 2005)

2.3.4. Antioxidant capacity

The antioxidant activity of propolis extracts was determined by three different procedures which are FRAP, ABTS, and DPPH methods.

In the FRAP (Ferric Reducing Antioxidant Power) assay; the Antioxidant activities of the samples were determined by the Fe^{3+} reduction method. The basis of the FRAP assay, known as the iron-reducing capacity, is the reduction of Fe^{3+} ions in the Fe $(TPTZ)^{3+}$ complex to the blue-colored $Fe(TPTZ)^{2+}$ complex in an acidic medium by antioxidant components. For analysis, three different chemicals were used which were acetate buffer (pH 3,6), TPTZ and $FeCl_3.6H_2O$, respectively. For preparation of acetate buffer, 3.1 g Sodium acetate was added in water, then 16 ml %37 acetic acid were added to this and the pH was adjusted 3.6. For TPTZ preparation, 0,156 g TPTZ was added to 50 ml ethanol. Finally, for $FeCl_3.6H_2O$ preparation, 0,5404 g $FeCl_3.6H_2O$ was mixed with water and 2 ml %37 HCl were added, then it was completed 100 ml with distilled water. After completed these three solvents, 8 ml was taken from acetate buffer (pH 3.6), 1 ml was taken from both TPTZ and $FeCl_3.6H_2O$, orderly. With this, FRAP solvent was prepared for the analysis. For analysis, 250 µl was taken and with FRAP, it was completed 2.5 ml. It was waited 4 minutes at room temperature. The absorbance of the formed blue complex was recorded at 593 nm against the pure water reference. Results were calculated in equivalents of Trolox, a standard antioxidant (Kocak et al., 2018; Keskin et al., 2020). The total antioxidant capacity of samples was determined in FRAP units.

In the ABTS method, firstly, to obtain ABTS radical, 2.45 Mm potassium persulfate was mixed with 7 mM ABTS solution and then it was waited for 12-16 hours. This radical was diluted with distilled water to measure 700±25 at 734nm. For analysis, 10-30 µl/ml of the prepared extracts were taken in 250 µl tubes and ABTS radical were added until 250 µl. It was stored for 6 minutes and the absorbance value was measured. The percentage reduction rate was calculated according to the initial and final values. These processes were repeated 3 times (Ozkan et al., 2010; Cemeroglu, 2013).

DPPH assay is the determination of the reducing ability of antioxidants toward DPPH. The ability can be determined by measuring the reduction of its absorbance (Popović et al., 2012). In the DPPH method; 1 mM DPPH was solved in methanol and waited 12-16 hours and this obtained solvents was used in the analysis. In the analysis, 10-30 µl/ml of the prepared extracts were taken in 2000 µl tubes and methanol were added until 2000 µl. Next, 500 µl mixed with the prepared solvents. It was waited 30 minutes at room temperature (Gulcin et al., 2005). In this method, a purple color turns to yellow color after interaction with the radical and antioxidant agents. The alteration in absorbance owing to colors can be spectrophotometrically displayed at 517 nm (Popović et al., 2012).

2.4. Statistical Analysis

Statistical analysis was done with IBM SPSS 20.0 program. Here, 2 different solvents and 2 different extraction methods were used. Analysis of variance was performed on the analysis results. Duncan Multiple Comparison Test, one of the multiple comparison tests, was applied to the different results. Correlation analysis was applied to determine the relationship between analyzes. Moreover, principal component analysis (PCA) was applied to some data to facilitate the identification of similarities and differences between the samples (SIMCA-P +14.1, UMETRICS).

3. Results and Discussion

SSC (°Brix), DPPH (IC_{50} µl/ml extract) and ABTS (IC_{50} µl/ml extract), FRAP (µM TE/g extract), Total Phenolic Contents (mg GAE/L extract), and Total Flavonoid Content (mg QE/L extract) of propolis extracts are presented in Table 1.

As a result of the analysis made, it was determined that the SSC value of the propolis extracts with distilled water and propylene glycol varied between 14.40-27.50 °Brix. While it was observed that the °Brix values of the propolis extracts prepared with distilled water (27.50-16.50) were higher than the samples prepared with propylene glycol (14.90-14.40), it was also observed that the extracts prepared by the classical method had higher °Brix values compared to the samples prepared by the ultrasonic method (Table 1). According to study conducted by Keskin and Kolayli (2019), they measured the amount of brix values of twenty various commercial propolis extracts prepared with different types of solvents. The results depicted that the amount of brix values of different commercial propolis extracts were between 0-61 °Brix.

The antioxidant tests of the samples were performed with total phenolic substance content, the total amount of flavonoid substance amount, FRAP, ABTS, and DPPH determination (Table 1). The total phenolic content of the extracts was determined between 721-33.621 mg GAE/L in the current study. This study showed that PKS had a higher SSC value with a greater value of total phenolic contents and PUPG had a lower value of SSC with a lower value of total phenolic contents. Additionally, the extracts with distilled water had again higher soluble solid content value with a greater value of total phenolic contents than the extract with propylene glycol. In addition, the propolis extracted with classical extraction methods had a higher total amount of phenolic substances and soluble solid content value than the propolis extracted with the ultrasonic extraction method. Therefore, the results indicate that the total amount of phenolic substances increases when the solid soluble content values increase consequently (Table 1).

Mujica et al. (2017), worked with propolis dissolved in propylene glycol to analyze the total phenolic compound of the extract. According to results, total phenolic compound (TPC) of the propolis extract prepared with propylene glycol was measured as 22.82 g GAE/L. In addition, Sagdic et al. (2020), worked with fourteen different commercial propolis samples which were prepared with different solvents including ethanol, water and propylene glycol. The results depicted that the total phenolic compounds vary from 2431 mg GAE/L to 127318 mg GAE/L, successively. The result of extract prepared with distilled water is 32490 mg GAE/L, while the result of propolis extract prepared with propylene glycerol is 80467 mg GAE/L. In our study, it was detected that while a higher amount of phenolic substance was detected in water-based samples, a lower amount of phenolic substance was detected in propylene glycol-based samples. This may be due to the solvent used or to the extraction method and conditions.

Table 1. SSC (°Brix), DPPH IC_{50} (µl/ml extract) and ABTS IC_{50} (µl/ml extract), FRAP (µM TE/g extract) Total phenolic contents (mg GAE/L extract), and Total Flavonoid Content (mg QE/L extract) of propolis extracts

Samples	SSC (Brix)	DPPH· (IC_{50} µl/ml extract)	ABTS+· (IC_{50} µl/ml extract)	FRAP (µM TE/g extract)	Total Phenolic Content (mg GAE/L extract)	Total Flavonoid Content (mg QE/L extract)
PKS	27.50±0.50^a	0.46±0.01^c	0.09±0.01^d	1783.02±74.18^a	33620.70±109.41^a	74021.42±12128.38^a
PKPG	14.90±0.10^c	15.21±0.08^b	2.71±0.02^b	54.72±2.88^c	1212.32±79.17^c	2144.77±105.46^c
PUS	16.50±0.25^b	1.36±0.01^c	0.21±0.01^c	639.43±63.09^b	14419.46±301.27^b	24884.70±173.98^b
PUPG	14.40±0.20^c	31.86±1.09^a	4.64±0.01^a	29.22±1.35^c	721.31±7.59^c	1137.52±24.78^c
BHA	-	6.98±0.10	4.16±0.14	-	-	-
BHT	-	19.84±0.56	7.87±0.28	-	-	-
Trolox	-	7.47±0.17	3.11±0.04	-	-	-
α-Tocopherol	-	11.24±0.15	12.47±0.12	-	-	-
Severity Level	**	**	**	**	**	**

PKS= propolis-distilled water, PKPG= propolis-propylene glycol, PUS= propolis-distilled water, PUPG= propolis-propylene glycol. Different letters in each column indicate significant differences of the means at P<0.01.

The amounts of flavonoids, which are a group of phenolic substances, ranged from 1137 to 74021 mg QE/L (Table 1). Flavonoids are the primary components of propolis that function as antioxidants and have antibacterial and anti-inflammatory activities (Gunce et al., 2021; Coneac et al., 2008). In our research the total flavonoid content of propolis extracts was determined at various extraction methods and different types of solvents. Among the extracts, PKS had the highest value of TFC (74021 mg/QE L extract) followed by PUS (24884 mg/QE L), PKPG (2145 mg/QE L), and PUPG (1138 mg/QE L), respectively. These results show that distilled water as an extraction solvent had a higher value of TFC compared to propylene glycol. Moreover, for the extraction method, the classical method increased the value of TFC more than the ultrasonic method (Table 1). As the amount of crude propolis dissolved in the unit volume of solvent increases, the Brix value and accordingly the total amount of polyphenol substance increases (Keskin and Kolayli, 2019). Sagdic et al. (2020) also showed the total flavonoid compounds for fourteen different commercial propolis samples and by means of this study, total flavonoid compounds were found between 104 mg/QE L and 40516 mg/QE L. Moreover, the results were measured as 343 mg/QE L and 20520 mg/QE L for propolis extracts prepared by distilled water and propylene glycol, respectively.

FRAP determination findings of propolis extracts were found to be between 29.22-1783.02 mM Trolox E/g. ABTS determination findings of propolis extracts were measured to be between 0.09-4.64 IC50 µl/ml. Moreover, the DPPH results of propolis extracts were calculated to be between 0.46-31.86 IC50 µl/ml (Table 1). Table 1 illustrates the DPPH IC_{50} (µg/ml) and ABTS IC_{50} (µg/ml) results of standard antioxidants (BHA, BHT, Trolox and α-Tocopherol) below. In the present study, one reducing power assay (FRAP) and two different radical scavenging assays (DPPH and ABTS) were used to calculate the antioxidant potential of propolis extracts prepared with different types of solvents and two types of extraction methods. In the assay of DPPH•, a smaller IC_{50} value shows more antioxidant activity, as a smaller mass of extract is needed to inhibit 50% of the DPPH• (Cottica et al., 2011). The best result was observed in the extract of PKS. According to the results, with the lower IC_{50} values, the distilled water propolis extracts displayed greater antioxidant potential. In addition, since the extracts prepared by the classical method have lower IC_{50} values, which are 0.46-1.36 $IC_{50\mu}$µl/ml extract, compared to the extracts prepared by the ultrasonic method (15.21-31.86 $IC_{50\mu}$µl/ml extract), it was determined that they showed greater antioxidant activity (Table 1). In ABTS assay, a lower IC_{50} result of the extract means greater capturing potential of the ABTS radical, so raised potential of the antioxidant (Asem et al., 2020). In the current study, propolis extracts displayed antioxidant activity in the ABTS scavenging assay and IC_{50} values varied from 0.09 $IC_{50\mu}$µl/ml extract to 31.86 $IC_{50\mu}$µl/ml extract. In the ABTS assay, PKS again showed the highest antioxidant activity with the lowest IC_{50} value. Additionally, PUPG had the smallest antioxidant potential with the highest IC_{50} value. In the FRAP assay, all propolis extracts (PKS, PKPG, PUS, and PUPG) displayed the Trolox Equivalent Antioxidant Capacity (TEAC) of the FRAP method (29.22-1783.02 µM TE/g extract) (Table 1). A higher TE value indicates the strongest reducing potential, therefore shows the greater antioxidant potential of a sample (Asem et al., 2020). According to the results, PKS with a greater TE value shows stronger reducing activity. But, PUPG with lower TE value indicates the lower reducing activity. While greater antioxidant activity (by FRAP and DPPH•) was observed in extract PKS lower antioxidant activity was noted in extract PUPG, both by FRAP and DPPH• (Table 1). Ulloa et al., (2017), used DPPH, ABTS and FRAP methods to demonstrate the antioxidant activity of propolis. Accordingly, DPPH results of propolis extracts were between 0.014 and 0.044 (mmol TE/mL). In addition, ABTS results ranged from 0.079 to 0.149 (mmol TE/mL), while FRAP results ranged from 0.206 to 0.801 (μmol TE/mL). Antioxidant activity is generally associated with total phenolic content and total flavonoid content in the samples (Zin et al., 2018). There are numerous reasons that could impact the antioxidant activity of the propolis extracts, for example type of bee, propolis collection location, solvents utilized in extraction, plant source, and chemical structures (Syed Salleh et al., 2021). To investigate the antioxidant capacity of propolis extracts, all methods can be compared but this can cause minor differences between the results. Since the results are various in each method, it required to make statistical analysis to calculate the correlation between each method (Asem et al., 2020). According to statistical analysis, a strong correlation was observed between TPC and TFC since flavonoid is classified under the group of phenol compounds.

Pearson's correlation coefficient was utilized to show the antioxidant potential arrays with each other, and also it was used to display correlation with both the total phenolic matter and flavonoid contents of the extracts. In the current study, according to the statistical analysis, SSC, TPC, and TFC displayed correlations on antioxidant potentials of propolis extracts varying from R^2=0.642 to R^2=1. The correlation between TFC and TPC was significant (R^2=0.995). The FRAP assay showed a significant correlation between TPC (R^2=0.997) and TFC (R^2=0.995). Also, SSC showed a significant correlation with FRAP (R^2=0.978), TPC (R^2=0.960), and TFC (R^2=0.983), respectively. In addition, while ABTS and DPPH assays indicated a significant positive correlation with each other (R^2=0.994), FRAP, TPC, TFC, and SSC showed negative correlations shown below in Table 2. There is a positive correlation between SSC and FRAP analyzes in the study. This shows that as the amount of SSC increases, the amount of TPC and TFC increases in the extracts. On the other hand, a positive correlation was found between ABTS and DPPH IC_{50} values (Table 2).

Table 2. Correlation analysis among SSC, TPC, TFC and antioxidant activity

Parameters	SSC	DPPH	ABTS+	FRAP	TPC	TFC
SSC	1	-.642	-.668	.978*	.960*	.983*
DPPH·	-.642	1	.994**	-.749	-.783	-.738
ABTS+·	-.668	.994**	1	-.784	-.819	-.772
FRAP	.978*	-.749	-.784	1	.997**	1**
TPC	.960*	-.783	-.819	.997**	1	.995**
TFC	.983*	-.738	-.772	1**	.995**	1

Additionally, Principal component analysis (PCA) was applied to determine the differences between samples by evaluating some physical properties, antioxidant activities, total phenolic and total flavonoid contents of propolis extracts obtained by using 2 different extraction methods and 2 different solvents. Figures 1a-d show hierarchical clustering, score scatter plot, loading scatter plot and biplot of principal component analysis of propolis extracts. The first two principal components (PC1 = 88.3.3% and PC2 = 11.3%) explained 99.6% of the variance (Figure 1).

As a result of the analysis, propolis extracts could be divided into two main groups (Figure 1a, b). The samples using water as solvent from propolis extracts extracted by classical and ultrasonic methods are on the right side of PCA 1, while the extracts using Propylene Glycol: Water as solvent are on the left side of PCA 1. (Fig. 2a). While the PKS sample using water as solvent and extracted with the classical method, TPC, TFC, FRAP and SSC analyzes are located close, DPPH and ABTS analyzes are located far away. This indicated that PKS had a higher FRAP capacity and the highest amount of SSC with higher total phenolic substance and total flavonoid substance compared to other samples (Figure 1d). Since it is known that the antioxidant activity increases as the IC_{50} value decreases in ABTS and DPPH methods, it is seen that the PKS sample has the highest antioxidant activity (Figure 1d). When the figures are examined, the PUPG sample extracted by ultrasonic method using Propylene Glycol: water as solvent and TPC, TFC, FRAP and SSC analyzes are located far away, while DPPH and ABTS analyzes are located close. This shows that the PUPG sample has the lowest amount of antioxidant activity, TPC, TFC, SSC (Figure 1).

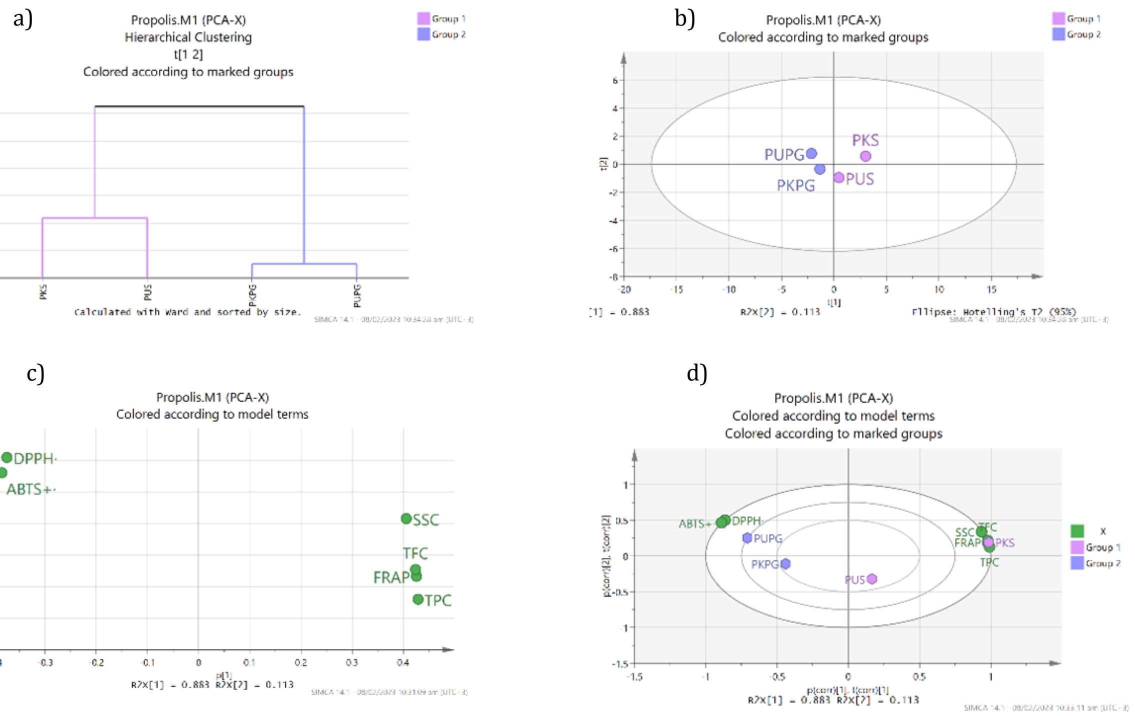

Figure 1. Dendrogram (a), score scatter plot (b), loading scatter plot (c), and biplot (d) of the principal component analysis (PCA) (PC1 vs. PC2) for the attributes in propolis extracts.

4. Conclusions

The present study showed the effect of various types of solvents and extraction methods on propolis antioxidant activities. All propolis extracts have antioxidant potential. When the results obtained are evaluated, it is clearly seen that there are differences between the amount and variety of bioactive substances of propolis extracts. When the previous studies were examined, it was seen that the bioactive substance content of the water-based samples obtained by using conventional extraction methods was lower than other samples. On the contrary, in our study, propolis extracted with distilled water and the classical method demonstrated the greatest antioxidant potential compared to other types of propolis extracts. Additionally, propolis extracted with distilled water and the classical method has the highest total amount of phenolic and flavonoid contents. In conclusion, extracts with the highest amount of phenolic and flavonoid contents indicate the strongest antioxidant potential. More studies and analyzes are needed to investigate the effects of solvents and extraction methods on propolis extracts, as well as on the antioxidant properties of these extracts. Since the amount and quality of bioactive components in the final product are directly affected by the extraction method applied, the method used in the extraction stage is of great importance. This study contributes to the literature as different extraction methods are evaluated together.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	S.U.	M.S.
C	50	50
D	50	50
S	50	50
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50
FA	50	50

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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INVESTIGATION OF AGRICULTURAL SUSTAINABILITY WITH IRRIGATION AND ECONOMIC FACTORS

Sedat KARADAVUT[1]*, Serdar ERDOĞAN[2], Volkan DAYAN[3]

[1]*Trakya University, Havsa Vocational College, Department of Park and Garden Plants, 22500, Edirne, Türkiye*
[2]*Trakya University, Uzunkopru School of Applied Sciences, Department of Accounting and Finance Management, 22300, Edirne, Türkiye*
[3]*Trakya University, Uzunkopru School of Applied Sciences, Department of Banking and Insurance, 22300, Edirne, Türkiye*

Abstract: Agricultural sustainability is becoming more and more important with the increasing world population. Therefore, the dissemination of sustainable agricultural practices; It is extremely important for future generations in terms of protecting the environment and natural resources, ensuring economic stability and increasing sustainable food production. This study investigates the sustainability in agriculture for Türkiye in terms of irrigation and economic factors in crop production change. Using the ARDL error correction model and Granger causality analysis methods for the period between 1995 and 2020, the short and long-term relationship between irrigation and economic factors and crop production value variables were analyzed. The research found that, the relationship between inflation variables irrigation, irrigation and the crop production value was found to be significant. In terms of agricultural sustainability, while the increase in the land opened to irrigation has led to an increase in crop production, the increase in the use of clean water from existing surface and groundwater resources has negatively affected the value of crop production. This has shown how important the water source and economic stability are in the sustainability of agriculture.

Keywords: Sustainable agriculture, Crop production value, Irrigation, Inflation and ARDL

***Corresponding author:** Trakya University, Havsa Vocational College, Department of Park and Garden Plants, 22500, Edirne, Türkiye
E mail: sedatkaradavut@trakya.edu.tr (S. KARADAVUT)
Sedat KARADAVUT https://orcid.org/0000-0001-5070-6747
Serdar ERDOĞAN https://orcid.org/0000-0001-8594-3929
Volkan DAYAN https://orcid.org/0000-0002-4297-4212

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1. Introduction

Today, agricultural areas are one of the leading areas where water resources are used intensively. Irrigation is the supply of water to the soil for the development, growth and yield of plants that cannot be met by natural means. One of Türkiye's economic development indicators is the richness of its water resources. Agricultural sustainability of water resources for Türkiye is of great importance in meeting all the economic and social needs of the society (Yuksel, 2015).

Sustainable agriculture is a form of agricultural production carried out by protecting the environment and natural resources for the purpose of obtaining maximum yield with optimum input from the unit area. Without sustainable agricultural practices, it is not possible to increase yield and ensure its continuity in the future. Protecting agricultural soils where agricultural production is carried out and surface and underground water resources used in agricultural irrigation is the main factor in the increase in crop production (Tugay, 2012). Crop production value, which is calculated according to the quantity, quality and sales prices of products grown in a certain area, is affected by soil fertility, water resources, climatic conditions, seed and other input costs. The management and allocation of surface and groundwater resources, which are among the water resources used to supply irrigation water needs that cannot be met by natural means, is an important factor affecting the value of crop production.

In terms of sustainable agriculture, increasing the irrigated areas, providing more fertile land with water, reaching more product amount and variety, meeting the food needs of the increasing world population and the value of plant production that constitutes the earnings of the producer are extremely important.

