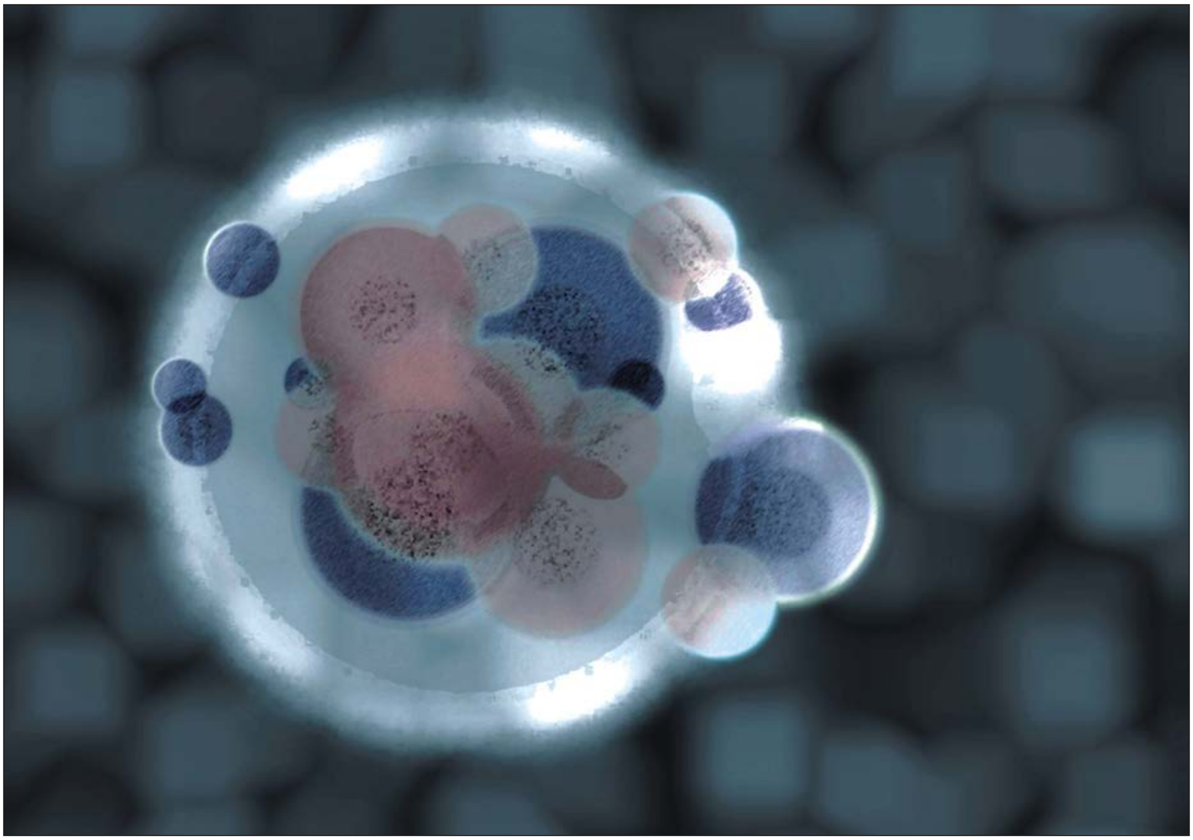

Journal of Biological Sciences

ISSN 1727-3048

Journal of Biological Sciences 7 (8): 1458-1462, 2007
ISSN 1727-3048

Effects of Fallow-Wheat and Lentil-Wheat Rotation Systems on Wheat Yield and Soil Water Storage in Dry Farming Areas

Mehmet Ülker and Vahdettin Çiftçı
Department of Field Crops, Agricultural Faculty,
Yuzuncu Yil University, 65080 Van, Turkey

Abstract: This research was carried out on dry farming areas in four locations around Van lake Basin in the eastern Turkey between 1998 and 2001. The aim of the experiment was to determine the effects of fallow and winter lentil (*Lens culinaris*) on wheat (*Triticum aestivum*) yield and the available water content in soil layers between 0 and 120 cm after fallow and lentil treatments. The experimental design was a randomized block with 4 replications. The results indicated that the highest water contents occurred in fallow plots in all locations. The highest fallow efficiency was observed in Erciş (9.4%) and the lowest was in Adilcevaz (-8.8%). Wheat yield was significantly reduced by lentil in all locations. Growing winter lentil was more profitable than fallow. Therefore, wheat-winter lentil rotation system is recommended in all locations.

Key words: Fallow, wheat, lentil, water content, water storage efficiency, yield

INTRODUCTION

Wheat (*Triticum aestivum*) is the major crop in dry farming areas in Turkey. In Van Lake Basin (Turkey), water is the most limiting factor of crop production in dryland farming. Fallow has been a traditional strategy to capture and store water. For this purpose, weeds in fields are removed by tillage or herbicide by the time of planting (Lampurlanes *et al*., 2002). Fallow period is approximately 15 months, for winter wheat, from harvest in July to planting in October of the next year. Summer fallow has been the most common cultural practice for soil water conservation in the eastern Anatolia. It also provides an efficient weed control, yield increase and release in plant nutrients (Connor and Loomis, 1991). Fallow is applied to conserve water in many places in the world (Bonfil *et al*., 1999). Up to 25% of the annual precipitation is held in the soil during fallow period (Farahani *et al*., 1998). The effectiveness of fallow depends on soil type, tillage practices, rainfall, topography, temperature and soil water-storage capacity. However, all the researchers are not in agreement regarding the effects of fallow in water conservation in semi-arid regions (Godwin, 1990). Farahani *et al*. (1998) stated that the most of water conserved is lost during the last summer of fallow.