Studies also support the results of the research. Especially in a country like Türkiye, which has both arid and semi-arid regions, various precautions should be taken, which will suffer more water shortage in the future. Water resources should not be used too much. As a requirement of sustainable agriculture, irrigation engineering studies such as the use of limited irrigation methods, selection of optimum plant pattern according to water availability, use of drip and sprinkler irrigation systems with minimum water loss, reuse of drainage water returning from irrigation, use of wastewater, creation of rain gardens and rain harvesting structures and smart agriculture should be emphasized.

Thus, without depleting our water resources and without damaging the hydrological cycle, the amount of net irrigated area can be increased within environmental sustainability and the value of crop production can be increased.

In this study, agricultural sustainability is discussed in terms of the important economic determinants of agricultural inputs, together with the irrigation factor. While the total water allocation and net irrigation land size for irrigation are included in the study; Inflation rate and market exchange rate took place as economic factors.

In the study, firstly, graphical and explanatory information of the data is given. Afterwards, the stationarity analyses of the variables in question were performed with the Perron 89 unit root test. Subsequently, a multiple regression model was established for regression analysis for the determinants of total crop production value. Then, ARDL error correction model analysis was carried out to determine both the long term and short term relationships. At the same time, the fact that the variables are stationary at different levels is also effective in the use of this model. Finally, the mutual causality relationships of the variables in the study were also evaluated with the Granger causality test.

The aim of this study is to analyze the amount of irrigation water supplied from surface and underground water resources with economic factors in terms of sustainable agriculture and agricultural water management.

Although there are few studies directly related to this topic in the literature, national and international studies that are close to the research were analyzed.

Venkateswarlu (1987), conducted a study on yield in drylands in India. He developed a system for this purpose. He analyzed dryland and rainy regions. He developed solutions for dryland areas.

Karaca and Selenay (2001), in their research compared the economic aspects of furrow and drip irrigation systems in Harran Plain in Türkiye. According to the results of the study, they made recommendations on water resource adequacy and irrigation method.

Bird et al. (2015), in their studies, used a model a special model. Value at risk model was used in the study. With the analysis made, increases and decreases in yield were revealed in all soil types.

Rosa et al. (2017), in their studies, analyzed many variables for agricultural sustainability in Rwanda, such as firewood, soil fertility, water availability, crop yield, etc. They developed a system for this purpose and achieved significant results. In this study, observations were made on productivity in a test field and solutions were developed.

Atzori et al. (2017), according to their studies, examined the effect of seawater salinity on irrigation. They determined what the salinity level affects sea water and what does not. According to the results of the analysis, tolerance values for salty agriculture were determined.

Sertyesilisik (2017), investigated on the political economy of Türkiye's water resources. A literature review was conducted in the study. Türkiye's water policies and possible future impacts of climate change was reported.

Akgis and Karakas (2018), in their studies, examined rural development supports by districts in Türkiye. Irrigation supports are also included in the study. Hot Spot Analysis was made and the spatial distribution profile of the supports was created.

Keskin et al. (2018), in their studies, made an economic analysis between irrigation area and dam height in Amasya province in Türkiye. The relationship between increasing the irrigation area by raising the dam body and project profitability was determined.

Li et al. (2020), according to their studies, propose a unified model for the simultaneous optimisation of irrigation water, crop area, and nitrogen fertiliser under uncertainty, which is applied to an irrigation district in northeast China. According to the results of the study, recommendations that can help to manage agricultural land, water and fertiliser resources sustainably in a changing environment are presented.

Van Hong et al. (2021), in their studies, evaluated the effectiveness of VIETGAP and GLOBAL GAP models, principles and standards applied in Vietnam’s agriculture value chain in a specific case study. They focused on improving the irrigation water use efficiency in agricultural production. As a result of the regression analysis made in the study, it was determined that the inflation and exchange rate were lowered in order to increase the GDP.

2. Materials and Methods

2.1. Materials

In this study, firstly, the stationarity analysis of the data will be performed and the regression model will be analyzed. Then, the study will be concluded with ARDL error correction model and causality analysis to reveal the short and long run relationship.

2.1.1. Dataset

In the Table 1, information about the variables used in the study were given.

Table 1. Definition of variables

Period	1995 – 2020	Annual data
Variables	Definition	Source
$LCPV_t$	Crop Production Value	Türkiye Statistical Institute
$LNIA_t$	Net Irrigation Area	General Directorate of State Hydraulic Works
TWA_t	Total Water Allocation	General Directorate of State Hydraulic Works
EXR_t	Exchange Rate	Central Banking Türkiye Republic
INF_t	Inflation Rate	World Bank

Crop production value represents the total value of the agricultural products produced in Türkiye. The exchange rate variable is the nominal value of Turkish Lira against US Dollar and is found to be an important determinant of agricultural exports and imports of intermediate goods especially in agriculture.

The inflation variable is the annual CPI inflation rate and is included in the study as an important indicator of the prices of agricultural products and real purchasing power.

Net irrigation area is the area open to agricultural irrigation in m2 and is included in the study as a factor of wetland size in agriculture. Total water allocation data is included in the study as an irrigation factor, which is an important input in agriculture as the total amount of groundwater and surface water.

After clarifying the variables in the study, the appearance of these series will be presented in the Figure 1. In the graphs, the x-axis represents periods and the y-axis represents values.

The net irrigation area and crop production value variables in the study were logarithmized so that the other variables were converted into close magnitude with each other. The unit root test used to analyse the stationarity of the variables, model types were determined based on the appearance of the series in the Figure 1.

2.1.2. Stationarity analysis

According to the endogenous break stationarity test developed by Perron (1989), the stationarity test is performed by taking into account the break periods of the series. The following Table 2 presents the unit root test results for the stationarity analysis of the variables in the study.

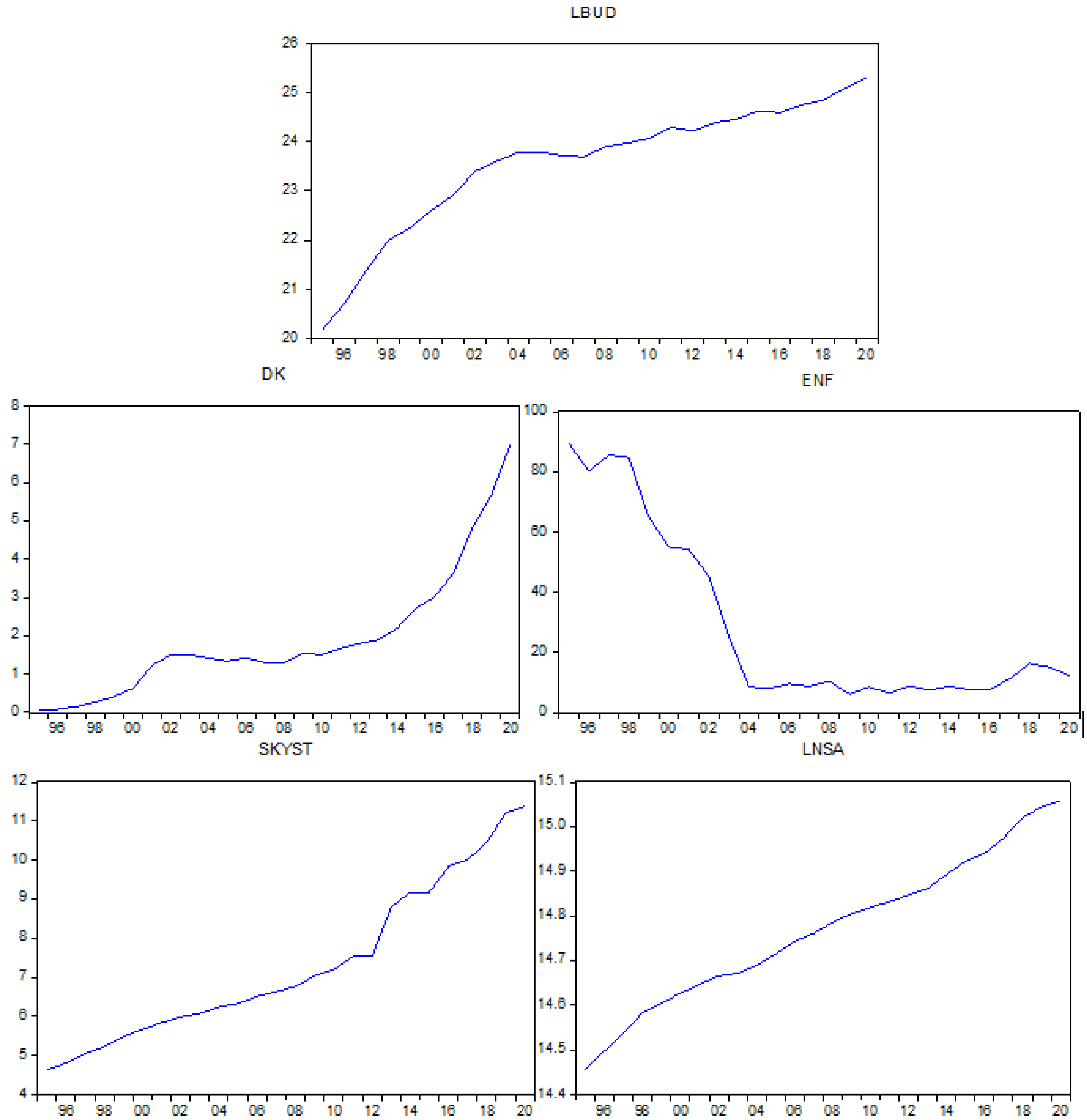

Figure1. Series view.

Table 2. Unit root test

Variables	Phillips Peron Unit Root Test				Phillips Peron 89 Breaking Unit Root Test				
	Constant		Constant and Linear Trend		Breaking Period	Model B		Model C	
	t-Statistic	Prob.	t-Statistic	Prob.		t-Statistic	Prob.	t-Statistic	Prob.
$LCPV_t$			-4.496	0.007	2018			-3.876	0.602
$\Delta LCPV_t$					2007			-5.936	0.000
$LNIA_t$			-2.717	0.238	2008			-4.934	0.089
$\Delta LNIA_t$	-2.813	0.071			2013	-5.529	0.000		
TWA_t			-0.489	0.977	2011			-7.047	0.000
ΔTWA_t	-5.237	0.000							
EXR_t			4.362	0.999	2015			-5.362	0.030
ΔEXR_t	-6.337	0.000							
INF_t			-0.821	0.949	2007			-7.021	0.000
ΔINF_t	-3.213	0.031							

Perron 89 Breaking Unit Root Test Crit. Values after test of unit root; In Model B with Trend without Constant %1:-5.067, %5: -4.524 and %10: -4.261 whereas in Model C with Constant and Trend, %1: -5.719, %5: -5.175, %10: -4.893. Phillips-Perron Unit Root Test Crit. Values; Model with Constant and Trend, %1: -4.374, %5: -3.603, %10: -3.238. Model with Constant, %1: -3.752, %5: -2.998, %10: -2.638.

According to table above, $LCPV_t$, $LNIA_t$variables were found to be stationary as I(1) with the first difference. In addition EXR_t, TWA_t and INF_t The variables are stationary at the I(0) level.. In line with the Phillips Perron unit root test, the variable $LCPV_t$, is stationary at I(0) level, while the other variables are stationary at I(1) level.

2.2. Method

2.2.1. Regression analysis

Multiple regression analysis, which is used to measure the effect of more than one independent variable on the dependent variable, is one of the common statistical methods. (Gemicioglu, 2019). A multiple regression model has been established to be used in this study, and the analysis of the model created with the following Equation 1 was carried out.

$$LCPV_t = \beta_0 + \beta_1 LNIA_t + \beta_2 TWA_t + \beta_3 EXR_t + \beta_4 INF_t \quad (1)$$

The Table 3 shows the results of the analysis of the multiple regression model created with the above equation.

According to the results of the multiple regression analysis obtained in the table above, a 1% increase in net irrigation area leads to a 7.87% increase in crop production value. A 1% increase in groundwater and surface water allocation leads to a 0.33% a fall in the value of the production of crops. A 1% increase in inflation leads to a 0.016% a fall in the value of the production of crops in terms of purchasing power in real terms. Here, the exchange rate variable is statistically insignificant. In this regression model, changes in the independent variables explain 95.9% of the changes in the dependent variable. In addition, the statistical significance of the F test indicates that the coefficients in the model are statistically significant as a whole.

2.2.2. ARDL model analysis

The Error Correction Model has a critical advantage in terms of providing clear and positive results in time series analyses with a small number of observations. (Duasa, 2007). For the ARDL model (Equation 2);

$$X_t = \beta_0 + \beta_1 Y_t + \beta_2 Z_t + u_t \quad (2)$$

in the model with an equation expressed as (Equation 3 and 4);

Table 3. Regression analysis results

Dep.Var.: $LCPV_t$			Method: Least Squ.	
Sample: 1995 – 2020			Inc. obs.: 26	
Var.	Coef.	Std. Error	t-Stat.	Prob.
C	-89.96793	36.15468	-2.488417	0.0213
$LNIA_t$	7.870848	2.518632	3.125048	0.0051
TWA_t	-0.338665	0.179608	-1.885574	0.0733
EXR_t	0.125311	0.095648	1.310136	0.2043
INF_t	-0.016546	0.004807	-3.442287	0.0024
R-squ.	0.959498	F-stat.	124.3747	
Adj. R-squ.	0.951784	Prob(F-stat.)		0.0000

$$\Delta X_t = \beta_0 + \sum_{i=1}^{p} \partial_i \, \Delta X_{t-i} + \sum_{i=0}^{p} \gamma_i \, \Delta Y_{t-i} + \sum_{i=0}^{p} \delta_i \, \Delta Z_{t-i} + \mu_1 x_{t-1} + \mu_2 y_{t-1} + \mu_3 z_{t-1} + e_t \quad (3)$$

$$\Delta X_t = \beta_0 + \sum_{i=1}^{p} \partial_i \, \Delta X_{t-i} + \sum_{i=0}^{p} \gamma_i \, \Delta Y_{t-i} + \sum_{i=0}^{p} \delta_i \, \Delta Z_{t-i} + e_t \quad (4)$$

The symbols ∂, β, γ, δ and μ in the above equations indicate the parameters of X, Y and Z variables, while u and e indicate the error terms of the model in the equation. In this method developed by Pesaran et al. (2001), it should be decided which is the optimal model among the ARDL models that have been tested. The table below shows the different information criteria that determine the number of lags of the ARDL error correction model.

In the Table 4, it has been revealed that the Akaike information criterion is required in determining the lag values of the ARDL model. In the decision stage for this, the model with the lowest information criterion was selected by establishing a model in the number of $(p+1)^n$, looking at the Akaike information criterion. Here; variable amount: n and delay number: p. ARDL error correction model established as (1-2-0-2-2).

The Table 5 shows that most of the lagged variables are statistically significant according to the ARDL model estimation results.

Table 4. ARDL model selection

	Mod. Sel. Crit. Tab.			Dependent Variable: $LCPV_t$		
	Sample: 1995 – 2020			Inc. obs.: 24		
Model	LogL	AIC*	BIC	HQ	Adj. R-sq	Specification
100	35.430981	-1.952582	-1.363555	-1.796313	0.993774	ARDL(1,2,0,2,2)
91	35.441437	-1.870120	-1.232007	-1.700828	0.993214	ARDL(1,2,1,2,2)
19	35.436370	-1.869697	-1.231585	-1.700406	0.993211	ARDL(2,2,0,2,2)
82	35.680754	-1.806729	-1.119531	-1.624416	0.992683	ARDL(1,2,2,2,2)
10	35.444231	-1.787019	-1.099821	-1.604705	0.992537	ARDL(2,2,1,2,2)

Table 5. ARDL model estimation results

Method: ARDL				Mod. Sel. Meth.: Akaike info criterion (AIC)
Dep. Var.: $LCPV_t$				Sample (adj.):1997 – 2020
Inc. obs.: 24 after adjustments				Max. dep. lags: 2 (Aut. Sel.)
Dyna. Reg. (2 lags, automatic): $LNIA_t, TWA_t, EXR_t, INF_t$				Fixed regressors: C
Num. of mod. Eval.: 162			Sel. Mod.: ARDL (1, 2, 0, 2, 2)	
Var.	Coef.	Std. Er.	t-Stat.	Prob*
$LCPV_{t-1}$	0.374335	0.157317	2.379501	0.0348
$LNIA_t$	4.072010	2.961918	1.374788	0.1943
$LNIA_{t-1}$	-15.98377	4.495479	-3.555521	0.0040
$LNIA_{t-2}$	12.66008	2.870985	4.409664	0.0009
TWA_t	0.049540	0.066358	0.746555	0.4697
EXR_t	0.112353	0.122204	0.919387	0.3760
EXR_{t-1}	0.292198	0.164356	1.777830	0.1008
EXR_{t-2}	-0.373718	0.147431	-2.534876	0.0262
INF_t	-0.014877	0.006698	-2.221155	0.0463
INF_{t-1}	0.014051	0.005137	2.735386	0.0181
INF_{t-2}	-0.008855	0.003660	-2.419496	0.0323
C	3.834420	17.45509	0.219673	0.8298
R-squ.	0.996752	F-stat.		334.7468
Adj. R-squ.	0.993774	Prob(F-stat.)		0.000000
Durbin-Watson stat	2.862513			

The Table 6 shows the long-run coefficients and error correction term coefficient values for the ARDL error correction model.

According to the Table 6, the coefficient is obtained as a negative value in the range of 0-1. Accordingly, the coefficient is statistically significant. The deviations caused by the shock effect of the changes in the independent variables used in the study on the dependent variable in the short term will ensure that it will reach equilibrium (Equation 5) in the long term after 1.60 periods.

Table 6. Error correction model

ARDL Coint. And Long Run Form				
Dep. Var.: $LCPV_t$				Sel. Model: ARDL (1, 2, 0, 2, 2)
Sample: 1995 2020				Inc. Obs.s: 24
		Coint. Form		
Var.	Coef.	Std. Err.	t-Stat.	Prob.
$DLNIA_t$	4.072010	2.961918	1.374788	0.1943
$DLCPV_{t-1}$	-12.660077	2.870985	-4.409664	0.0009
$DTWA_t$	0.049540	0.066358	0.746555	0.4697
$DEXR_t$	0.112353	0.122204	0.919387	0.3760
$DEXR_{t-1}$	0.373718	0.147431	2.534876	0.0262
$DINF_t$	-0.014877	0.006698	-2.221155	0.0463
$DINF_{t-1}$	0.008855	0.003660	2.419496	0.0323
$VECM$	-0.625665	0.157317	-3.977109	0.0018
		Long Run Coef.		
Var.	Coef.	Std. Err.	t-Stat.	Prob.
$LNIA_t$	1.196036	1.937317	0.617367	0.5485
TWA_t	0.079179	0.105915	0.747575	0.4691
EXR_t	0.049280	0.078334	0.629096	0.5411
INF_t	-0.015473	0.005571	-2.777309	0.0167
C	6.128550	28.017556	0.218740	0.8305

$$VECM = LBUD_t - (1{,}196 * LNSA_t + 0{,}049 * DK_t + 0.079 * SKYST_t - 0{,}015ENF_t + 6{,}128) \quad (5)$$

Table 7. ARDL model bounds test

Period: 1997 – 2020			Inc. obs.: 24
Test Stat.	Val.	k	
F-stat.	16.72408	4	
	Crit. Value Bounds		
Sign.	I0	I1	
10%	2.45	3.52	
5%	2.86	4.01	
2.5%	3.25	4.49	
1%	3.74	5.06	
R-squ.	0.911710	F-stat.	11.26511
Adj. R-squ.	0.830778	Prob(F-stat.)	0.000105
Durbin-Watson stat	2.943804		

In ARDL analysis, the bounded and unbounded Error Correction Model equations called the Bounds test are estimated. In the estimation, if the table values prepared by Peseran et al. (2001) are smaller than the F statistic value estimated as a result of the establishment of the hypothesis H0: α1= α2 = α3 = 0, The H0 value will be rejected and the H1 value will be accepted. In this case, the variables x, y, z are assumed to be integrated in the long run and the model has statistical significance. (Shresta, 2006). The Table 7 presents the results of the Bounds test for the ARDL error correction model.

According to the results of the Bounds test, the F value is above the lower and upper limits of the Bounds critical values. Accordingly, it is determined that all variables used in the ARDL model are cointegrated in the short and long run.

The Table 8 presents the descriptive statistics calculated to measure the validity of the ARDL error correction model.

Table 8. ARDL analysis model assumptions test results

Tests	Calculated Value	Prob. Value
Ramsey Reset	0.88	0.397*
LM(1)	3.136	0.104*
LM(2)	2.574	0.125*
WHITE	0.792	0.646*
Jarque Bera	0.895	0.638*

Probability values with (*) sign greater than 5% indicate the significance of these tests.

The tests for the descriptive, autocorrelation, variance and normality assumptions of the ARDL model were found to be significant. This reveals the validity of the ARDL analysis.

2.2.3. Causality analysis

In the literature, causality tests can be used to measure the cause-and-effect relationship between variables. Especially for long time series, these tests developed by Granger are widely used (Granger, 1969).

The Table 9 presents the Granger causality results, which is the last analysis test of the study.

Table 9. Granger causality test

Variables	Direction of Causality	Prob.
Net Irrigation Area - CPV	→	0.002*
CPV - Irrigation Area	-	0.342
Total Water Allocation - CPV	→	0.012*
CPV - Water Allocation	-	0.622
Exchange Rate - CPV	→	0.005*
CPV - Exchange Rate	-	0.243
Inflation - CPV	↔	0.092*
CPV - Inflation		0.037*

According to the results obtained in the causality test table above, it is found that irrigation area, water allocation and exchange rate are unidirectional causes of crop production value (CPV). In addition, it was found that the causality test was significant for inflation and crop production value in a reciprocal manner.

3. Results and Discussion

In this study, the sustainability of agriculture is analysed in terms of the impact of irrigation and economic factors on the value of crop production. Accordingly, total water allocation and net irrigation area are included as irrigation variables. Exchange rate and inflation variables were included as economic variables.

When the results obtained in the study are analysed, it is seen that the effects of water allocation, irrigation area and inflation variables on crop production value are statistically significant and theoretically in the expected direction. In this study, which was carried out using the data of our country by considering irrigation and economic factors of sustainability in agriculture, it is seen that a 1% increase in net irrigation area provides an increase of 7.87% in crop production value. Again in terms of sustainable agriculture; in a region with water shortage, the continuous supply of water from underground and surface sources will cause pollution and destruction of water resources over time and will cause a decrease in the yield and production value of the same region over time. According to this study, it was economically calculated that a 1% increase in groundwater and surface water allocation will cause a 0.33% decrease in crop production value. In the evaluation of the use of irrigation water within the sustainability of agriculture in terms of economic factors; the increase in crop production value is realised by increasing the irrigated areas with effective irrigation management practices without reducing water resources. If the increase in irrigation areas and irrigation amount is provided only from surface and groundwater resources, it reveals that a decrease in the value of crop production will be realised in terms of sustainable agriculture, especially in countries with water shortages such as our country.

4. Conclusion

In addition, the conclusion that the variables in the study are short and long term co-integrated was reached by ARDL method. Here, it is also determined that the short-term deviation effect of the changes in irrigation and economic variables on the value of crop production will reach equilibrium at the end of approximately 1.60 periods. Finally, it is concluded that all variables are the cause of the value of crop production, and in addition, the reciprocal causality relationship of the inflation variable is significant.

The amount of irrigation water supplied from surface and underground water resources has been analyzed with economic factors in terms of sustainable agriculture and agricultural water management. Since the study is original and interdisciplinary, it is thought that it will be beneficial to researchers who will work in this field.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	S.K.	S.E.	V.D.
C	40	40	20
D	40	30	30
S	50	25	25
DCP	30	50	20
DAI	30	50	20
L	30	30	40
W	30	30	40
CR	40	40	20
SR	50	25	25

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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PERFORMANCE OF NEW LACTIC ACID BACTERIA STRAINS AS INOCULANTS ON THE MICROORGANISM COMPOSITION DURING FERMENTATION OF ALFALFA SILAGE CONTAINING DIFFERENT DRY MATTER CONTENT

Fatma AKBAY[1]*, Tuğba GÜNAYDIN[1], Seda ARIKAN[1], Mustafa KIZILŞİMŞEK[1]

[1]Kahramanmaras Sutcu Imam University, Faculty of Agriculture, Department of Field Crops, 46100, Kahramanmaras, Türkiye

Abstract: Alfalfa is the most planted perennial legume in the world due to its high nutritive value, protein content, productivity, and digestibility in addition to high vitamin and mineral content. It is also one of the hardest plants to ensile owing to its low reducible sugar and dry matter (DM) contents and high buffering capacity. In this study, the effects of inoculation with *Lactobacillus bifermentans* which is homofermentative and *Lactobacillus brevis* which is heterofermentative on the silage fermentation of different DM containing alfalfa forage. Alfalfa forages were unwilted, or wilted for 9 or 24 hours in order to achieve low (L), moderate (M) and high (H) DM contents. As a result of the research, it was determined that wilting improved the fermentation properties, decreased the pH value, and increased dry matter recovery. Microbial inoculation decreased the pH value, increased the dry matter recovery, and decreased the number of undesirable enterobacteria in silage. As a result of the research, it was determined that the wilting and inoculation should be applied for successful fermentation of alfalfa silage. It was also determined that inoculation with *L. bifermentans* gave the highest crude protein (CP) content while *L. brevis* gave the highest dry matter recovery (DMR).

Keywords: Alfalfa, *L. bifermantans*, *L. brevis*, Lucerna, Inoculant, Wilting

***Corresponding author:** Kahramanmaras Sutcu Imam University, Faculty of Agriculture, Department of Field Crops, 46100, Kahramanmaras, Türkiye
E mail: ftm.akbay01@gmail.com (F. AKBAY)
Fatma AKBAY https://orcid.org/0000-0002-0156-9974
Tuğba GÜNAYDIN https://orcid.org/0000-0002-4458-1287
Seda ARIKAN https://orcid.org/0000-0002-7545-8660
Mustafa KIZILŞİMŞEK https://orcid.org/0000-0002-0295-0603

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1. Introduction

The main limited factors for livestock production in Türkiye are related to shortage of feed production and inadequate quality of feed source. Sufficient quality of feed may be produced from pastures and field production of forages in crop rotation system, however, both of them are insufficient for feeding livestock properly in Türkiye. The most vital and crucial problem to be urgently solved is about quality feed production amount (Canbolat, 2012). Green forage production and hay making are the methods for production quality forage for animal nutrition, but it is obvious that they are far from meeting the deficit in feed need by themselves, especially a large term of the year. Ensiling and preserving green forage without a significant loses from quality for all the year round may be one of the best way for solving the problem.

Alfalfa is known as the queen of fodder plants due to its high adaptation ability (NLO, 2010), high yield due to its multi-cutting, high palatability for livestock and high protein content compared to many other forage crops as well as high essential nutrients such as vitamins and minerals necessary for the ruminant nutrition (Tharanathan and Mahadevamma 2003; Arndt et al., 2015). Even though alfalfa is extensively used for silage processing, however, it is known as hard to ensile successfully plant (Liu et al., 2016) due to its low content of water-soluble carbohydrate, high buffering capacity (Dewhurst et al., 2003; Yang et al., 2004; Li and Wan, 2005; Muck et al., 2007) and in many cases insufficient lactic acid bacteria (LAB) on its epiphytic flora. Additionally, frequent rains in some regions especially during the first and the last cuttings periods prevent field drying of fresh forage, reduce its nutritional value and increase the risk of the reproduction of unwanted microbes. Therefore, need of ensiling process arises after a short wilting treatment or without wilting, rather than completely drying alfalfa particularly mowed at the beginning or at the end of the growing season of the plant. Primarily, dry matter (DM) content significantly influences silage fermentation profile (Xiccato et al., 1994). Low dry matter (DM) content (25%) generally causes high pH and significant DM loss compared to higher DM content (McDonald et al., 1991) and moreover may elicit protease activity and clostridial growth in silage, limiting its use as animal feed (Wan et al., 2021). Wilting may help to preserve the silage properly reducing the number of undesirable microorganisms

(Tao et al., 2021) which compete for fermentable carbohydrates against lactic acid bacteria. On the other hand, excessive wilting reduces the nutritional value of silage (Muck, 1987). Current study was carried out to determine the effects of wilting and different LAB inoculation, selected among 695 isolates obtained from the results of the TUBITAK project, on the fermentation characteristics of alfalfa silage.

2. Materials and Methods

Bilensoy-84 alfalfa cultivar grown under irrigated conditions in farmer's field was used as crop material. Fourth cut alfalfa plants at 50% flowering stage were mowed in the early morning hours and the weeds in the forage were removed. Two different lactic acid bacteria isolated from Türkiye's grassland flora within the scope of a project supported by the Turkish Scientific and Technical Research Organization (TUBITAK) were used as inoculant microorganisms. *Lactobacillus bifermentans* isolate with code number LS-65-2-1 was homofermentative while *Lactobacillus brevis* with code number LS-55-2-2 was heterofermentative in terms of sugar metabolism.

The wilting process was applied to the alfalfa forage on the purpose of defining the effects of different dry matter content on the fermentation profile and behavior of bacterial strains used in the study. After harvesting, the alfalfa plants were wilted for 9 and 24 hours in the shade at outdoor after chopped into approximately 2-3 cm theoretical length. The targeted DM contents were approximately 30% and 35% for moderate (MDM) and high (HDM) DM content, respectively, compared to untreated alfalfa containing low DM (LDM) content around 25%. Accordingly, three different DM content as control (LDM), moderate (MDM) and high (HDM) DM containing silage were evaluated in the study.

Previously regenerated two LAB strains (*L. bifermentans* and *L. brevis*) in MRS broth media were inoculated to different DM containing alfalfa forage after chopping and wilting, at a rate of 10^7 cfu/g fresh forage. Bacteria containing medium were diluted in 20 ml of distilled water and sprayed on the tops of the chopped plant and was homogeneously mixed all over the forage by hand wearing sterile gloves. Only 20 ml of distilled water non-inclusive LAB strain was added for control group. Approximately 400 g of green material was compressed into plastic silage bags, approximately 99.9% of the air in the silage packages was removed with a vacuum machine and then sealed automatically. Totally 27 vacuumed silage packages were prepared, for three DM content (LDM, MDM and HDM), three bacterial inoculations (Control, *L. bifermentans* and *L. brevis* LAB) and three replications. In order to be able to compare silage properties of the forages, forage samples were taken both before (T_0) and 60 days after (T_{60}) ensiling. For microbiological and chemical analysis as well as DM and pH measurements, 20 g samples were taken from the fresh material from T_0 and T_{60} forages, added 180 ml of Ringer solution and mixed with a blender at high speed for one minute. The blended samples (silage extracts) were filtered through Whatman 54 filter paper and a pH measurement was made immediately. Microorganism counts were made from the same filtered samples by making ten-fold dilution series. Serially diluted filtered extracts were analyzed for LAB, enterobacteria, yeasts and molds. LAB numbers were determined by pour plating in de Man, Rogosa, Sharpe agar with double overlaying for anaerobic conditions and plates were incubated at 32 °C for 48 to 72 h. Enterobacteria counts were enumerated by pour plating in violet-red bile glucose agar with a single overlay and plates were incubated at 36 °C for 18 h. Acidified malt extract agar after autoclaving by adding 85% lactic acid was used for yeasts and molds determination and plates were incubated aerobically at 32 °C for 48 to 72 h. The DM content of fresh forages and silage samples were determined by drying in a 70 °C forced-air oven for 48 h. Dried samples of fresh forage and silages were ground to prepare the samples for chemical analyzes with a laboratory mill using a 1-mm sieve. The nitrogen content of the samples was determined by the Kjeldahl method and multiplied by the coefficient of 6.25 to calculate the crude protein content (AOAC, 1990).

The data were analyzed according to the factorial design (wilting and different LAB inoculation) in randomized parcels using the JMP statistical program and the differences between the applications were determined by using LSD test.

3. Results and Discussion

As described in Table 1, DM content, wilting applications, LAB inoculations and their interactions were found to be significant in terms of pH value of forage before ensiling (T_0). The pH value of the uninoculated (Control) alfalfa forage was 6.48 which is the highest compared to *L. bifermentans* (LS-65-2-1) and *L. brevis* (LS-55-2-2) strains inoculations whose pH values were 6.44 and 6.40, respectively. Wilting procedure caused a significant increase of alfalfa forage before ensiling, probably yeast and mold growth on chopped forage during wilting (Wilkinson and Davides, 2013).

There was a significant interaction between wilting and LAB inoculation (Figure 1a). The pH values of T_0 samples were increased by wilting but these raises changed dependently on the LAB used. For example, pH changes in *L. bifermentans* form LDM to MDM were higher than that of other applications. Similarly, pH changes of Control from MDM to HDM were bigger than that of *L. bifermentans* and *L. brevis*. Eventually, it can be manipulated that wilting caused increases in pH values however raises were changed depending on the LAB applications. In other words, LAB strains behaved differently in different DM content resulting a significant interaction.

Table 1. pH values of different DM containing and LAB inoculated alfalfa silages

	pH (T_0)				pH (T_{60})			
Bacteria Inoculant	LDM	MDM	HDM	Mean	LDM	MDM	HDM	Mean
Control	6.28^{de}	6.31^{de}	6.86^{a}	6.48^{A}	5.01	4.68	4.59	4.76A
L.bifermentans	6.25^{e}	6.32^{d}	6.77^{b}	6.44^{A}	4.54	4.66	4.55	4.58B
L. brevis	6.26^{de}	6.28^{de}	6.67^{c}	6.40^{B}	4.62	4.58	4.52	4.57B
Mean	6.27^{C}	6.30^{B}	6.77^{A}	6.44	4.73	4.64	4.55	4.64
LSD	W:0.04** LAB:0.04*WXLAB:0.06**				W: ns LAB:0.17** WXLAB: ns			

DM= dry matter, W= wilting, LAB= lactic acid bacteria inoculation, W X LAB= wilting X LAB inoculation interaction, LDM= control with low DM content, M= moderate DM content, H= high DM content, **=P<0.01, *=P<0.05 statistically significant, ns= non-significant, LSD= least significant difference.

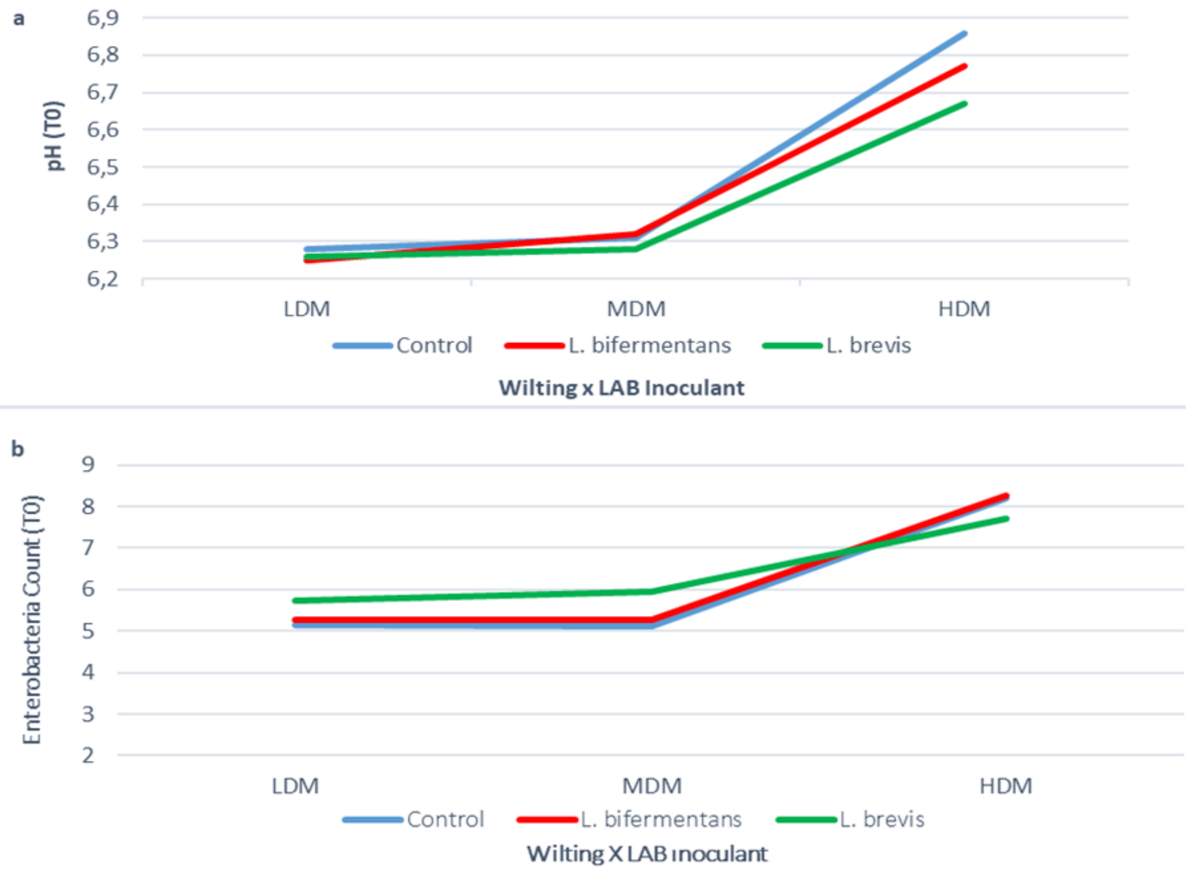

Figure 1. a) pH value of WX LAB interaction b) Enterobacteria count (T_0) of WX LAB interaction.

This finding was in accord with some authors. As an example, Agarussi et al. (2019) determined that wilting would modify the pH during the fermentative process, and the combination of a microbial inoculant and wilting would not change the pH value of its silages.

Resulting silage pH (T_{60}) is one of the most important parameters for evaluating fermentation quality. Silage pH value for leguminous forage is considered sufficient when it falls between 4.5 and 4.9. (Davies et al., 2005). However, reaching this value is quite hard for legumes silages, especially in LDM content. LAB inoculation caused a significant decrease in pH value of silages (Hanagasaki, 2020) regardless to wilting procedure for increasing DM content. In other words, it can be clearly said that bacterial inoculations as well as wilting procedure are a critical factor in lowering the pH value to a satisfactory extend of the alfalfa silage. There were not significant differences between inoculated LAB strains in terms of pH value of T_{60} silages but some researchers found different results from inoculation studies of alfalfa silages. For example, Kızılşimşek et al. (2020) reported that *L. brevis* culture was more effective in lowering the pH level in wilted silages. Muck and Kung (1997) noted that lower pH was obtained in silages treated with homofermentative bacteria in legume plants compared to control. According to the results obtained from the study, it can be said that wilting procedure is a very effective method of reducing the pH of alfalfa silage. It has been revealed that silage obtained from wilted and increased DM content of alfalfa crop positively affects silage quality (Gül et al., 2015). The DM content and bacteria inoculant had significant (P<0.01) effects on crude protein (CP) content of both T_0 and T_{60} alfalfa forage and silage samples (Table 2).

Table 2. Crude protein values of different DM containing and LAB inoculated alfalfa silages

	CP (T_0)				CP (T_{60})			
	DM Content				DM Content			
Bacteria Inoculant	LDM	MDM	HDM	Mean	LDM	MDM	HDM	Mean
Control	20.46	20.47	20.73	20.55^{b}	18.55	19.04	19.92	19.17b
L.bifermentans	22.19	20.84	22.76	21.89^{a}	19.34	20.37	21.28	20.33a
L. brevis	21.35	20.56	22.93	21.62^{ab}	18.44	17.88	19.83	18.72b
Mean	21.33^{ab}	20.59^{b}	22.14^{a}	21.35	18.77^{b}	19.10^{b}	20.35^{a}	19.41
LSD	W:1.08** LAB: 1.08** WXLAB: ns				W:1.03** LAB: 1.03** WXLAB: ns			

DM= dry matter, W= wilting, LAB= lactic acid bacteria inoculation, W X LAB= wilting X LAB inoculation interaction, LDM= control with low DM content, M= moderate DM content, H= high DM content, **=P<0.01, *=P<0.05 statistically significant, ns= non-significant, LSD= least significant difference.

Table 3. Dry matter ratio and dry matter recovery values of different DM containing and LAB inoculated alfalfa silages

	DM (T_0)				DM (T_{60})			
	DM Content				DM Content			
Bacteria Inoculant	LDM	MDM	HDM	Mean	LDM	MDM	HDM	Mean
Control	24.73	30.73	35.41	30.29	22.6	26.9	33.5	27.67
L.bifermentans	25.51	31.36	35.75	30.88	22.6	28.2	34.3	29.35
L. brevis	24.71	30.33	36.14	30.40	23.6	29.5	32.5	28.53
Mean	24.99^{c}	30.81^{b}	35.77^{a}	30.52	23.91^{c}	28.19^{b}	33.44^{a}	28.52
LSD	W:0.65** LAB: NS WXLAB: ns				W:2.60** LAB:ns WXLAB:ns			

DM= dry matter, W= wilting, LAB= lactic acid bacteria inoculation, W X LAB= wilting X LAB inoculation interaction, LDM= control with low DM content, M= moderate DM content, H= high DM content, **=P<0.01, *=P<0.05 statistically significant, ns= non-significant, LSD= least significant difference.

The CP content of T_0 samples ranged from 20.59 to 22.14% for wilting procedures and from 20.55 to 21.89% for inoculation applications while that of T_{60} samples changed between 18.77-20.35% and 18.72-20.33%, respectively.

It can be clearly said that *L. bifermentans* inoculation had the highest CP content of resulted silages (T_{60}) compared to both *L. brevis* inoculation and control application. This increase can be explained by the fact that LAB inoculated silages have less protein degradation compared to control silages, which are affected by many factors such as pH level, buffering capacity, and VFA content (Ertekin and Kızılşimşek, 2020). Similarly, Silva et al. (2016) found that CP content increased with the application of inoculation LAB. The CP contents increased significantly in HDM treatment compared to the LDM. Similarly, Kızılşimşek et al. (2020) reported that alfalfa plants that wilted for 3 hours achieved higher CP content than those that were not wilted. Blajman et al. (2022) found that CP content was higher in alfalfa silages wilted for 21 hours. Lee et al. (2021) pointed out that the CP content of rye plant wilted for 12 hours was higher than that of non-wilted rye. In contrast, Muck (1987) reported that excessive wilting causes the nutritional value of silage to decrease. Similarly, Zhang et al. (2020), Wan et al. (2021), and Liu et al. (2021) indicated that CP contents decreased by wilting. This situation is related to the wilting conditions such as duration of wilting or environment temperature etc. and can also be explained by cultivar properties.

The DM contents of fresh material (T_0) and resulting silages (T_{60}) did not significantly change by LAB inoculants, but DM contents increased significantly by wilting (P<0.01) as it is supposed to be (Table 3). When the DM values of silages opened on the 60th day were examined, it was determined that there were small dry matter losses. The losses associated with fermentation in the silo seem like mostly due to CO_2 production. The amount of DM lost during fermentation depends on both the dominant microbial species and WSC content of the crop material (Oliveria et al., 2017).

Both inoculations and different DM content did not significantly affect the DMR values, statistically (Table 4). However, it can be said that the increase in the dry matter content of alfalfa caused an increase in DMR compared to the low DM content. In other words, it was determined that plants with high dry matter content had more dry matter recovery which is preferred in terms of economic perspective (Uslu et al., 2017). Moreover, it can be said that dry matter recovery is low in uninoculated (control) silages compared to LAB inoculation applications, and especially the least dry matter loss occurs in *L. brevis* (LS-55-2-2) strain inoculation.

Jatkauskas and Vrotniakiene (2016) explained that dry matter recovery increased significantly in alfalfa silages which are treated by different bacterial strains as inoculants. Similarly, Kızılşimşek et al. (2020) and Günaydın et al. (2023) reported that bacterial inoculation is effective in reducing dry matter expected losses.

Although there was no significant difference according to bacterial applications, lactic acid bacteria numbers among the bacterial inoculants in T_0 varied between 3.94 and 3.96 (log_{10} cfu/g silage). (Table 5). On the 60th day after ensiling, it was determined that there was no statistical difference in the number of the LAB in terms of the bacterial inoculations, and the number of lactic acid bacteria varied between 5.42 and 5.49 (log_{10} cfu/g silage). Although no statistical difference was observed, the highest LAB count at the fresh material (T_0) and resulting silages (T_{60}) was obtained from the control application.

Table 4. Dry matter recovery values of different DM containing and LAB inoculated alfalfa silages

	DM Content			
Bacteria Inoculant	LDM	MDM	HDM	Mean
Control	91.29	87.43	94.65	91.12
L.bifermentans	90.45	89.90	95.95	92.13
L. brevis	95.50	97.15	89.98	94.21
Mean	92.41	91.53	93.53	92.49
LSD	W: ns LAB: ns WXLAB: ns			

DM= dry matter, W= wilting, LAB= lactic acid bacteria inoculation, W X LAB= wilting X LAB inoculation interaction, LDM= control with low DM content, M= moderate DM content, H= high DM content, **=P<0.01, *=P<0.05 statistically significant, ns= non-significant, LSD= least significant difference.

Table 5. Numbers of lactic acid bacteria in different DM containing and LAB inoculated alfalfa silages

	LAB (T_0)				LAB (T_{60})			
	DM Content				DM Content			
Bacteria Inoculant	LDM	MDM	HDM	Mean	LDM	MDM	HDM	Mean
Control	4.09	3.50	5.10	4.22	5.06	5.50	5.90	5.49
L.bifermentans	3.27	3.21	5.37	3.94	5.09	5.20	5.99	5.42
L. brevis	3.39	3.30	5.19	3.96	5.20	5.02	6.06	5.43
Mean	3.58^B	3.34^B	5.22^A	4.04	5.09^B	5.31^B	5.98^A	8.17
LSD	W:0.30** LAB: ns WXLAB: ns				W: 0.27** LAB: ns WXLAB: ns			

DM= dry matter, W= wilting, LAB= lactic acid bacteria inoculation, W X LAB= wilting X LAB inoculation interaction, LDM= control with low DM content, M= moderate DM content, H= high DM content, **=P<0.01, *=P<0.05 statistically significant, ns= non-significant, LSD= least significant difference.

Ertekin and Kızılşimşek (2020) have explained that the highest lactic acid bacteria count in the alfalfa plant, in which five different bacterial inoculants were applied together with the control, were obtained from the control applications in fresh alfalfa (T_0) and ensiled during six hours (T_6) and ensiled during 75 days (T_{75}). However, the researchers reported that *L. brevis* isolate gave the highest LAB number in the openings 12 and 24 hours after ensiling, followed by *L. bifermentans* (LS-65-2-1) isolate. It can be clearly stated that there is no parallelism between the number of LAB and pH values. In other words, the high lactic acid bacteria count in control does not mean that the lowest pH value would be obtained from the control. Therefore, it has become understood that the ability of lactic acid bacteria to function effectively in the silo is related to the microorganism composition in the silo and the lactic acid production potential of LABs train individuals. Accordingly, Kızılşimşek et al. (2020) stated that bacterial inoculation and wilting increased lactic acid production resulting in decline in silage pH level. Before ensiling, the number of LAB in LDM and MDM alfalfa was 3.58 and 3.34 (log10 cfu/g silage), respectively, which was substantially lower than that in HDM, which was 5.22 (log10 cfu/g silage), indicating that the greater the DM content, the higher LAB counts in forage.

Correlatively, Tyrolová and Výborná (2011) stressed that the LAB population increased with the wilting applications. Similar results were obtained from resulting silage (T_{60}) which are about 100 times much more than T_0 samples. The LAB count was 5.09 and 5.31 (log_{10} cfu/g silage) for LDM and MDM, respectively, and 5.98 (log_{10} cfu/g silage) in HDM silages in T_{60}. Hence, Rangrab et al. (2000) concluded that the LAB population increased from 5.28 to 6.88 log cfu/g with increasing DM of alfalfa silages. Kızılşimşek et al. (2016), reported that many different microflora groups are competing with each other in silage and that LAB groups need to be dominant in the raw material before ensilage in order to obtain high-quality silage.

When inoculation is taken into consider, the number of enterobacteria among the bacterial inoculants in fresh material (T_0) varied between 6.16 and 6.46 (log_{10} cfu/g silage), and there was no statistical difference between applications (Table 6). Generally, enterobacteria numbers are high in the first stages of ensiling, but their numbers are tended to decrease in the silo as the fermentation continues (Bolsen et al., 1996). Similarly, the study determined that the presence of enterobacteria at the beginning of ensiling decreased from 6.29 to 3.85 by means of fermentation.

Table 6. Numbers of enterobacteria in different DM containing and LAB inoculated alfalfa silages

	Enterobacteria (T_0)				Enterobacteria (T_{60})			
	DM Content				DM Content			
Bacteria Inoculant	LDM	MDM	HDM	Mean	LDM	MDM	HDM	Mean
Control	5.16^{e}	5.12^{e}	8.20^{ab}	6.16	4.18	4.19	4.28	4.22^{A}
L.bifermentans	5.27^{de}	5.28^{de}	8.25^{a}	6.26	3.42	3.49	3.54	3.48^{C}
L. brevis	5.74^{cd}	5.95^{c}	7.71^{b}	6.46	3.53	4.10	3.91	3.85^{B}
Mean	5.39^{B}	5.45^{B}	8.05^{A}	6.29	3.71	3.93	3.91	3.85
LSD	W:0.29** LAB: ns WXLAB:0.52**				W: ns LAB:0.30** WXLAB:ns			

DM= dry matter, W= wilting, LAB= lactic acid bacteria inoculation, W X LAB= wilting X LAB inoculation interaction, LDM= control with low DM content, M= moderate DM content, H= high DM content, **=P<0.01, *=P<0.05 statistically significant, ns= non-significant, LSD= least significant difference.

Table 7. Numbers of yeast in different DM containing and LAB inoculated alfalfa silages

	Yeast (T_0)				Yeast (T_{60})			
	DM Content				DM Content			
Bacteria Inoculant	LDM	MDM	HDM	Mean	LDM	MDM	HDM	Mean
Control	6.93^{d}	7.09^{cd}	7.38^{bc}	7.13	6.11^{bc}	5.93^{bc}	5.15^{e}	5.73
L.bifermentans	6.99^{cd}	6.08^{e}	7.58^{b}	6.88	6.16^{b}	5.80^{bcd}	5.41^{de}	5.79
L. brevis	6.32^{e}	7.16^{bcd}	8.07^{a}	7.18	6.89^{a}	5.64^{cd}	5.10^{e}	5.87
Mean	6.74^{B}	6.78^{B}	7.67^{A}	7.06	6.39^{A}	5.79^{B}	5.22^{C}	5.80
LSD	W:0.26** LAB: ns WXLAB:0.45**				W:0.26** LAB:ns WXLAB:4.57**			

DM= dry matter, W= wilting, LAB= lactic acid bacteria inoculation, W X LAB= wilting X LAB inoculation interaction, LDM= control with low DM content, M= moderate DM content, H= high DM content, **=P<0.01, *=P<0.05 statistically significant, ns= non-significant, LSD= least significant difference.

The enterobacteria count in untreated silages in T_{60} was 4.22 (log $_{10}$ cfu/g silage), while this value significantly decreased to 3.85 in *L. brevis* (LS-55-2-2) and 3.48 in *L. bifermentans* inoculations, showing that *L. bifermentans* (LS-65-2-1) inoculation was more effective than *L. brevis* (LS-55-2-2). Since enterobacteria can compete with lactic acid bacteria for water-soluble sugars (WSC), this is an undesirable microorganism to form in silage (Muck, 2010; Coblentz and Muck, 2012; Gomes et al., 2021). It was determined that the enterobacteria count was insignificantly higher in MDM and HDM than LDM content silage. It can be speculated that the content of WSC in the ensiled material increases proportionally by wilting, which may cause an increase in the number of enterobacteria. These findings were similar to Keklik (2020), who concluded that the number of enterobacteria is higher in alfalfa silage with higher DM content.

DM content and interaction of DM content and bacteria inoculant had significant (P<0.01) effects on concentrations of yeast (T_0; T_{60}) (Table 7).

The yeast count of LAB and wilting interaction in fresh material are shown in Figure 2a. In general perspective, yeast counts were increased in HDM content. However, L.bifermentans application induced a decrease in yeast number in MDM causing an interaction between applications. In Figure 2b, LAB inoculants have shown different effects in the number of yeast count depending on the DM content. ^{Homo}LAB tends to increase the level of lactic acid, whereas ^{heto}LAB increase the level of acetic acid and butric acid. Acetic acid is known to improve aerobic stability by inhibiting the formation of yeast and molds (Muck et al., 2018). At the beginning of the fermentation, a very high (7.06 log_{10} cfu/g silage as mean) yeast number was counted. It was determined that there was no statistical difference among bacteria applications resulting silage (T_{60}); however, the presence of yeast decreased compared to initial fresh materials.

Kızılşimşek et al. (2016), reported that the number of yeasts decreased at the end of ensiling and the presence of yeast in silages may change depending on the ensiling conditions. In addition, yeast count increased as DM content increases before ensiling (T_0), but this changed in mature silages (T_{60}), and the yeast count decreased as DM content increases. This situation may have resulted from the higher number of LAB growth in the higher DM content. Agarussi et al. (2019) found that the decrease in LAB in silos opened on the seventh day of ensiling caused the dominance of enterobacteria, yeasts, and clostridia.

5. Conclusion

As a result of the study, the combination of lactic acid bacteria (LAB) inoculation and increasing DM content by wilting improved the fermentation profile of alfalfa silages compared to have high moisture content forage. The DM contents of fresh material (T_0) and resulting silages (T_{60}) did not significantly change by LAB inoculants, but DM contents increased significantly by wilting. Additions, the amount of LAB and the CP content and DM recovery in the silages increased by wilting. *L. bifermentans* (LS-65-2-1) was the best strain among the applications, with the highest CP content, the lowest enterobacteria, and the lowest yeast counts while *L.*

brevis (LS-55-2-2) isolate was better in terms of dry matter recovery. Satisfying low pH values were achieved by inoculation of both strains.

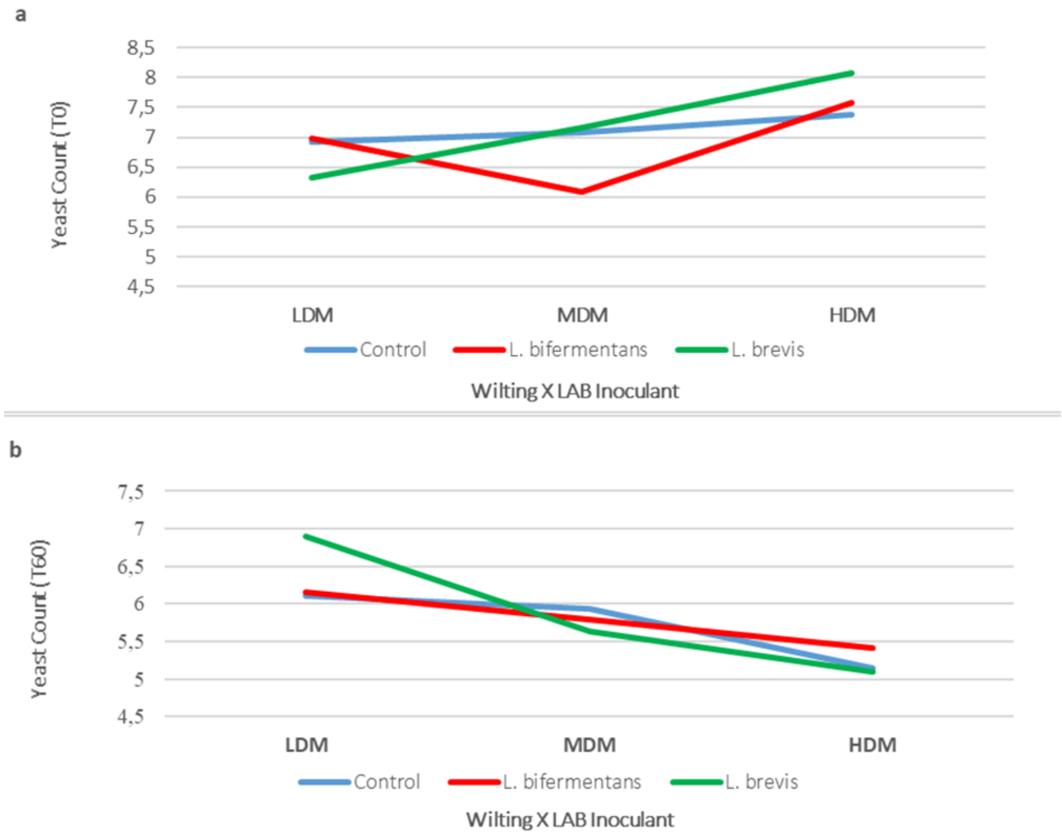

Figure 2. a) yeast count (T_0) of WX LAB interaction, b) yeast count (T_{60}) of WX LAB interaction.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	F.A.	T.G.	S.A.	M.K.
C	30	20	10	40
D	50			50
S	40	10	10	40
DCP	50	25	25	
DAI	60			40
L	70			30
W	60			40
CR	50	10	10	30
SR	50	10	10	30
PM	40	20		40
FA				100

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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ESTIMATE OF STRUCTURAL FRACTURES IN WHEAT CULTURE AND PRODUCTION IN TÜRKİYE BY ECONOMETRIC ANALYSIS

İsmail GÖK[1]*, Mustafa ŞAHİN[2]

[1]Kahramanmaraş Sütçü İmam University, Faculty of Agriculture, Department of Bioengineering, 46100, Kahramanmaraş, Türkiye
[2]Kahramanmaraş Sütçü İmam University, Faculty of Agriculture, Department of Agricultural Biotechnology, 46100, Kahramanmaraş, Türkiye

Abstract: This study, it was aimed to determine the amount of wheat fields planted in Türkiye and the structural breaks in wheat yield in the specified years. The data set obtained for this purpose was obtained from the wheat production and wheat cultivation area in the statistical tables between 1995 and 2020 published by the Turkish Grain Board (TMO). According to the estimation results; the data set obtained from the wheat planting area in the statistical tables between 1995 and 2020 was stabilized by taking the first differences and the red lines in the given table were left from the second half of 2005 to the beginning of 2014, there was a structural break between these years. It was determined by the analysis that there was a structural break between these years, since the data set was stabilized by taking the first differences and the red lines in the given chart were exceeded from the second half of 2005 to the beginning of 2015.

Keywords: Wheat, Wheat yield, Cultivation area, Years, Econometric program

***Corresponding author:** Kahramanmaraş Sütçü İmam University, Faculty of Agriculture, Department of Bioengineering, 46100, Kahramanmaraş, Türkiye
E mail: gkisoo1995@gmail.com (İ. GÖK)
İsmail GÖK https://orcid.org/0000-0002-0759-1187
Mustafa ŞAHİN https://orcid.org/0000-0003-3622-4543

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1. Introduction

Wheat has been among the most basic food sources since the existence of human life. The history of collecting itself and accompanying grains from nature dates to approximately 17,000 BC (Tanno and Willcox, 2006). It is also known that the first domestic use of wheat was in the southeast of Türkiye (Diamond, 2006). Although it is possible to come across various types of wheat in our age, three main groups are that are most commonly used. These are defined as bread wheat, biscuit and wheat (Kurt, 2012).

Production amounts of countries or regions vary due to changes in climatic conditions. The fact that some countries need more than they can produce affects the wheat trade. Wheat is produced in almost every part of the world and Türkiye; it is a very important grain product because it both affects the large producer mass and is a basic food source. In terms of production, it affects almost 4 million businesses, that is, about 15 million people, and the entire population of Türkiye in terms of consumption (TMO, 2021). For these reasons, developments in wheat production technology in the world are followed closely and tried to be applied in Türkiye. However, despite the high diversity in Türkiye, the appropriate variety was standard in wheat, yield and quality problems were not exactly a suitable solution. The fact that the production is spread over a very wide area, production even in dry conditions reduces the amount of production obtained in general.

Grain is cultivated in an area of 11.13 million hectares in Türkiye. Wheat comes first with 62% of the grain cultivation area (TMO, 2021).

In wheat production in Türkiye, the yield is low since mostly dry cultivation areas are used. In addition to wheat cultivation in some regions, there is almost no other crop cultivation (Anonymous, 2001).

This study, it was aimed to determine the amount of wheat fields planted in Türkiye and the structural breaks in wheat yield in the specified years.

2. Materials and Methods

The data set in this study was obtained from the wheat production and wheat cultivation area in the statistical tables between 1995 and 2020 published by the Turkish Grain Board (TMO, 2021). In Table 1. Wheat cultivation area and wheat yield are given by years.

In this research, unit root tests were used to make the time series stationary in the given data set. If there is a unit root, the time series is not stationary. Dickey-Fuller (DF) and Argumented Dickey-Fuller (ADF) tests, which are used to detect the presence of a unit root, are the most well-known methods (Dickey and Fuller, 1979; 1981).

The relationship of the variable y_t with its value one period ago is formulated as given in Equation 1.

Table 1. Wheat cultivation area and wheat yield by years

Years	Wheat Plantation Area (HA)	Wheat Yield (Tons)	Years	Wheat Plantation Area (HA)	Wheat Yield (Tons)
1995	9.400.000	18.000.000	2008	8.090.000	17.782.000
1996	9.350.000	18.500.000	2009	8.100.000	20.600.000
1997	9.340.000	18.650.000	2010	8.103.400	19.674.000
1998	9.400.000	21.000.000	2011	8.096.000	21.800.000
1999	9.380.000	18.000.000	2012	7.529.639	20.100.000
2000	9.400.000	21.000.000	2013	7.772.600	22.050.000
2001	9.350.000	19.000.000	2014	7.919.208	19.000.000
2002	9.300.000	19.500.000	2015	7.866.887	22.600.000
2003	9.100.000	19.000.000	2016	7.671.945	20.600.000
2004	9.300.000	21.000.000	2017	7.668.879	21.500.000
2005	9.250.000	21.500.000	2018	7.299.270	20.000.000
2006	8.490.000	20.010.000	2019	6.846.327	19.000.000
2007	8.100.000	17.234.000	2020	6.922.236	20.500.000

$$\gamma_t = \beta\gamma_{t-1} + u_t \quad (1)$$

The hypotheses are based on the model;

$H_0 = \beta = 1$ (the series contains a unit root, the series is not stationary).

$H_1 = \beta < 1$ (there is no unit root in the series, the series is stationary).

Here, u_t has independent identically distributed (iid) constant variance and zero means.

The error term with these properties is called white noise and the equation is shown as given in Equation 2.

$$u_t \approx iid(0, \sigma^2) \quad (2)$$

If $\beta = 1$, the series is under the influence of its value one period ago and random shocks.

It can be said that the series contains a unit root. If $\beta < 1$, the effect of γ_{t-1} on γ_t will gradually decrease depending on the value of β.

Here, the 'τ' (tau) statistic, which emerged in Dickey-Fuller's Monte Carlo application, is used. If the absolute value of the τ statistic exceeds the absolute value of the Dickey-Fuller critical value, the hypothesis that the time series is stationary is accepted and the Dickey-Fuller test is generally applied to the following regression patterns:

1) Dickey-Fuller equation with no constant term and no trend (Equation 3):

$$\Delta\gamma_t = \delta\gamma_{t-1} + u_t \quad (3)$$

2) Dickey-Fuller equation with constant term and no trend (Equation 4):

$$\Delta\gamma_t = \beta_0 + \delta\gamma_{t-1} + u_t \quad (4)$$

3) Dickey-Fuller equation with constant term and trend (Equation 5):

$$\Delta\gamma_t = \beta_0 + \beta_1 t + \delta\gamma_{t-1} + u_t \quad (5)$$

As a result of the Dickey-Fuller test, if the stationarity of the series is not mentioned, it is retested by taking the difference of the dependent variable. If the series becomes stationary as a result of the first difference operation, the first difference is said to be stationary. If the series does not become stationary as a result of the first difference, the second difference of the series is tested and continued. The series that becomes stationary at this stage is called second-order difference stationary. It is continued in this way for further difference taking operations. However, since the interpretation of the coefficients will be difficult and the degree of freedom will decrease, in practice, the difference is usually stopped after the second difference (Dickey and Fuller, 1979; Dickey and Fuller, 1981). In case of autocorrelation in the estimated regressions, the DF test results are invalid. An extended DF test is applied to fix this problem. Simply put, the lagged values of the dependent variable are to the right of the equation. The equations to be estimated in the ADF test are as follows.

$\Delta\gamma_t = \delta Y_{t-1} + \sum_{j=1}^{k} \alpha\Delta Y_{t-j} + u_t$ (without a fixed term)

$\Delta\gamma_t = \beta_0 + \delta Y_{t-1} + \sum_{j=1}^{k} \alpha\Delta Y_{t-j} + u_t$ (constant term)

$\Delta\gamma_t = \beta_0 + \delta Y_{t-1} + \sum_{j=1}^{k} \alpha\Delta Y_{t-j}\ \alpha_t + u_t$ (constant term and trend variable added)

$H_0 = \delta = 0$ If there is a unit root in the series, the series is not stationary.

$H_1 = \delta < 0$ on the other hand, there is no unit root in the series and the series is stationary (Dickey and Fuller, 1981).

Afterward, Cusum of Squares test, which is an econometric program, was used to determine structural breaks. The Cusum of Squaraes test is a way of using squares of consecutive residuals (Equation 6).

$$S_t = \frac{\sum_{s=1}^{n} w_S^2}{\sum_{s=k+1}^{n} w_t^2} \qquad t=k+1, k+2, \dots, n \quad (6)$$

S_t graphed after its value is calculated. The expected value of this test (Equation 7),

$$E(S_t) \cong \frac{t-k}{n-k} \quad (7)$$

is calculated as. The expected value is 0 when t=k is present, and 1 when t=n is present. Confidence level limits are $E(S_t) \pm C_0'$. This value can be obtained with α margin of error, n number of observation values and k number of parameters. C_0value is obtained with m and α values as well as the tables that can be created in case the analysis is double or unilateral. α for one-sided analysis; C_0 value is obtained by using α/2 for bilateral analysis. If the n-k value for analysis is an odd number (Equation 8),

$$m = \frac{1}{2}(n-k) - 1 \quad (8)$$

form is obtained. If n-k is an even number (Equation 9-10),

$$m = \frac{1}{2}(n-k) - \frac{3}{2} \quad (9)$$

$$m = \frac{1}{2}(n-k) - \frac{1}{2} \quad (10)$$

estimation must be made. Then, the Cusum of Squares graph is obtained by drawing the lower and upper limits with the values determined from the table. If the graph is outside the limits of the determined confidence level, it is decided that there is a structural break, and if it stays within the limits of the determined confidence level, there is no structural break (Brown et al., 1975).

3. Results

This study, it was aimed to determine the amount of wheat fields planted in Türkiye and the structural breaks in wheat yield in the specified years. For this purpose, data were obtained from the wheat production and wheat cultivation area in the statistical tables between 1995 and 2020 published by the Turkish Grain Board (TMO, 2021). In the research, the data set was stabilized using Argumented Dickey Fuller method and analysis was made with the help the Cusum of Squares method.

According to the results of the research, the series is stationary because the probability value of the wheat planted area is less than 0.05, and at the same time, the Argument Dickey-Fuller test statistic is 9.630941 in the absolute value, and the series is stationary when the absolute values of the crystal test values are greater than 9.389762. In addition, since the probability value of wheat yield is less than 0.05, the series is stationary, and at the same time, the Argument Dickey-Fuller test statistic 9.633309 value within the absolute value of the crystal test values is determined to be stationary when the sum of the absolute values of the crystal test values is 9.365273.

In the data set obtained by years from the wheat cultivation area in the statistical tables between 1995 and 2020, published by the Turkish Grain Board (TMO, 2021), it is seen that there is a structural break between these years, since the red lines in the given table are gone from the second half of 2005 to the beginning of 2014. In the data set obtained from the wheat yield and wheat yield by years, it was determined by the analysis that there was a structural break between these years, as the red lines in the given table were exceeded from the second half of 2005 to the beginning of 2015.

In order to obtain better results in the data set obtained from the wheat production and wheat cultivation area in the statistical tables between 1995 and 2020, published by the Turkish Grain Board (TMO, 2021), it is necessary to keep the number of observations in the data set wider, to determine the economic and climatic conditions in the selected years. It should be taken into account that changes should not be ignored and the decrease in efficiency due to natural events and global warming that has occurred in Türkiye in recent years. In order to avoid these and similar problems in future articles or thesis research, the deficiencies mentioned should not be ignored.

4. Discussion and Conclusion

The data set in this study was obtained from the wheat production and wheat cultivation area in the statistical tables between 1995 and 2020 published by the Turkish Grain Board (TMO, 2021). In the obtained data set, as a first step, the stationarity of the series was tested with the help of The Argumented Dickey Fuller (ADF) method.

In Table 2, the first differences were taken with the help of the unit root test and the data set of the cultivated area was made stationary.

In Table 3, the first differences were taken with the help of the unit root test and the data set of wheat yield was made stationary.

The years of structural breaks between the wheat field planted and the amount of production received according to the years were tested with the help of the econometric program Cusum Square.

Table 2. Unit root test result of wheat planted area

		Level		First Difference	
		t- statistics	Probability	t- statistics	Probability
ADF		-0.004695	0.9495	-9.630941	0.0026
	%1	-3.724070		-3.752946	
	%5	-2.986225		-2.998064	
	%10	-2.632604		-2.638752	

Table 3. Wheat yield unit root test result

		Level		First Difference	
		t- statistics	Probability	t- statistics	Probability
ADF		-4.790087	0.0620	-9.633309	0.0000
	%1	-3.724070		-3.737853	
	%5	-2.986225		-2.991878	
	%10	-2.632604		-2.635542	

In the data set obtained from the wheat cultivation area according to the years in the statistical tables between 1995 and 2020 published by the Turkish Grain Board (TMO, 2021) in Figure 1 and Figure 2. It was determined by the analysis that there was a structural break between them.

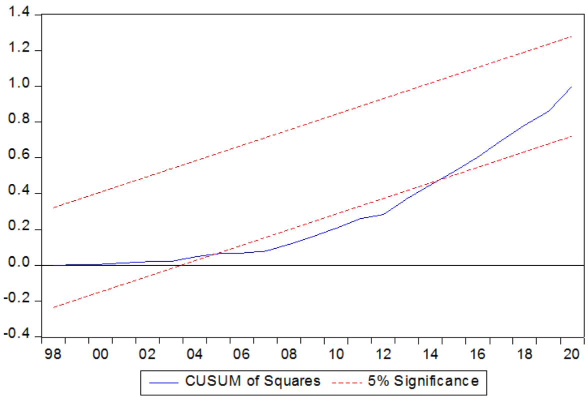

Figure 1. Test of wheat planted area of Cusum of Squares.

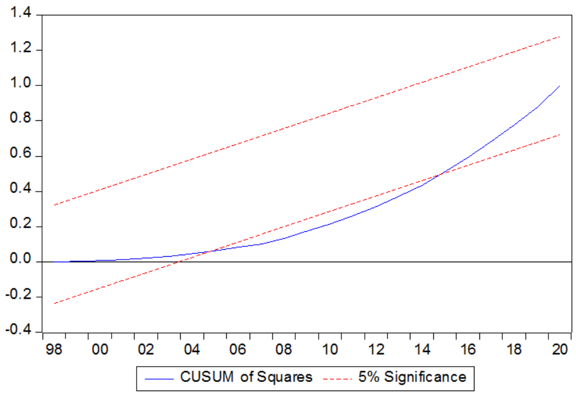

Figure 2. Wheat yield test of Cusum of Squares.

The data set obtained from the wheat yield in the statistical tables between 1995 and 2020 published by the Turkish Grain Board (TMO, 2021) in Table 3. It was determined by the analysis that there was a structural break.

In a study, the negative effects on the pasta industry were investigated. As a result of the research, it has been determined that solving the problems such as raw material problem in the sector, low consumption, marketing problems and insufficient support will increase the competitiveness of the sector and help its development (Turhan, 2008). In a study, it was concluded that there has not been a certain increase in wheat production in the last two decades in developed countries and that developing countries have to make up for this deficiency (Atar, 2017). In a study, it was concluded that irrigation and fertilizer amounts affect productivity in Hatay, and the age of the producer in Şanlıurfa in addition to Hatay province (Tiryakioğlu et al., 2017). In a study, it was concluded that the progress in wheat production in Türkiye lags behind the world average and population growth rate (Duru et al., 2019). In a study, it was concluded that when it comes to adequacy in agricultural production, it started to decrease as of 1990 and it started to become dependent on foreign sources in the 2000s (Çetin, 2020). In a study, it was concluded that there is a moderate relationship in the ARDL limit test applied to the effect of climate change on honey yield in Türkiye (Duru and Parlakay, 2021). In a study conducted to examine the relationship between onion production and its price in Türkiye, it was concluded that there is a long-term relationship between onion production and price (Gümüşsoy, 2021). The difference between this researches from the studies in the literature is the determination of the amount of wheat field planted by years and the structural breaks in wheat yield in Türkiye.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	İ.G.	M.Ş.
C	50	50
D	50	50
S	50	50
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50
FA	50	50

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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IN VITRO COMPATIBILITY OF ENTOMOPATHOGENIC FUNGI *Beauveria bassiana* (BALS.) VUILL. WITH DIFFERENT FUNGICIDES

Oktay ERDOĞAN[1]*, Zehra SAĞLAN[2]

[1]*Pamukkale University, Faculty of Applied Sciences, Department of Organic Farming Business Management, 20680, Civril, Denizli, Türkiye*
[2]*Pamukkale University, Graduate School of Natural and Applied Sciences, Department of Organic Farming Business Management, 20020, Denizli, Türkiye*

Abstract: *Beauveria bassiana* (Balsamo) Vuillemin is one of the entomopathogenic fungi used against broad host insects and plant pathogens. Fungicides have side effects on entomopathogenic fungi. *In vitro* assay was performed to examine the compatibility of *B. bassiana* with eight commonly used fungicides (Azoxystrobin 75 g/l+Metalaxyl-m 37.5 g/l+ Fludioxonil 12.5 g/l FS, Boscalid 25%+ Pyraclostrobin 12% WG, Copper Hydroxide 361.1 g/l SC, Azoxystrobin 250 g/l SC, Triticonazole 80 g/l + Pyraclostrobin 40 g/l FS, Fludioxonil 12.5 g/l + Metalaxyl 10 g/l SC, Captan 50% WP, Tebuconazole 250 g/l EC) using contact application technique. Fungicides at various concentrations (Recommend Dose-RD, half of the Recommend Dose-0.5 x RD and twice the Recommend Dose-2 x RD) were mixed in Potato Dextrose Agar (PDA) media post-autoclaving. Approximately 25 ml of the mixture was poured into a Petri dish (90 mm) and allowed to cool. Mycelium disc (5 mm in diameter) was taken from 14-days-old *B. bassiana* grown on PDA using a sterile cork borer and placed in the center of each Petri dish containing fungicide + PDA. PDA plates without fungicide were used as a control. Petri dishes were incubated in the dark at 25±1 °C for 14 days. *In vitro* experiments were carried out with three replicates depending on a completely randomized plots design. In the study, the compatible fungicide with *B. bassiana* ET 10 isolate was found to be Copper Hydroxide at 0.5 x RD concentration. Azoxystrobin and Copper Hydroxide were compatible with Bb 18 isolate. Only two (Azoxystrobin + Metalaxyl-m + Fludioxonil and Tebuconazole) of the eight fungicides completely inhibited the mycelial growth of ET 10 isolate and were found harmful. Azoxystrobin + Metalaxyl-m + Fludioxonil completely inhibited the growth of Bb 18 isolate and was not found compatible. This study clearly shows that fungicides have the potential to inhibit the mycelial growth of entomopathogenic fungi under *in vitro* conditions. However, these results need to be further verified *in vitro* under both greenhouse and open-field conditions.

Keywords: Entomopathogenic fungi, *Beauveria bassiana*, Fungicides, Compatibility, Inhibition, Harmful

***Corresponding author:** Pamukkale University, Faculty of Applied Sciences, Department of Organic Farming Business Management, 20680, Civril, Denizli, Türkiye
E mail: oktaye@gmail.com (O. ERDOĞAN)
Oktay ERDOĞAN https://orcid.org/0000-0003-1466-3035
Zehra SAĞLAN https://orcid.org/0000-0001-5990-4213

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1. Introduction

Biological control preparations containing entomopathogenic fungi were used in conventional farming systems. However, pesticides are also still used in this production system. Pesticides have effects such as leaving residues, inducing pathogen resistance and harming non-target beneficial organisms. Today, the importance of biological control methods and low-residue chemicals has increased even more. Entomopathogenic fungi (EPF) have been used as a biological control agent for more than 100 years (Roberts, 1989).

Beauveria spp. are entomopathogenic fungi (EPF) that can be easily isolated and produced from almost all ecosystems (Rehner et al., 2011). More than 700 species of entomopathogenic fungi have been described in the kingdom of Fungi, belonging to at least 90 genera (Goetteal et al., 2010). Some of these defined EPFs, such as *B. bassiana*, *Metarhizium anisopliae*, *Isaria fumosorosea* (=*Paecilomyces fumosoroseus*) and *Lecanicillium lecanii*, are commercially produced and used in many countries to control against many pests (Rath, 2000). Nowadays, *B. bassiana* has 707 different hosts. These hosts are contained in 521 genera, 149 families and 15 orders (Zimmermann, 2007). EPF show antagonistic effects against pathogens in the phyllosphere and rhizosphere or plant tissues as endophytes, with their mechanisms of action of parasitism, competition, and antibiosis (Ownley et al., 2010). EPF has many advantages such as being non-toxic to mammals, does not develop resistance to pests, long-term control in nature, being effective at all stages of insect development, can be used with most insecticides, inexpensive and easy to use (Sevim et al., 2015).

In laboratory and field studies, fungicides affect natural infections with entomopathogenic fungi, reduce infection rates, and delay disease in animals (Sosa-Gomez et al., 2003). Therefore, EPF isolates selected as mycopesticides need to be tested for compatibility with chemical pesticides for their application in IPM programs (Shah et al., 2009). Studies have shown that fungicides affect radial growth and sporulation, but not germination (Li and Holdom, 1994). Kouassi et al. (2003) observed that delayed application of fungicides increases the effectiveness of *B. bassiana*. Faion (2004) reported that sulphur is not compatible with *B. bassiana* and *M. anisopliae*. In some laboratory studies, researchers have reported that fungicides do not effect on EPFs. For example, *B. bassiana*, *P. lilacinus*, *Metarhizium* spp., *M. anisopliae*, *Evlacovaea* sp. and *Tolypocladium cylindrosporum* were reported to grow better on media modified with Guanidine, Dodine, Benomyl, Thiabendazole or Copper Sulphate (Beilhartz et al., 1982; Luz et al., 2007). Some researchers have reported that Mancozeb and Copper Oxychloride are highly toxic to many EPF isolates (Rachappa et al., 2007).

This study aims to determine the effect of eight fungicides commonly used by conventional farmers in Türkiye, on the mycelial growth of native isolates of *B. bassiana* under laboratory conditions.

2. Materials and Methods

2.1. Fungal Cultures

B. bassiana ET 10 isolate was isolated from *Sphenoptera antiqua* in Erzurum province, Türkiye (Tozlu et al., 2017) and Bb 18 isolate was isolated from field soil in Düzce province, Türkiye (Erdoğan and Sağlan, 2023). EPF isolates were grown in the dark at 25±1°C for 14 days and after that subcultured on Potato Dextrose Agar (PDA-Difco) medium.

2.2. Fungicide Treatments

The commercial fungicides selected for *in vitro* studies were the most frequently used by farmers and described in Table 1. For compatibility tests, the formulations of fungicides were tested at three different doses viz., field recommended dose (RD), half of the recommended dose (0.5 × RD) and twice the recommended dose (2 × RD) (De Olivera and Neves, 2004).

2.3. Influence of Fungicides on Mycelial Growth of *Beauveria bassiana*

The inhibitory effect of commercial fungicides against *B. bassiana* isolates (ET 10 and Bb 18) was investigated according to the contact application test with Petri dishes under *in vitro* conditions. PDA was prepared and sterilized in autoclave at 121 °C for 15 minutes. Eight fungicides at different concentrations (RD, 0.5 x RD and 2 x RD) were mixed into PDA post-autoclaving, while the media was still liquid (45±5 °C), approximately 25 ml of the mixture was poured into 90 mm Petri dishes and allowed to cool and solidify. Mycelium plug (5 mm in diameter), taken from the leading growth edge of a 14-day-old culture of *B. bassiana* grown on PDA, was placed in the center of a Petri dish containing fungicide + PDA. PDA plates without fungicide were used as a control. Parafilm-sealed Petri dishes were incubated in the dark at 25±1 °C for 14 days. *In vitro* experiments were performed using three replicates in a completely randomized plots design. Inhibition rates for *B. bassiana* were calculated using the formula (Equation 1) described by Wang et al. (2012). Compatibility ratings for commercial fungicides were classified according to Hassan (1989) in evaluation categories of 1-4 scoring index (Table 2).

$$\text{Mycelial growth inhibition (\%): (C-T) x 100 / (C-6)} \qquad (1)$$

where; C is the diameter of the mycelial growth in control petri plates, 6: the diameter of pathogen disk, T: the diameter of mycelial growth in treated petri plates.

2.4. Statistical Analysis

The data were analyzed by performing the ANOVA (one-way analysis of variance). Statistically significant differences between mean values were determined using LS Means Differences Student's" multiple comparison test (LSD) ($P \leq 0.01$). All statistical analyses were performed using JMP software version 13 (SAS Institute Inc., Cary, NC, USA).

Table 1. Basic data about fungicides used *in vitro* assay

Brand name	Active ingredient	Recommended dosage g or ml/100 liter water	Manufacturer
ASTRADYN	Azoxystrobin 75 g/l+Metalaxyl-m 37.5 g/l+ Fludioxonil 12.5 g/l FS	250 ml	ASTRANOVA
Bellis®	Boscalid 25% + Pyraclostrobin 12% WG	40 g	BASF
CASNOX H2 F	Copper Hydroxide 361.1 g/l SC	250 ml	SAFA
FUNGIROL	Azoxystrobin, 250 g/l SC	75 ml	CANSA
Insure®	Triticonazole 80 g/l + Pyraclostrobin 40 g/l FS	250 ml	BASF
MALVIN	Fludioxonil 12.5 g/l + Metalaxyl 10 g/l SC	250 ml	SAFA
massCAPTAN	Captan 50% WP	250 g	ERTAR
SOLIZOL	Tebuconazole 250 g/l EC	50 ml	DOĞAL

Table 2. 1-4 Scoring index

Score index	The average reduction in growth over an untreated control	Compatibility status
1	<20 % reduction in growth	Harmless
2	20-35 % reduction in growth	Slightly harmful
3	36-50 % reduction in growth	Moderately harmful
4	>50 % reduction in growth	Harmful

3. Results

Mycelial growth of *B. bassiana* ET 10 and Bb 18 isolates was significantly different between fungicides (P≤0.01). All the fungicides inhibited the mycelial development of *B. bassiana* isolates (ET 10 and Bb 18) in PDA medium either partially or completely at all three concentrations (Table 3 and 4). All the concentrations of Azoxystrobin + Metalaxyl-m + Fludioxonil and Tebuconazole completely inhibited mycelial growth of *B. bassiana* ET 10 isolate and showed 100% effect. At 0.5 x RD concentration, the best mycelial growth (22.40 mm) and the lowest percentage of inhibition (26.80%) were detected in Copper Hydroxide compared to the control. Mycelial growth of other fungicides was determined between 3.25 mm-12.23 mm and % inhibition rate between 60.13%-89.38%. The best mycelial development (15.13 mm, 14.97 mm) and the lowest effect (50.65%, 50.98%) were also observed with Copper Hydroxide at RD and 2 x RD concentrations, respectively. Other fungicides showed inhibition of 60% or higher at RD and 2 x RD concentrations. At 0.5 x RD concentration, only Copper Hydroxide showed slightly harmful (2 on the scale), while other fungicides were found to be harmful (4 on the scale). The RD and 2 x RD concentrations of Azoxystrobin + Metalaxyl-m + Fludioxonil completely suppressed mycelial growth of *B. bassiana* Bb 18 isolate and showed 100% inhibition. The best mycelial growth (30.57 mm, 30.00 mm) and the lowest effect (21.74%, 23.27%) were determined with Azoxystrobin at 0.5 x RD and RD concentrations, respectively. At 0.5 x RD concentration, Captan moderately inhibited *B. bassiana* Bb 18 isolate (53.96%), while at RD concentration, Copper Hydroxide (56.52%) and Captan (58.06%) also exhibited moderate inhibition. The best mycelial development (21.00 mm) and the lowest percentage of inhibition (46.29%) were observed in Copper Hydroxide at 2 x RD concentration. Boscalid (47.31%) and Azoxystrobin (53.71%) moderately inhibited Bb 18 isolate. At 0.5 x RD concentration, only Azoxystrobin was found to be slightly harmful, while other fungicides were found to be harmful. ET 10 isolate was found to be susceptible to all fungicides except Copper Hydroxide at all three concentrations. Bb 18 isolate was found to be susceptible to all fungicides except Azoxystrobin at 0.5 x RD and RD concentrations, and Copper Hydroxide at 2 x RD concentration (Table 3 and 4).

Table 3. Effect of different fungicides on mycelial growth of *B. bassiana* (I)

Active ingredient	*Beauveria bassiana* ET 10 isolate						
	0.5 x RD		RD		2 x RD		Scoring at 0.5 x RD
	MG[1]	PI	MG[1]	PI	MG[1]	PI	
Azoxystrobin 75 g/l+Metalaxyl-m 3.5g/l+ Fludioxonil 12.5 g/l FS	0.00[e*]	100.00	0.00[e*]	100.0	0.00[e*]	100.00	4
Boscalid 25%+ Pyraclostrobin 12% WG	3.25[d]	89.38	4.47[de]	85.29	4.73[de]	84.64	4
Copper Hydroxide 361.1 g/l SC	22.40[b]	26.80	15.13[b]	50.65	14.97[b]	50.98	2
Azoxystrobin, 250 g/l SC	11.58[c]	62.09	11.63[bc]	62.09	9.47[bcd]	76.80	4
Triticonazole 80g/l + Pyraclostrobin 40 g/l FS	4.40[d]	85.62	6.57[cd]	78.43	5.23[de]	83.01	4
Fludioxonil 12.5 g/l + Metalaxyl 10 g/l SC	10.07[c]	66.99	7.13[cd]	76.80	9.20[cd]	69.93	4
Captan 50% WP	12.23[c]	60.13	12.40[bc]	59.48	12.83[bc]	58.17	4
Tebuconazole 250 g/l EC	0.00[e]	100.00	0.00[e]	100.00	0.00[e]	100.00	4
Control	30.57[a]	0.00	30.57[a]	0.00	30.57[a]	0.00	-
$CV_{(0.01)}$	3.2	-	3.8	-	3.4	-	
LSD	5.66	-	5.71	-	6.50	-	

[1]Data are means of three replicates; *Means followed by different letters within a column are significantly different according to LSD test (P≤0.01); MG= Mycelial growth (mm); PI= Per cent inhibition; RD= Recommended dosage; 1= Harmless (<20% inhibition); 2= Slightly harmful (20-35% inhibition); 3= Moderately harmful (36-50% inhibition); 4= Harmful (>50% inhibition).

Table 4. Effect of different fungicides on mycelial growth of *B. bassiana* (II)

Active ingredient	*Beauveria bassiana* ET 10 isolate						
	0.5 x RD		RD		2 x RD		Scoring at 0.5 x RD
	MG[1]	PI	MG[1]	PI	MG[1]	PI	
Azoxystrobin 75 g/l+Metalaxyl-m 37.5g/l+ Fludioxonil 12.5 g/l FS	2.90[g*]	92.58	0.00[e*]	100.00	0.00[e*]	100.00	4
Boscalid 25%+ Pyraclostrobin 12% WG	6.57[efg]	83.12	15.57[c]	60.10	20.57[bc]	47.31	4
Copper Hydroxide 361.1 g/l SC	15.30[cd]	60.87	17.00[c]	56.52	21.00[b]	46.29	4
Azoxystrobin, 250 g/l SC	30.57[b]	21.74	30.00[b]	23.27	18.13[bc]	53.71	2
Triticonazole 80g/l + Pyraclostrobin 40 g/l FS	10.03[ef]	74.35	9.90[d]	74.68	8.13[e]	79.28	4
Fludioxonil 12.5 g/l + Metalaxyl 10 g/l SC	10.80[de]	72.38	7.73[de]	80.31	10.00[de]	74.42	4
Captan 50% WP	17.97[c]	53.96	16.40[c]	58.06	14.57[cd]	62.66	4
Tebuconazole 250 g/l EC	5.63[fg]	85.68	4.50[e]	88.49	5.07[ef]	86.96	4
Control	39.17[a]	0.00	39.17[a]	0.00	39.17[a]	0.00	-
$CV_{(0.01)}$	1.9	-	1.3		2.4	-	
LSD	5.02	-	3.62		6.28	-	

[1]Data are means of three replicates; *Means followed by different letters within a column are significantly different according to LSD test (P≤0.01); MG= Mycelial growth (mm); PI= Per cent inhibition; RD= Recommended dosage; 1= Harmless (<20% inhibition); 2= Slightly harmful (20-35% inhibition); 3= Moderately harmful (36-50% inhibition); 4= Harmful (>50% inhibition).

4. Discussion

This study clearly showed that fungicides have variable effects on the mycelial growth of *B. bassiana* isolates. Indeed, Shah et al. (2009) and Martins et al. (2012) reported decreased fungal growth when the concentration of the active ingredient of a fungicide increased. The enhanced effects of *B. bassiana* on the processes of radial growth and sporulation vary depending on the fungal isolates and the nature and concentrations of the fungicide (Olmert and Kenneth, 1974). In the study, out of the total eight tested fungicides, only Azoxystrobin + Metalaxyl-m + Fludioxonil and Tebuconazole completely inhibited the mycelial growth of *B. bassiana* ET 10 isolate at all three concentrations. Again, Azoxystrobin + Metalaxyl-m + Fludioxonil completely inhibited the mycelial growth of *B. bassiana* Bb 18 isolate at RD and 2 x RD concentrations and showed a negative effect. Copper Hydroxide against *B. bassiana* ET 10 isolate, Azoxystrobin and Copper Hydroxide against Bb 18 isolate was determined as a slightly harmful fungicide (Table 3 and 4). Similar to our findings, Loureiro et al. (2002) reported that fungicides viz. Thiophanate Methyl, Captan, Tebuconazole, Metalaxyl and Mancozeb inhibited the mycelial growth and sporulation of *B. bassiana*. In triazole fungicides (Tebuconazole), ergosterol biosynthesis is inhibited and consequently fungal cell membrane formation is prevented (Bartlett et al., 2002). Kouassi et al. (2003) found that Copper Oxide, Metalaxyl, and Mancozeb, at the recommended doses, inhibited the radial growth of *B. bassiana* (MK2001 isolate) on solid medium after 8 days of application. Er and Gökçe (2004) showed that Captan and Iprodione suppressed the conidial germination of *Isaria fumosorosea* and also inhibited mycelial development. Gatarayiha et al. (2010) reported that Azoxystrobin showed very little effect on the mycelial growth of *B. bassiana* at a concentration of 10^{-2}. Azoxystrobin was most compatible with *B. bassiana*, while Flutriafol was the most harmful fungicide. Shah et al. (2009) determined that Azoxystrobin inhibited the spore germination of *M. anisopliae* and *Lecanicillium longisporum*, and only Captan exhibited fungistatic effects on *I. fumosorosea.* The tolerance of *B. bassiana* to Cu-based fungicides was investigated and at the recommended application rate, Cu hydroxide did not significantly inhibit mycelial growth (Martins et al., 2012). Khan et al. (2012) found that among the 12 fungicides tested, Chlorothalonil (0.1%), Thiram (0.2%), and Metalaxyl (0.1%) exhibited the lowest spore germination and vegetative growth in both *B. bassiana* and *M. anisopliae.* Fiedler and Sosnowska (2017) reported that Chlorothalonil, Azoxystrobin, and Thiophanate-methyl fungicides inhibited the sporulation and mycelial growth of *B. bassiana*. Reddy et al. (2018) found that Tebuconazole was highly toxic and completely inhibited the mycelial growth of all tested entomopathogenic fungi (*B. bassiana*, *M. anisopliae*, and *L. lecanii*) at concentrations of 1000 and 10,000 ppm. Furthermore, even at a concentration of 100 ppm, Tebuconazole completely inhibited the growth of *L. lecanii*. Celar and Kos (2020) found that only in two cases, Copper Oxide at 15°C and Copper Hydroxide at 25°C, at the lowest concentration of 6.5%, did not significantly inhibit the mycelial growth of *B. bassiana*.

5. Conclusion

As indicated by the results of the study, Azoxystrobin + Metalaxyl-m + Fludioxonil and Tebuconazole fungicides completely inhibited the mycelial growth of *B. bassiana* ET 10 isolate at all three concentrations and were found to be incompatible. Azoxystrobin + Metalaxyl-m + Fludioxonil fungicides completely inhibited the mycelial growth of Bb 18 isolate and were found to be incompatible. The current study demonstrates the potential risks posed by fungicides on the entomopathogenic fungus *B. bassiana*. Only Copper Hydroxide was found to be compatible with *B. bassiana* ET 10 isolate, while Azoxystrobin and Copper Hydroxide were found to be compatible with Bb 18 isolate. These fungicides were determined to be slightly harmful. However, additional field and/or greenhouse studies are being done to confirm the compatibility of Copper Hydroxide and Azoxystrobin fungicides and *B. bassiana* within an Integrated Pest Management strategy.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	O.E.	Z.S.
C	50	50
D	50	50
S	100	
DCP	50	50
DAI	100	
L	50	50
W	100	
CR	50	50
SR	100	

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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COMPARATIVE ANALYSIS OF CNN, LSTM AND RANDOM FOREST FOR MULTIVARIATE AGRICULTURAL PRICE FORECASTING

Cevher ÖZDEN[1]*

[1]Mugla Sitki Kocman University, Faculty of Bodrum Fine Arts, Department of Digital Game Design, 48420, Mugla, Türkiye

Abstract: Time series forecasting is an important research topic among agriculture economics. Especially, multivariate, multi-step and multiple output prediction tasks pose a challenge in research as their nature requires the investigation of intra- and inter-series correlation. The common statistical methods like ARIMA and SARIMA fall short in this kind of tasks. Deep learning architectures like Convolutional Neural Networks and Long Short-Term Memory networks are quite good at modelling the structures of complex data relations. In this study, a new dataset is composed through manual collection of data from the Ministry of Commerce of Turkish Republic. The dataset contains daily trade volumes and prices of potato, onion and garlic, which are most commonly consumed products in Turkish cuisine. The data pertains to the period between January 1, 2018 and November 26, 2022 (1791 days). A simple CNN and LSTM architectures as well Random Forest machine learning method are used to predict the next 10-day prices of the products. Accordingly, three models provided acceptable results in the prediction tasks, while CNN yielded by far the best result (MAE: 0.047, RMSE: 0.070).

Keywords: Time series, CNN, LSTM, Price prediction, Agriculture

***Corresponding author:** Mugla Sitki Kocman University, Faculty of Bodrum Fine Arts, Department of Digital Game Design, 48420, Bodrum, Mugla, Turkiye
E mail: efeozden@gmail.com (C. ÖZDEN)
Cevher ÖZDEN https://orcid.org/0000-0002-8445-4629

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1. Introduction

Natural conditions have a significant impact on agricultural production because of its inherent qualities. Farmers must deal with risks and uncertainties in the production process as a natural result of this circumstance (Skendžić et al., 2021). Production is specifically significantly impacted by unfavorable meteorological events, illnesses, pests, and price uncertainty (Pham et al., 2021). Farmers, producers, and other agricultural industry players' decision-making processes are impacted by price uncertainties in agricultural output. These uncertainties are linked to the erratic and unpredictable nature of agricultural commodity price movements (Molitor et al., 2017). Weather conditions, political and economic variables, diseases and pests, global marketplaces, and the market's supply-demand dynamics are all elements that affect price uncertainty in agriculture (Mili and Bouhaddane, 2021).

The predictability of the future price change of these products is very important for the producers and consumers, as well as for the intermediaries, exporting and importing countries, because the prices of agricultural products can affect the general economic situation not only in the national but also in the international market (Duarte et al., 2021). Prices fluctuate abruptly as a result of shifts in supply and demand for agricultural goods, which has a direct impact on people's daily life. Accurately predicting the future price of a commodity aids farmers and consumers in being aware of the risks posed by price variations, taking into account how changes in the pricing of agricultural products also impact supply and demand. (Zou et al., 2022).

Time series analysis is a statistical technique that is used to look at how data changes over time and forecast future values. Data that is measured and organized in time series at regular intervals (Nielsen, 2020). Future value forecasting, trend identification, seasonal variation understanding, cycle identification, and other patterns of change across time are all accomplished through time series analysis (Jebb et al., 2015). These days, a variety of fields employ this technique to generate future forecasts. This technique, for instance, is used to forecast market prices (Dingli and Fournier, 2017; Yadav et al., 2020), to estimate air quality (Freeman et al., 2018; Espinoza et al., 2021), and to forecast the number of deaths during the Covid-19 outbreak (Kırbaş et al., 2020; Shastri et al. 2020).

Making critical judgments is made easier when the course of events or metrics can be properly predicted. by this vantage point, all parties involved in this industry can profit by being able to forecast the prices of agricultural products. Using historical datasets to make predictions is challenging because it necessitates modeling both intra-series temporal models and inter-series correlations jointly. Analyzing multivariate time series with several steps and outputs can be challenging. The ability to capture inter-series correlations and provide various outputs is one of the limitations of conventional statistical analysis techniques like ARIMA and SARIMAX. The development of deep learning algorithms has allowed for the use of fresh viewpoints in the solution of this issue. The most extensively studied neural network models in this regard include LSTM and CNN. The architectural layouts of the LSTM model allow it to accurately forecast sequence pattern information. The final prediction model will benefit more from the ability of the CNN model to filter out noise in the input data and extract more valuable features (Casado-Vara et al., 2021). In contrast to standard CNNs, which are well suited to handle spatial autocorrelation data but are typically not adapted to correctly manage complex and long temporal dependencies, LSTM networks are designed to handle temporal correlations but only use the features that are present in the training set (Bengio et al., 2013).

In this study, future price predictions of 3 basic foodstuffs such as potatoes, onions and garlic were compared using deep learning methods. Potatoes, onions and garlic are important products for staple food consumption in Türkiye. These products play an important role in the nutrition of the people as basic foodstuffs. They contain high amounts of vitamins, minerals and other nutrients and provide the components necessary for a balanced diet. Therefore, the production of potatoes, onions and garlic is of great importance in terms of maintaining domestic food production and ensuring food security. They are mostly used together in preparing daily meals in traditional Turkish cuisine and constitute the main ingredients of daily nutrition of large part of Turkish people. Therefore, any price change in these products has direct effects on family budget in Türkiye. Also, their trade volumes and prices are interconnected and effective on each other. In this study, we have curated daily trade volumes and prices of potato, onion and garlic from the official market website of Turkish Ministry of Commerce (www.hal.gov.tr). The resulting dataset requires multivariate input, multi-step and multiple output time series analysis. For this purpose, LSTM, CNN and RandomForest methods are applied to forecast future prices of the products. The main contribution of the study is that a new dataset is made publicly available for scientists who would like to experiment on agricultural product price analysis. Another important contribution is that policy makers and traders can use the results while taking their decisions in trade.

Agricultural commodity futures price forecasting is a crucial topic in the agricultural sector since it helps to reduce market uncertainty and risks by not only giving decision-makers with accurate price information for agricultural commodities in advance (Bayona-Oré,2021). In this context, it is noteworthy that various studies have been carried out by using time series and deep learning algorithms in price predictions of agricultural products.

Madaan et al. (2019) forecasted the price of potato and onion goods in India using the ARIMA, SARIMA, and LSTM models. The research's findings showed that the LSTM model performed better than the ARIMA and SARIMA models. A model was developed to predict mandi prices over a 30-day period, and it provided an average RMSE value of 754.6 (or 25.15 for a single day) over those periods. With a mean normalized deviation of 0.041, the performance was acceptable. This approach might assist farmers in determining whether to offer price forecast data, hold onto their produce for a few weeks, or sell it right away.

In order to forecast the price of squash in Sri Lanka, Navaratnalingam et al. (2020) used a deep learning system called the LSTM and ARIMA model. The research's findings showed that the multivariate CNN LSTM model outperformed other models, offering an average RMSE of 19.46 Sri Lankan rupees per kilogram with an average RMSPE of 14.9%. The analysis also revealed that there is a connection between price variation and typical days of the week.

Dharavath and Khosla (2019) used ARIMA and SARIMA models to predict the price of fruits such as Mango and Pineapple. Although the researchers tested various models on the data they obtained, they could not obtain 100% accurate results. As the most important factor in this, they emphasized the necessity of providing regular data for time series analysis.

2. Materials and Methods

In this study, daily trade volumes and prices of onion, potato and garlic are collected from the official site of Marketplace Registration System, which is affiliated to the Ministry of Commerce of Türkiye. The resulting data pertains to the period between January 1, 2018 and November 26, 2022 (1.791 days). The curated dataset, analysis results and codes are made publicly available in a Github repository (https://github.com/cevher/Potato-Onion-Garlic-Time-Series).

A quite basic CNN architecture is applied to forecast multi target price outputs in the study. The model contains Conv1D (kernel size=2), MaxPooling1D (pool_size=2), Conv1D (kernel_size=3), MaxPooling1D, Flatten, Dense (activation=ReLU), Dense (output layer) with adam optimizer and 'mse' loss function. The network is trained for 200 epochs. A quite simple architecture is chosen for LSTM network, which contains LSTM and Dense layers with adam optimizer and 'mse' loss function. This network is trained for 200 epochs, as well.

3. Results

The data consists of daily trade volumes of prices of potato, onion and garlic which are the main ingredients of Turkish cuisine. The data pertains to the period between January 2st 2018 and November 6th 2022 and contains no missing value. Prior to analysis, min-max scaler is used to standardize the values in order to overcome any bias among data. Outline data are cleaned and first difference is taken to establish non-stationarity. The pre- and post-states of the dataset are given in Figure 1.

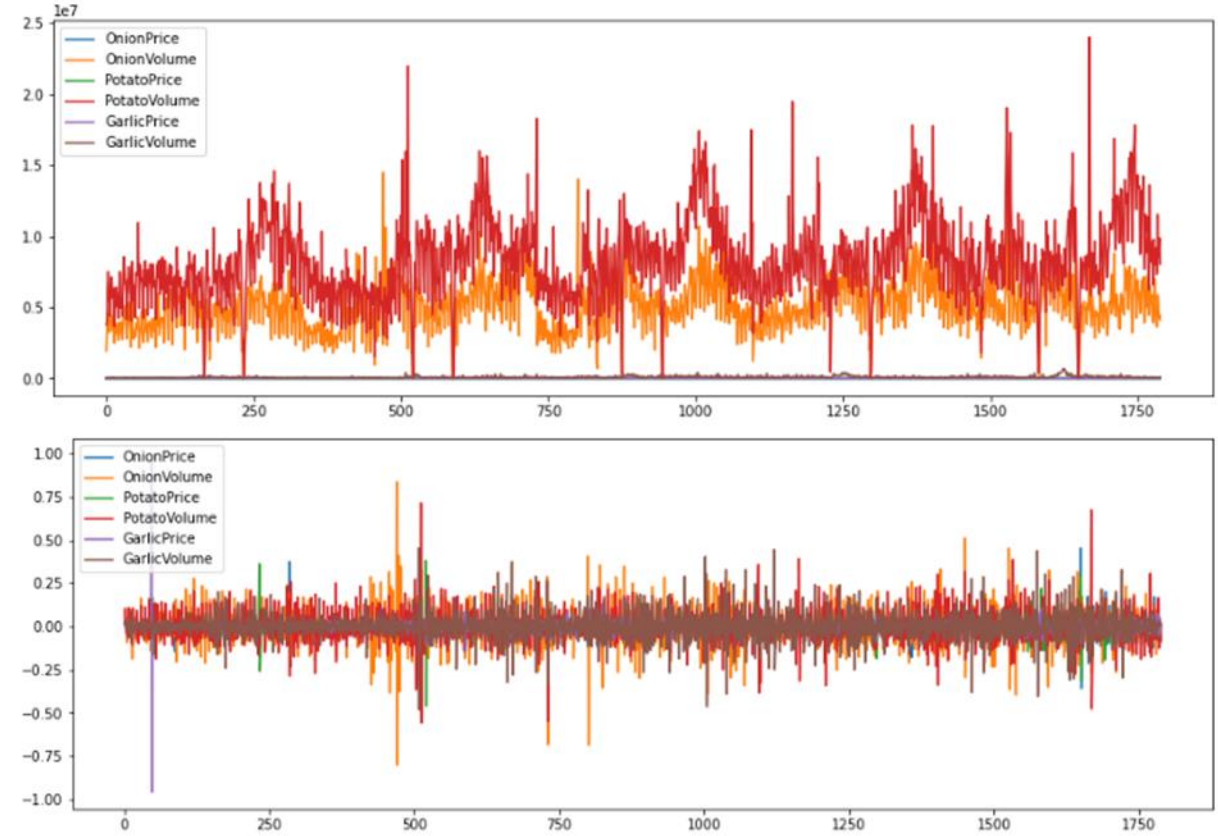

Figure 1. Pre- and post-state of data following the preprocessing.

Data is split into train (90%) and test sets (10%). Subsequently, 6 columns of 28 days containing price and trade volume of three products are considered for input and 3 price columns of three products are forecasted for the next 10 days. Models are run in a computer with the following specifications (Intel(R) Core(TM) i7-7500U CPU, 2.70GHz). Model results are evaluated through Mean Absolute Error (MAE) and Root Mean Square Error (RMSA), which are common methods used in time series analysis. The performance is considered better with lower metric scores. The metric scores of the evaluated models are given in Table 1. Accordingly, all three models provided quite good results in predicting prices for the next 10 days, while CNN clearly obtained by far the best results in both metrics.

Table 1. Forecasting results for 5 days and 10 days

	10 days forecast	
	MAE	RMSE
Random Forest	3.953	6.0797
CNN	0.047	0.070
LSTM	3.837	5.929

4. Discussion

The results indicate that CNN models detected the inter- and intra-series correlations among data points. Similar results have been reported by the previous researches on wheat yield prediction, oil production prediction and nonlinear time history prediction of seismic responses. The results of the current study support the previous findings. Wang et al. (2018) compared the performance of CNN models with traditional time series models for agricultural price forecasting. The results demonstrated that CNNs can effectively capture spatial dependencies in multivariate time series data and outperform traditional models like ARIMA and SVM. Wibawa et al. (2022) discussed the successful application of CNNs in various time series forecasting tasks, including agricultural price prediction. The research highlighted the ability of CNNs to automatically learn relevant features and patterns from multivariate time series data, leading to improved forecasting accuracy. Torres et al. (2020) provided an overview of deep learning techniques for time series forecasting, with LSTM being one of the prominent methods. The study showcased the effectiveness of LSTM models in capturing long-term dependencies and demonstrated their superior performance compared to traditional time series models in various domains, including agriculture. Klompenburg et al. (2020) discussed the application of various machine learning algorithms, including Random Forests, for crop yield prediction. Although not solely focused on price forecasting, the review indicated that Random Forest models could be adapted to predict agricultural prices based on relevant features.

5. Conclusion

This study makes a comparative investigation into the applicability of three different AI methods (CNN, LSTM and Random Forest) on multivariate, multi-step and multiple output prediction task. The dataset contains daily price and trade volumes of three most commonly used agricultural products (onion, potato, garlic) in Türkiye. These products are the main ingredients of Turkish dietary and their prices have direct effects on food expenditures of a large segment of population. The models have been tested on 10 days' price forecast tasks for three products at the same run, and their results are compared with each other. Accordingly, all three models yielded good results in prediction tasks; however, CNN model clearly outperformed other models. CNN, RandomForest and LSTM models have been commonly used for prediction tasks in literature. Many of the studies employed deep architectures of the models consisting of large number of layers. In the current study, a quite basic form of models are considered. Despite their low number of layers, all models are concluded to be good alternatives for prediction tasks in agriculture. Further studies can be carried out using combination of CNN, LSTM, GRU networks with more layers.

Author Contributions

The percentage of the author contributions is present below. The author reviewed and approved final version of the manuscript.

	C.Ö.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100
PM	100
FA	100

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The author declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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METEOROLOGICAL AND HYDROLOGICAL DROUGHT ANALYSIS OF THE KIZILIRMAK BASIN

Derya SELCUK OZTURK[1], Aslı UKE KESKİN[1], Utku ZEYBEKOGLU[2]*

[1]*Ondokuz Mayıs University, Faculty of Engineering, Department of Civil Engineering, 55139, Samsun, Türkiye*
[2]*Sinop University, Boyabat Vocational School of Higher Education, Department of Construction, 57200, Sinop, Türkiye*

Abstract: Global climate variation revealing its effects intensely after the Industrial Revolution, have increased extremely with the rise in the number and variation of flood and drought problems worldwide within the years from1990 to 2000. Our country is strongly suffering from this climate variation and its undesired consequences increasing every year. Extreme temperature values, serious flood, and drought problems occuring in some regions have begun to produce considerable damages on daily human life. As a result of the decrease in the discharge of streams, the lack of freshwater resources have become a serious problem which have been considered to be solved with the derivation of fresh water resources for natural life and for other human purposes. Drought conditions of the basin were analyzed using hydrological and meteorological data of Kızılırmak Basin. Standardized precipitation index (SPI) expressing meteorological drought with rainfall parameter and streamflow drought index (SDI) expressing hydrological drought with current parameter were calculated. Droughts were observed in the basin and it was understood that these two indices give harmonious results.

Keywords: Kızılırmak basin, Drought, SPI, SDI, Climate change

***Corresponding author:** Sinop University, Boyabat Vocational School of Higher Education, Department of Construction, 57200, Sinop, Türkiye
E mail: utkuz@sinop.edu.tr (D. SELCUK OZTURK)
Derya SELCUK OZTURK https://orcid.org/0009-0009-7736-8886
Aslı UKE KESKİN https://orcid.org/0000-0002-9676-8377
Utku ZEYBEKOGLU https://orcid.org/0000-0001-5307-8563
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1. Introduction

As a result of the increase in the world population, urbanization, climate changes, deforestation, and desertification, drought reaches dimensions that threaten society, the environment and countries. Droughts have economic and social dimensions. It is closely related to the economy, health, psychology and trade of the society. Although drought is increasing its impact in the world, its scope has not yet been fully understood and its effects have not been adequately evaluated. As a natural consequence of this, a precise definition of drought cannot be made. The definitions made are in terms of meteorological, hydrological, agricultural, geographical or industrial, energy production, water supply, maritime and recreation areas according to occupations. (Şen, 2001). Drought in the International Convention to Combat Desertification; It is defined as a natural event that adversely affects land and resource production systems and causes serious hydrological imbalances as a result of precipitation falling significantly below the recorded normal levels (WMO, 1997).

Climate change on a global scale shows its effects locally in the form of different disasters such as floods, floods, droughts, and storms. It is known that there has been an increase in the number of natural disasters with the effect of global climate change, which has been the subject of many articles in recent years. The increase in natural disasters can also pave the way for technological disasters. At this point, it was stated that community education and resilience are important. It is seen that the increasing effect of the disasters affects the society economically and socially. In this context, regardless of the cause and type of the disaster, it is clear that it should be managed holistically, as in the modern disaster management approach (Çelik et al., 2020; Gunduz, 2022; Usta, 2023).

Priority regions affected by climate change in Türkiye, according to IPCC reports; Mediterranean, Aegean, Eastern and Central Anatolia regions. However, flood disasters in the Central Black Sea region in recent years are the biggest indicator of climate change in this region. The drought in the summer months has reached extraordinary situations such as the inability to provide water from drinking water networks in the city centers. Drought; It is a disaster that occurs less frequently than other natural disasters such as earthquakes and floods, develops slowly unlike other natural disasters, covers larger areas and threatens the lives of more living things. According to the generally accepted principles in precipitation-related climate classifications, places with an average annual precipitation of less than 250 mm are defined as arid climates, and places between 250 and 500 mm are defined as semi-arid climates. (Kömüşçü and Erkan, 2000). Knowing the number of rainy days in terms of precipitation characteristics is important in terms of drought possibilities. In most of Türkiye, the number of rainy days is low and varies between 60 and 175 days on average according to the regions. The highest values are on the strip extending along the Black Sea coast in the north of the country, and the number of rainy days in this belt reaches up to 138 and 141 in places. On the other hand, since the precipitation in the Mediterranean Region belongs to a certain period of the year, the sum of the precipitation amount and the number of rainy days is not high. In Türkiye, a significant part of Central and Eastern Anatolia falls into the semi-arid area. The number of rainy days falls below 100 in the Central Anatolia and Eastern Anatolia Regions, which constitute the semi-arid regions of Türkiye. There are no areas in Türkiye that can be considered seriously arid due to precipitation alone. However, Salt Lake and its surroundings in Central Anatolia show characteristics close to the border of being an arid region with annual precipitation of close to 300 mm (Kömüşçü et al., 2003). When the drought trends are evaluated for Türkiye, the sudden decrease in precipitation in the Sahel and the Subtropical belt that started in the 1960s began to be effective in the Eastern Mediterranean Basin and Türkiye with the 1970s. Significant decreasing trends in precipitation and drought events were more evident in the winter season. Aegean, Mediterranean, Marmara and Southeastern Anatolia Regions were affected the most by the dry conditions between the early 1970s and the early 1990s (Turkes, 1996). The most severe and widespread drought events in Türkiye; It happened in the 1971-1974 period and in 1983, 1984, 1989, 1990, 1996 and 2001. It has been observed that these drought events and water shortages, which are effective in many regions of Türkiye, have reached a critical point not only in terms of agriculture and energy, but also in terms of water resources management including irrigation, drinking water, other hydrology systems and activities. The last drought events that occurred in the period of December 2006 – August 2007 were especially effective in the Marmara, Aegean and Central Anatolian regions of Türkiye, as well as in the Western Mediterranean and Western-Central Black Sea regions (Turkes, 1996, 2007, 2017; Komuscu, 2001; Kapluhan, 2013; Akturk and Yildiz, 2018). One of the first studies on drought in Türkiye was carried out by Tanoğlu (1943) in 1943. A drought map was created by applying De Martonne's drought index to temperature and precipitation values. Erinç (1949 and 1950), using the monthly precipitation, temperature and evaporation values, the drought degree of Türkiye and arid areas were determined by Thornthwaite method. Central Anatolia Region and Iğdır Basin are described as semi-arid climate zone. Tumertekin (1956) examined the number of dry months in Türkiye with the indices he calculated according to the De Martonne and Thornwaite formulas. In another study (Tumertekin, 1957), he created a map showing the distribution of drought by using the De Martonne index. Çelenk (1973) used Erinç and Crowe's formulas and De Martonne and Thornthwaite formulas to determine drought in order to compare. Sırdaş and Şen (2003) obtained the drought amplitude, duration and severity values for different cut-off levels by using the SPI method. Operational drought monitoring for Türkiye, minimum and maximum drought magnitudes, maps were created to describe the extent of areal drought. Pamuk et al. (2004) stated that the climate of the Aegean Region has two extreme groups, between these two groups formed by Uşak, Afyon, Kütahya and Gediz, the Coastal Aegean belt is drier during the precipitation period, and the Inner West Anatolian Region is more humid; In the summer period, they reached the conclusion that the Inner West Anatolian Section is drier and the Coastal Aegean is more humid.

Drought analysis in the Kızılırmak Basin, which is the subject of this study, has also come to the fore in studies in the literature (Bacanli et al., 2011; Yildiz 2014; Oguzturk et al., 2015; Arslan et al., 2016; Beden et al., 2020; Çıtakoglu and Minarecioglu, 2021; Akturk et al., 2022). The Kızılırmak Basin was chosen as the study area in order to examine an important problem of the region and to serve the region. This study is a preliminary study that should be done in the basin regarding the drought that has started to make itself felt as a result of global climate change in recent years. Considering both precipitation and flow parameters, the necessity of considering drought not only as a lack of precipitation is discussed. In this context, it is aimed that this study will fill an important gap and contribute to the region. In terms of sustainable integrated watershed management, the future water potentials of the basin will be revealed in a more realistic way with drought analysis under the influence of climate change. Standard Precipitation İndex (SPI) and Streamflow Drought İndex (SDI) methods were used in the drought analysis of the basin.

2. Materials and Methods

2.1. Study Area

The Kızılırmak River is the longest river that originates in Türkiye and empties into the sea from Türkiye. Its length is 1355 km. Its main tributaries are Delice River, Devrez and Gökırmak. Kızılırmak, named after the color of its water and known as Halys, which means salty river in ancient times, has hosted civilizations established in Anatolia. The river originates from the southern slopes of Sivas Kızıldağ in the easternmost part of Central Anatolia, flows first to the west and southwest, and then forms an arc. It flows to the west, then to the northwest, passing the Salt Lake in the northeast. It then heads north and north east. Delice River joins and flows to the northwest by drawing zigzags. It flows with the Devrez River and turns to the Northeast. While passing through the provinces of Sivas, Kayseri, Nevşehir, Kırşehir, Kırıkkale, Ankara, Aksaray, Çankırı, Çorum and Samsun respectively, it collects the waters of many streams and streams and pours into the Black Sea from Bafra. There are eight dams on the river. These are the Yamula Dam, which was established in Sarıoğlan, Yemliha town in Kayseri, Kesikköprü, Hirfanlı and Kapulukaya dams near Ankara, and Altınkaya and Derbent dams near Bafra. The Obruk Dam was built on the river and it started to hold water in 2007. The country's surface is divided into 25 drainage basins in order to identify, develop and use water resources, which are one of the most important and non-renewable natural resources of Türkiye (Erkek and Ağıralioğlu, 1998). The map showing the basins and geographical locations is given in Figure 1.

Figure 1. Turkish hydrological basins (T.C. Orman ve Su İşleri Bakanlığı, 2015).

The Kızılırmak Basin is located in the eastern part of Central Anatolia and the Black Sea. The Kızılırmak Basin, with a total area of 78180 km^2, is the second largest basin in Türkiye. 15043 km^2 of Kızılırmak Basin is forest area. The basin accounts for 3.48% of Türkiye's average annual flow, with an average flow volume of 6.48 km^3/year. The climate in the Kızılırmak Basin, which draws a wide arc in Central Anatolia, varies greatly. Most of the springs between Kastamonu and Sivas are semi-arid; North of Kastamonu, east of Sivas and Yozgat section have arid-less humid climate. The whole basin is first degree mesothermal and is located in the zone of temperate climates closest to cold climates. Summers in the basin are dry. More than half of the precipitation falls in the winter and spring months. Precipitation distribution varies according to proximity to the sea and landform characteristics. The middle part of the basin, far from the sea, is the driest part of the basin. This place receives precipitation between 300-400 mm. The Bafra plain and the ridges and peaks of the mountains here receive 1000 mm of precipitation. On the slopes of the mountains facing Central Anatolia, precipitation falls to 500 mm. Except for the coastal part, summers are hot and winters are cold in the basin. From Bafra to the south, the temperature decreases as the altitude increases. Yozgat, Sivas and the east of the basin are the coldest parts. The average temperature here is below 10 degrees. Except for the cold eastern part and the warm northern coastline, the average annual temperature in the centers is between 10-12°C (Uçgun, 2010).

Within the scope of this study, precipitation stations located on the Kızılırmak Basin, which is a very important water resource for Türkiye, will be used. These stations are; Tomarza, Gemerek, Sivas, Cicekdagi, Keskin, Kirikkale, Bala, Kulu, Urgup, Corum, Osmancik, Tosya, Kastamonu, Ilgaz, Bafra and Sarkisla. The characteristics of precipitation observation stations are given in Table 1, and the basic statistical values of precipitation records are given in Table 2.

The flow observation stations to be studied are Yamula, Söğütlühan and Bulakbaşı in the Kızılırmak basin. The characteristics of the flow observation stations are given in Table 3, and the basic statistical values of the flow records are given in Table 4.

While determining the stations used in the study, attention was paid to the absence of any water intake structures in the measurement area and upstream. Thus, the estimated data obtained were reached in a near-accurate manner. Since Yamula dam started to hold water in 2004, flow records of Yamula for 2004 and later years were not included in the study. The locations of precipitation and flow observation stations on the basin are shown in Figure 2.

Table 1. Geographical features of precipitation observation stations.

State	Station	Period	Longitude-Latitude	Altitude(m)
Kayseri	Tomarza	1975–2010	38°45'22'' N/35°79'12'' E	1402
	Gemerek	1975 - 2014	39°18'50'' N/36°08'05'' E	1182
Sivas	Sivas	1975–2014	39°74'37'' N/37°00'20'' E	1294
	Şarkışla	1975–2009	39°33'31'' N/36°44'08'' E	1253
Kırşehir	Çiçekdağı	1975–2010	39°60'67'' N/34°42'35'' E	900
Kırıkkale	Keskin	1977–2012	39°66'82'' N/33°61'18'' E	1140
	Kırıkkale	1975–2014	39°84'33'' N/33°51'81'' E	751
Ankara	Bala	1975–2013	39°55'46'' N/33°10'89'' E	1250
Konya	Kulu	1975–2012	39°07'88'' N/33°06'57'' E	1005
Nevşehir	Ürgüp	1979–2012	38°62'18'' N/34°91'44'' E	1068
Çorum	Çorum	1975–2014	40°54'61'' N/34°93'62'' E	776
	Osmancık	1976–2012	40°97'87'' N/34°80'11'' E	419
Kastamonu	Tosya	1975–2011	41°01'32'' N/34°03'67'' E	870
	Kastamonu	1975–2013	41°37'10'' N/33°77'56'' E	800
Çankırı	Ilgaz	1975–2012	40°91'56'' N/33°62'58'' E	885
Samsun	Bafra	1975–2012	41°55'15'' N/35°92'47'' E	103

Table 2. Basic statistical information of precipitation observation stations records.

Station	Mean	Std. Dev.	Skewness	Max.	Min.
Tomarza	397.56	26.13	0.77	129.4	0
Gemerek	420.85	28.28	1.04	159.9	0
Sivas	457.84	29.24	0.80	139.2	0
Şarkışla	319.19	22.94	1.21	135.1	0
Çiçekdağı	357.19	24.34	1.23	171.1	0
Keskin	445.14	29.49	0.91	145.9	0
Kırıkkale	390.66	26.68	0.91	138.2	0
Bala	312.43	26.95	1.27	158.7	0
Nulu	450.33	38.56	2.58	312.1	0
Ürgüp	373.88	25.65	0.89	138.3	0
Çorum	446.57	29.01	1.45	220.1	0
Osmancık	380.63	23.91	1.00	124.3	0
Tosya	481.41	28.09	0.91	156.4	0
Kastamonu	496.02	31.41	1.97	278.4	0
Ilgaz	443.47	28.35	1.16	188.2	0
Bafra	797.07	45.97	1.47	343.9	0

Table 3. Geographical features of streamflow observation stations.

State	Station	Period	Longitude-Latitude	Altitude(m)
Sivas	Söğütlühan	1963 2009	39°43'59'' N/36°58'59'' E	1243
Kayseri	Yamula	1939 - 2003	38°89'02'' N//35°25'86'' E	995
Sivas	Bulakbaşı	1972-2009	39°87'80'' N//37°56'30'' E	1298

Table 4. Basic statistical information of streamflow observation stations records.

Station	Mean	SD	Skewness	Max.	Min.
Söğütlühan	1174.15	127.88	2.30	892.17	7.72
Yamula	2121.34	208.15	2.25	1295.48	14.20
Bulakbaşı	423.72	54.25	2.50	365.99	0.17

SD= standard deviation

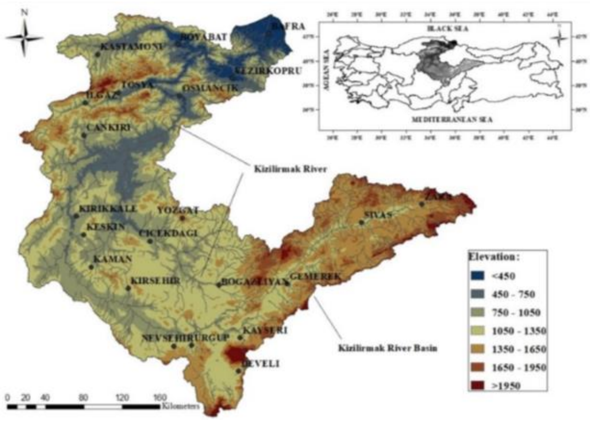

Figure 2. Study area (Akturk et al., 2022).

2.2. Standard Precipitation Index (SPI)

SPI developed by McKee et al., (1993, 1995). SPI is used for the modelling of rainfall and is obtained by dividing the difference between the precipitation and mean of precipitation in a specific period by the standard deviation (equation 1) and the SPI classes are shown in Table 5 (McKee et al., 1993). The advantages of SPI are that it quickly determines the drought months and can be calculated in different time periods (Sirdas and Sen, 2003).

$$SPI = \frac{x_J - \mu}{\sigma} \qquad (1)$$

Table 5. Drought classification by SPI

SPI	Drought category	State
SPI ≥0.0	No Drought	0
-1.00 ≤ SPI < 0.00	Mild Drought	1
-1.50 < SPI ≤ -1.00	Moderately Drought	2
-2.00 < SPI ≤-1.50	Severe Drought	3
SPI ≤ -2.00	Extremely Drought	4

Thom (1958) proposed Gamma distribution for historical precipitation time series (Yacoub and Tayfur, 2020). Probability density function of Gamma distribution is defined as equation 2 (Yacoub and Tayfur, 2020);

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta}; x, \alpha, \beta > 0 \quad (2)$$

Where x is the amount of rainfall, Γ(α) is the gamma function and α is shape, β is scale parameter. Shape and scale parameters can be estimated as equation 3 (Bacanli, 2017; Yacoub and Tayfur, 2020);

$$\alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right), \beta = \frac{\bar{x}}{\alpha}, A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n} \quad (3)$$

Here, n refers to the number of rainfall observations, with cumulative probability distribution function given below equation 1 (Bacanli, 2017);

$$G(x) = \int_0^x g(x)dx = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-x/\beta} dx \quad (4)$$

Then cumulative probability function is calculated for a given period (1, 2, 6, 9, 12, 24 months). If the precipitation series have zero values, then cumulative probability becomes as follows equation 5;

$$H(x) = q + (1 - q)G(x) \quad (5)$$

The cumulative probability value H(x) is converted into a Z variable with the standard normal random value showing the SPI with a mean value of zero and variance that equals to 1 (Abramowitz and Stegun, 1965; Yacoub and Tayfur, 2017). H(x) is the value of the SPI. Normalization of the SPI values enables the prediction of temporal and spatial variations in the precipitation series for that station (McKee et al., 1993; Guttman, 1999).

2.3. Streamflow Drought Index (SDI)

The SDI method was developed by Nalbantis (2008). It is hypothesized that a series of monthly streamflow volumes, ($Q_{i,j}$) is available, with i refering to the hydrological year and j denoting the month in that year, that is, October- September (Gumus and Algin, 2017). Based on this, cumulative volumes are shown in equation 6;

$$V_{i,k} = \int_{j=1}^{3k} Q_{i,j}\,; i = 1,2, \dots ,12; k = 1,2,3,4 \quad (6)$$

Here, $V_{i,k}$ refers to the cumulative streamflow volume of ith hydrological year, and Nth reference period (Nalbantis, 2008; Nalbantis and Tsakiris, 2009). Based on the cumulative streamflow volumes, $V_{i,k}$, the SDI is defined for the ith hydrological year, as follows equation 7;

$$SDI_{i,k} = \frac{V_{i,k} - \overline{V_k}}{S_k}; i = 1,2, \dots, k; k = 1,2,3,4 \quad (7)$$

From the mean (V_k), and standard deviation (S_k), of the cumulative stream flow volume, the SDI for Nth reference period within ith hydrological year can be calculated via Equation 7, with the truncation level set at V_k, although other values can be used.

The SDI has five categories ranging between extreme wet and extreme drought, as given in Table 6 (Nalbantis, 2008).

Table 6. Drought classification by SDI

State	Drought category	SDI
0	No Drought	SDI ≥ 0.00
1	Mild Drought	-1.00 ≤ SDI < 0.00
2	Moderately Drought	-1.50 ≤ SDI < -1.00
3	Severe Drought	-2.00 ≤ SDI < -1.50
4	Extremely Drought	SDI < -2.00

3. Results and Discussion

3.1. SPI Results

In this study, SPI analysis was performed for the determination of meteorological drought in the Kızılırmak Basin. SPI values were calculated for each station and graphics were prepared. Since the graphics of all stations used take up too much space, the results of 3, 6, 12 and 24 SPI of Tomarza are given in Figure 3 as an example.

When the graphs are examined, it is seen that the most severe droughts are seen in the 3 and 6-month time series, while the drought Intensities are relatively less in the 12-month time series, but the dry periods are intense. Serious droughts were not observed in the 24-month time series, and the number of these droughts, which are seen as mild severe, is less than in other time series. As it can be understood from here, droughts are observed in almost every time series, even if the severity is classified according to the time series in places where drought is seen. Whether the time series is short or long period does not generally change whether drought is seen or not, but it causes the severity to be described as mild in long periods. When the SPI graphs of the other stations given in Annex-1 are examined, similar results are seen. While the SPI values vary between 0 and -3 in the 3, 6 and 12 month periods, they vary between 0 and -1 in the 24 month period. The most intense periods of drought in the basin are between 1982-1987, 1990-1997 and 2000-2008.

Table 7 gives information about the longest drought periods seen at precipitation stations. According to the table, the longest period when the SPI value fell below 0 was chosen as the maximum drought period, the sum of the SPI values in the longest period represents the degree of drought, the maximum drought severity is the minimum value of the SPI values of the time period, the drought frequency is the number of drought recurrences in the time series.

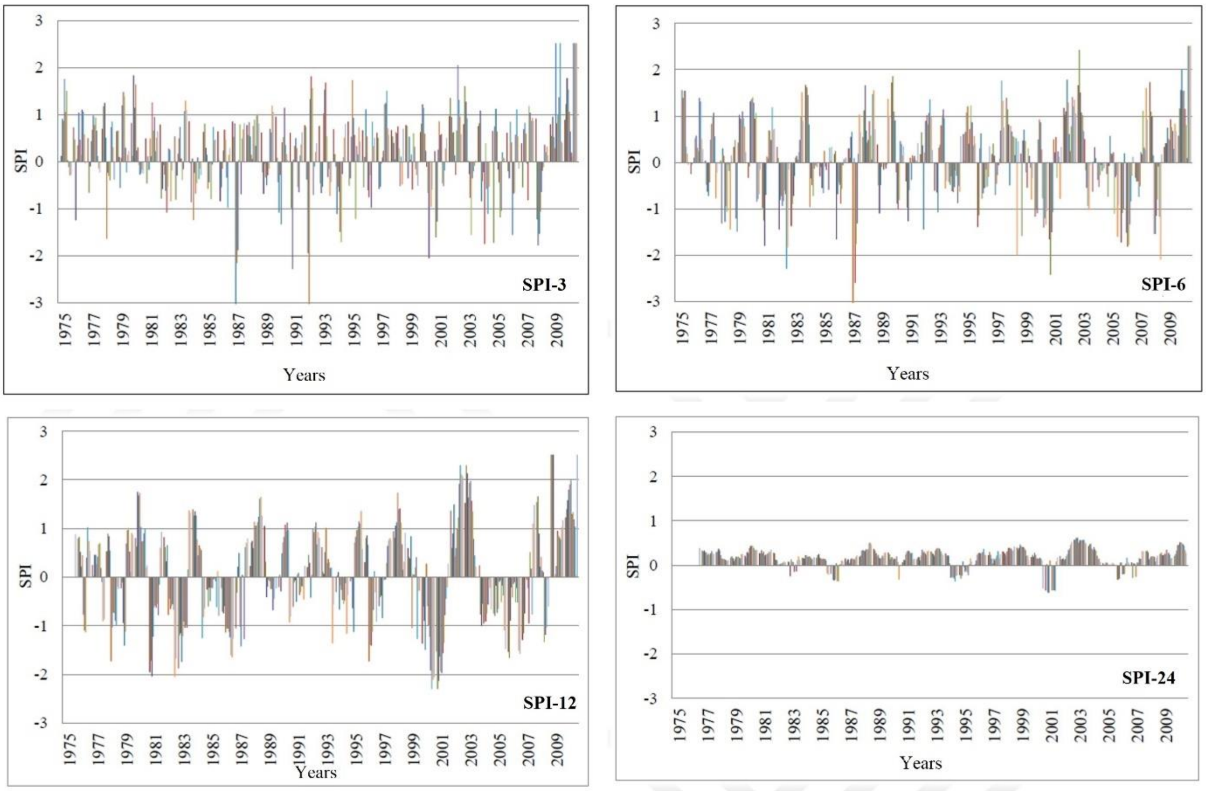

Figure 3. Temporal distribution of SPI results for Tomarza.

Table 7. Maximum drought periods for precipitation stations

Station	P	F	D	LDP	MED	DE
Bafra	3	65	13	1984/10-1985/09	-2.83	-11.82
	6	38	17	2006/07-2007/11	-2.60	-16.03
	12	25	39	2005/12-2008/11	-2.66	-26.99
	24	15	9	1982/05-1983/01	-0.49	-1.65
Bala	3	35	13	1986/03-1987/03	-4.12	-22.71
	6	22	22	2001/02-2002/11	-5.46	-11.71
	12	25	26	1988/10-1990/11	-3.68	-27.39
	24	5	62	1986/03-1991/04	-1.38	-33.13
Çiçekdağı	3	61	12	1994/04-1995/03	-3.13	-10.77
	6	34	26	1981/08-1983/09	-3.07	-21.83
	12	26	28	2006/05-2008/08	-2.42	-17.62
	24	13	12	2008/01-2008/12	-0.51	-4.31
Çorum	3	64	8	1976/03-1976/10	-2.75	-9.25
	6	41	16	1993/08-1994/11	-2.90	-11.50
	12	30	27	2006/11-2009/01	-2.29	-30.07
	24	12	22	1994/06-1996/03	-0.64	-1.45

P= period, F= frequency, D= duration (Month), LDP= longest dry period, MED= most extreme drought, DE= degree

Table 7. Maximum drought periods for precipitation stations (continuing)

Station	P	F	D	LDP	MED	DE
Gemerek	3	65	12	2002/11-2003/10	-3.08	-12.34
	6	44	16	1994/05-1995/08	-3.23	-7.54
	12	31	19	1994/04-1994/10	-3.35	-3.64
	24	9	12	1994/11-1995/10	-0.41	-2.22
Ilgaz	3	55	13	1975/09-1976/09	-2.25	-9.10
	6	38	30	2006/03-2008/08	-2.36	-18.88
	12	22	34	2006/04-2009/01	-2.41	-33.55
	24	15	23	2007/03-2009/01	-0.78	-9.72
Kastamonu	3	70	11	2007/02-2007/12	-2.66	-12.71
	6	42	31	1975/06-1977/12	-2.78	-18.64
	12	27	29	2006/04-2008/08	-2.85	-39.80
	24	14	23	1994/06-1996/04	-0.92	-1.51
Keskin	3	63	9	1994/02-1994/10	-4.99	-9.05
	6	30	41	1991/11-1995/03	-2.55	-31.83
	12	16	47	1992/04-1996/02	-2.14	-31.89
	24	10	35	1992/12-1995/10	-0.47	-6.09

P= period, F= frequency, D= duration (Month), LDP= longest dry period, MED= most extreme drought, DE= degree

Table 7. Maximum drought periods for precipitation stations (continuing)

Station	P	F	D	LDP	MED	DE
Kırıkkale	3	67	8	1979/03-1979/10	-3.14	-6.23
	6	45	21	1993/06-1995/02	-2.57	-10.38
	12	24	61	1992/04-1997/04	-2.55	-69.13
	24	20	52	1992/09-1996/12	-0.77	-14.02
Kulu	3	48	8	1989/02-1989/09	-5.43	-3.79
	6	40	9	2004/02-2004/10	-5.59	-4.58
	12	23	60	2004/04-2009/03	-3.33	-36.54
	24	18	62	2005/04-2010/05	-0.93	-9.14
Osmancık	3	65	11	1986/02-1986/12	-3.73	-7.27
	6	32	25	2006/12-2008/12	-2.38	-25.68
	12	23	39	1976/12-1980/02	-2.06	-15.15
	24	12	15	1994/06-1995/08	-0.77	-2.66
Sivas	3	67	11	1984/02-1984/12	-1.90	-7.10
	6	43	13	1993/11-1994/11	-2.74	-7.12
	12	26	14	2004/03-2005/04	-0.29	-2.86
	24	8	1	1979/12-1979/12	-0.35	-0.35
Tomarza	3	58	7	2008/02-2008/08	-3.05	-6.54
	6	38	14	1982/03-1983/04	-3.69	-13.64
	12	24	42	2004/02-2007/07	-2.30	-27.98
	24	17	10	1994/06-1995/03	-0.36	-2.70
Tosya	3	69	11	2007/02-2007/12	-2.39	-13.86
	6	38	25	2006/12-2008/12	-2.56	-33.75
	12	24	41	1992/02-1995/06	-2.60	-34.66
	24	13	24	2007/03-2009/02	-0.89	-12.45
Ürgüp	3	52	6	1984/07-1984/12	-3.56	-2.40
	6	32	18	2003/03-2004/08	-2.06	-6.93
	12	25	25	2003/07-2006/05	-2.48	-19.96
	24	12	23	2004/07-2006/05	-0.71	-1.68
Şarkışla	3	51	11	1994/02-1994/12	-2.96	-7.63
	6	34	31	1993/01-1995/07	-2.82	-25.79
	12	22	47	1920/04-1996/02	-3.63	-60.73
	24	7	38	1993/04-1996/05	-0.76	-10.08

P= period, F= frequency, D= duration (Month), LDP= longest dry period, MED= most extreme drought, DE= degree

When Table 7 is examined, it is understood that generally the longest and most severe drought periods are observed in the 12-month time period. Since 3-month periods express seasonality and are a relatively short period of time, and 24-month periods are a rather long period of time, they will reflect relatively less drought severity and droughts less frequently; values were found to be more decisive.

Considering the need for agricultural water, the development of plants, periods of intense water consumption, the construction of water structures and the measures to be taNen regarding drought, it is also important to determine the seasonal drought situation. It is possible to examine the seasonal distributions of droughts by looking at the results of the 3-month SPI assessment. As an example, seasonal SPI graphs for Tomarza station are shown in Figure 4. Seasonal drought distributions of other stations are given in Table 8.

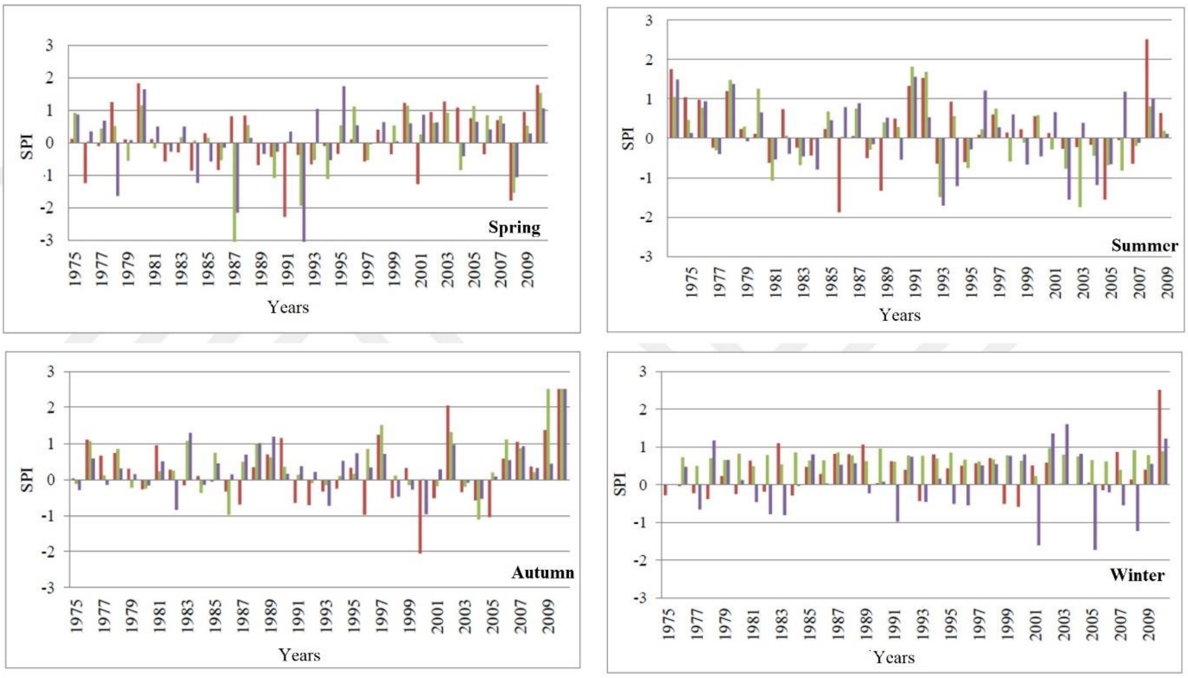

Fıgure 4. Temporal distribution of seasonal drought distributions for Tomarza.

Table 8. Seasonal distributions of droughts for precipitation stations

	State	Tomarza	Gemerek	Sivas	Şarkışla	Çiçekdağı	Keskin	Kırıkkale	Bala	Kulu	Ürgüp	Çorum	Osmancık	Tosya	Kastamonu	Ilgaz	Bafra
	4	0	0	1	1	1	1	1	3	0	1	2	3	2	2	0	4
W	3	2	3	2	2	5	3	0	1	0	0	7	4	6	4	0	3
	2	1	6	4	9	6	7	5	0	0	5	6	7	7	7	1	5
	4	4	3	2	1	1	5	0	2	3	0	3	2	1	1	0	0
Sp	3	4	5	7	7	3	4	2	0	0	1	5	5	6	5	2	5
	2	6	15	17	14	8	12	9	0	4	2	8	7	11	13	14	13
	4	0	2	3	2	5	2	2	3	2	0	5	3	3	2	1	4
S	3	5	6	3	3	1	4	5	0	1	0	2	3	6	4	2	10
	2	5	15	15	7	9	5	13	2	3	3	7	13	13	7	9	11
	4	1	5	4	2	3	3	1	2	3	2	3	3	2	4	1	2
A	3	0	3	4	3	4	5	5	0	1	0	4	5	7	6	2	7
	2	2	7	8	4	7	15	6	4	0	5	10	13	17	8	5	11

W= winter, Sp= spring, S= summer, A= autumn

When the Figure 4 and Table 8 are examined, it is seen that the droughts are more and more severe in the spring period compared to the other seasons, and the observed drought numbers and severity decrease as the summer, autumn and winter seasons go, respectively. When Table 8 examined, the most drought was observed in the spring season at Tomarza, Gemerek, Sivas, Sarkisla, Kulu, Kastamonu, Ilgaz. The most drought was observed in the autumn season at Keskin, Bala, Ürgüp, Çorum Osmancık and Tosya. The most drought was observed in the summer season at Çiçekdağı, Gemerek, Kırıkkale and Bafra. Although the season in which the most drought is seen differs according to the stations, the most drought in the basin was observed in the spring, summer, autumn and winter seasons, respectively.

3.2. SDI Results

According to the hydrologic drought assessment made according to the SDI; Droughts were observed in each of the different periods (3, 6, 9, 12 months) for all three stations. In Table 9, information on the longest drought periods seen at flow stations is given. According to the table, the longest period when the SDI value fell below 0 was chosen as the maximum drought period.

Table 9. Maximum drought periods for streamflow stations

Station	P	F	D	LDP	MED	DE
Söğütlühan	3	48	10	2001/6-2002/3	-0.86	-5.93
	6	42	20	1972/10-1974/5	-1.22	-13.7
	12	16	94	2001/4-2009/1	-1.92	-92.58
	24	7	110	2000/8-2009/9	-1.93	-118.90
Yamula	3	66	20	2000/8-2002/3	-0.95	-12.83
	6	58	29	1972/11-1975/3	-1.30	-21.19
	12	20	94	1955/4-1963/1	-2.14	-71.47
	24	15	56	1956/3-1963/4	-2.18	-83.01
Bulakbaşı	3	39	10	1994/6-1995/3	-0.82	-5.96
	6	34	19	2000/10-2002/4	-1.20	-14.26
	12	21	60	2001/4-2006/3	-2.11	-3.76
	24	10	62	2001/3-2006/4	-2.16	-73.34

P= period, F= frequency, D= duration (Month), LDP= longest dry period, MED= most extreme drought, DE= degree.

Contrary to the results of the SPI, the SDI shows that the severity and duration of droughts increase over long time periods. In both indices, drought frequency observed in long time periods decreased compared to short time periods. The longest and most severe droughts were seen after 2000 and the periods of maximum drought were similar to the SPI. Figure 5 shows the change curves of the SDI of all three flow stations over the 3, 6, 9 and 12 month periods.

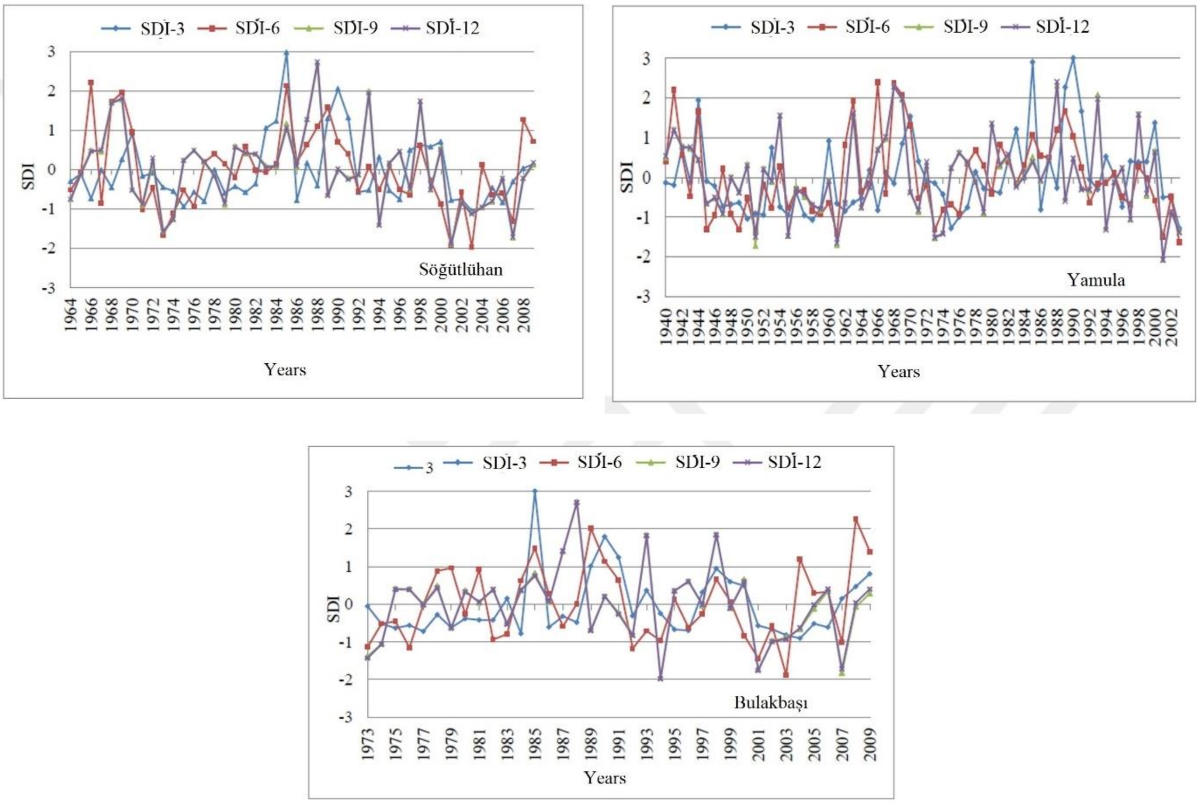

Figure 5. Temporal distribution of SDI results for streamflow stations.

3.3. Combined Evaluation of SPI and SDI Results

In order to understand whether hydrological drought is also seen during periods of meteorological drought and whether these two indices are compatible with each other, the equi-period results of SPI and SDI indices of precipitation and flow observation stations located close to each other were compared.

Sivas (rainfall) and bulakbaşı (flow) were evaluated together. According to SPI, the maximum droughts seen in Sivas are given in Table 8. The change graph of Bulakbaşı's SDI in various time periods is given in Figure 5. According to the SPI results, the average Severity of the drought, which started in the 2nd month of 1984 and lasted for 11 months in a 3-month period, was calculated as -0.66 and was graded as mild drought. Looking at the SDI results for the same time period in similar years, a mild drought that started in the 9th month of 1983 and ended in the 2nd month of 1984, with an average severity of -0.69, was observed for 7 months. There was no drought until the 8th month of 1984, and another mild drought that lasted 4 months with an average severity of -0.48 was seen between the 8th and 11th months of 1984. In the 6-month time period of SPI, the average Severity of the drought, which started in the 11th month of 1993 and lasted for 13 months, was calculated as -0.55 and was characterized as mild drought. When similar years are examined in the 6-month time period of SDI, a drought with an average severity of -0.96 was observed that started in the 10th month of 1992 and continued until the 4th month of 1993, and then another drought that started in the 11th month of 1993 and ended in the 3rd month of 1995. A drought was observed and its average Severity was calculated as -0.84. According to SPI, for the 14-month drought, which started in the 3rd month of 2004 and ended in the 4th month of 2005 and whose severity was calculated as -0.20 in a 12-month period, when the SDI was analyzed in the same time period and similar years, it was observed that the drought started in the 4th month of 2001 and ended in the 4th month of 2006. There was a drought lasting for 60 months, with an average Severity of -0.90, which lasted until the month of May.

Sarkisla (rainfall) and Söğütlühan (flow) were evaluated together. The maximum droughts seen in Sarkisla are given in Table 8. The graph of the change of SDI of Söğütlühan in various time periods is given in Figure 5. According to SPI, the maximum drought in the 3-month period started in the 2nd month of 1994 and lasted for 11 months. When we look at the results of the 3-month period of SDI, the drought that started in the 8th month of 1993 continued until the 4th month of 1994, and there was no drought for the next 2 months, and the drought continued from the 6th month of 1994 to the 3rd month of 1995. During this drought, the average drought Intensity according to SDI was calculated as -0.59, which is in line with the SPI of -0.69 average drought Intensity, and both are characterized as mild droughts. According to the 6-month SPI results, the drought, which started in the 1st month of 1993 and continued for 31 months and ended in the 7th month of 1995, started in the 11th month of 1993 according to the 6-month SDI and continued until the 3rd month of 1995, lasting 17 months and the average drought intensity was calculated as -0.70. The average drought Intensity according to SPI is -0.83, and both indices indicate mild drought during this drought. In the 12-month SPI results, the average Severity of the maximum drought starting in the 4th month of 1992 and continuing for 47 months until the 2nd month of 1996 is -1.29 and moderately dry. When the periods of the SDI results covering this period are examined, there was a drought that started in the 10th month of 1990 and continued until the second month of 1993, lasted for 29 months and the average drought severity was calculated as -0.23. There was no drought until the 4th month of 1994, a new drought was seen in the period from the 4th month of 1994 to the 5th month of 1995 and its average severity was calculated as -1.23. This drought, which lasted for 13 months, was described as moderate drought. In the 3rd month of 1996, a one-month drought of -0.06 intensity was observed and no other drought was observed until the 3rd month of 1997.

Tomarza (precipitation) and Yamula (flow) were evaluated together. The maximum droughts seen in Tomarza are given in Table 8. The change graph of Yamula's SDI in various time periods is given in Figure 5. According to SPI, the maximum drought in the 3-month period was in 2008, and in the 12-month period between 2004 and 2007, however, the SDI was not calculated in 2004 and following years due to the impoundment of the Yamula dam in 2004. According to the 6-month SPI results, the maximum drought started in the 3rd month of 1982 and ended in the 4th month of 1983. The average Severity of this drought, which lasted for 14 months, was calculated as -0.97, rated as mild drought. When the SDI results in the same period and time period are examined, the drought that started in the 10th month of 1982 continued until the 4th month of 1983, and the average severity of the drought lasting for this 6 months was calculated as -0.64, and it was described as a mild drought. Then another drought started in the 9th month of 1983 and continued until the 4th month of 1984. The average severity of this drought, which lasted for 6 months, was calculated as -0.77 and was described as mild drought.

In summary; Considering the results of SDI, although the duration and severity of droughts are relatively less compared to SPI, hydrological droughts in Sivas and Bulakbaşı were more severe and longer lasting than meteorological droughts. In SPI, the Severity and duration of droughts decrease as the duration of the examined time period increases, while the Severity and duration of droughts in SDI can increase with the increase of the examined time period. Hydrological drought was also observed in the periods when meteorological drought was observed in the compared flow and precipitation stations. It has been noticed that hydrological drought is seen intermittently in the time periods where the meteorological drought continues uninterrupted, and the drought start and end times of both indices are close to each other even though they are not exactly the same. Although the hydrological drought sometimes started before the meteorological drought, sometimes later and continued intermittently, the time periods in which the droughts are seen cover each other. Considering that the SDI is based on the water year, unlike the SPI, it is reasonable that the drought start and end times are not exactly the same. As can be understood from here, meteorological and hydrological drought indices give results that are compatible with each other and the effects of meteorological drought can be seen more in a short time.

4. Conclusion

In this study conducted for the Kızılırmak basin, the drought situation was analyzed in terms of hydrological and meteorological. The SPI for meteorological drought was calculated at 3, 6, 12 and 24 month periods. When the SPI results were examined throughout the basin, it was understood that the most severe droughts were seen in the periods of 3 and 6 months, while the drought intensities were relatively less frequent in the 12-month periods. There was generally very little drought in 24-month periods, and all droughts were classified as mild droughts. As the time period examined according to the SPI got longer, the severity and intensity of the drought decreased. By looking at the 3-month time periods of the SPI, seasonal droughts in the basin were examined and it was seen that the most droughts in the basin were experienced in spring, summer, autumn and winter, respectively.

SDI expressing hydrological drought was calculated in 3, 6, 9 and 12 month periods. In the examined time intervals, the greatest droughts were seen in 2000 and later years. Contrary to the SPI results, the severity and duration of drought increased over long time periods in the SDI.

During periods of maximum meteorological drought, hydrological drought was also observed. A meteorological drought that continues uninterrupted for a long time is intermittent in terms of hydrological drought, and the start-end times of the drought are not exactly the same, but the time periods in which the droughts occur are of a nature that covers each other.

Drought is a disaster that starts as a meteorological drought, develops as an agricultural, hydrological drought and continues as a socio-economic drought. The effects of drought are felt the most when the demand for water is the highest and crisis management is carried out during these periods, but since our country has a semi-arid climate, risk management should be done regularly instead of crisis management, and measures related to drought should be taken and these measures should always be developed. The climate of water basins and their surroundings should be monitored regularly.

The measures to be taken in the fight against drought can be listed as follows;

In regions where drought risk is high, the number of meteorological and hydrological stations should be increased and regular measurements should be made. By determining the total water deficiency, water transfers between basins should be made from regions with excess water to regions with water scarcity. With short and long-term forecasts, the amount of water in the water reservoirs should be determined continuously and the available water should be used in a planned way.

The unconscious use of pesticides and fertilizers, low irrigation efficiency or excessive irrigation reduce the existing water quality and quantity. Trainings should be given in schools, institutions and community centers on water conservation and the rational use of water resources, and drought awareness should be created in the society.

As a result of global climate change, drought in the basin is expected to increase even more in the future. In line with this expectation, it is important to identify risks and hazards, take all necessary precautions, take responsibility for disasters and to raise awareness in order to prevent and reduce damages within the scope of the modern disaster management approach.

Water is of great importance for our country in terms of agriculture and energy. Many water structures have been established to be used in irrigation and energy production and investments are still being made in this regard. It is possible for water structures to serve their purpose and to maintain the profitability of investments only if sufficient precipitation falls.

Although it is very important to find the meteorological and hydrological records in the past in order to carry out scientific studies, the measurements; the fact that it is recorded uninterruptedly, simultaneously and for many years has the feature of being data that can be used in scientific studies. In order to shed light on current and future studies, the stations recording the events in nature should be positioned in a way that best reflects the reality and should be capable of making accurate, regular and uninterrupted measurements.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	A.U.K.	D.S.O.	U.Z.
C	40	30	30
D	40	30	30
S	40	30	30
DCP	40	35	25
DAI	30	40	30
L	30	40	30
W	30	40	30
CR	40	20	40
SR	30	30	40
PM	40	35	25

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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