There are also some disadvantages of fallow. It may lead to poor soil water storage efficiency and enhanced soil erosion (Aase and Pikul, 2000). Additionally, growing only wheat can cause exploitation of the same soil profile and also tillage for fallow can cause hard and impermeable soil formation in time; root systems of cereals can not grow in this profile and active root zone gets smaller. Decreases of infiltration during fallow may enhance the loss of water through surface flow and evaporation. To avoid these, legumes that are deep rooted and consume less water can be utilized during fallow. Eser *et al*. (1999), reported from Shultz (1927), indicated that annual legumes form deep root canals that are reach in nitrogen and organic matter, thus enhancing biological soil process. There are some reports regarding growing legumes in fallow years. In Western Australia, white lupine, blue lupine, faba bean and field pea preceding cereals are used in fallow (Thomson *et al*., 1997). In Canada, field pea, lentil and chickpea in sequences with spring wheat have been proposed to use in fallow (Miller *et al*., 2002; Miller *at al*., 2003). Larney and Lindwall (1995), found that the amount of available water for winter wheat in fall in Canada was least 45 mm after canola, 59 mm after winter wheat, 74 mm after lentils and 137 mm after fallow. Additionally, Gan *et al*. (2003) stated that grain yield and protein increase much better if pulses are grown before spring wheat than if spring wheat precedes spring wheat.

Approximately 5 million ha of land is left for fallow in Turkey. Application of legume-wheat rotation system in places where annual precipitation is sufficient will provide crop production every year and biological process of soil in deep profiles. Even decrease in the amount of water because of consumption by legumes in fallow may limit

Corresponding Author: Mehmet Ülker , Department of Field Crops, Agricultural Faculty,
Yuzuncu Yil University, 65080 Van, Turkey

wheat yield at the beginning, this will become reverse because infiltration and organic matter content of soil will increase in time.

The objective of present study was to investigate the effects of fallow and alternative crop (winter lentil) on soil-water content and wheat yield in Van-Lake Basin in dry farming areas. To investigate different perspectives, the studies were pursued in four locations (Van, Erciş, Adilcevaz ve Gevaş) that included sandy, sandy-loam, sandy-loam-clay soils and in slopped and smooth lands.

MATERIALS AND METHODS

Field experiments were carried out in four locations in Van-Lake Basin in the east of Turkey between 1998 and 2001. The locations were Van (38°25′ N, 43°21′ E; altitude: 1720 m; average temperature: 8.8°C; average rainfall: 381.3 mm), Erciş (39°00′ N, 43°28′ E; altitude: 1730 m; average temperature: 7.9°C; average rainfall: 458.0 mm), Adilcevaz (38°58′ N, 42°48′ E, altitude: 1730 m; average temperature: 9.0°C; average rainfall: 578.2 mm) and Gevaş (38°18′ N, 43°07′ E, altitude: 1710 m; average temperature: 8.8°C; average rainfall: 516.9 mm). Soil samples were analyzed at the laboratories of Erzurum Village Affairs Research Institute. The soil types of experimental locations were sandy-loam-clay in Van and Gevaş, Sandy-loam in Erciş and sandy in Adilcevaz. Soils of all locations were slightly alkaline, poor in organic matter, N and P.

Sazak-91 (lentil) and Tir (wheat) cultivars were used in the study. Experimental areas, except Gevaş (8 % slopped) were flat. Each plot was 5×10 m = 50 m^2. The experiment was done in a randomized complete block design with 4 replications. Wheat and lentil were sown in early October each year, using plot drill. Plant density was 250 seeds m^{-2} for lentil and 450 seeds m^{-2} for wheat in rows spaced 20 cm apart. Lentil and wheat were harvested in early and late July, respectively. Fertilizer, 140 kg ha^{-1} Diamoniumphosphate (18% N, 46% P_2O_5) was applied to each plot at sowing. In addition, wheat plots received 50 kg ha^{-1} N as Ammonium Sulfate (21% N) at the stem elongation stage. In the first season (1998-1999), all plots were sown with wheat; in the second year (1999-2000), some plots were sown with winter lentil and the other plots left for fallow. All plots were sown with wheat in the third year (2000-2001). Soil water storage and wheat yield between fallow-wheat and winter lentil-wheat rotation systems were compared. The soil samples were taken from 0-30, 30-60, 60-90 and 90-120 cm depths at the beginning (July-1999) and end (October-2000) of fallow in all plots. The soil water content was obtained by Gravimetric Method (Kacar, 1995).

The data were analyzed using ANOVA (SAS, 1996). Mean separation was performed for the significant main effects through Duncan test at p = 0.05 (Montgomery, 1991).

RESULTS AND DISCUSSION

The highest precipitation during fallow was observed in Gevaş (421.9 mm), followed by Adilcevaz (338.4 mm), Van (312.0 mm) and Erciş (247.3 mm). The WSE in Gevaş was lower than in the other locations because experimental area was 8% slopped (Table 1).

The highest soil water content was obtained in Van (151.8 mm) while the least occurred in Adilcevaz (74.3 mm). The rates of water that could be conserved through fallow, but consumed by lentil were 28.5% in Van, 24.8% in Erciş, 42.7% in Adilcevaz and 19.8% Gevaş (Table 2).

The highest water storage efficiency during fallow was observed in Erciş and Van locations as 9.42 and 7.70 %, respectively (Table 1). Erciş had less precipitation, but higher WSE than Van during the fallow. This could be because Van had higher average temperature than Erciş, which was conducive to higher evaporation during the fallow. The WSE was the lowest (-8.81%) in Adilcevaz location because the soil of this location was sandy and water holding capacity was very low. The similar results were reported by Lampulanes *et al*. (2001). Although Gevaş had the same soil structure with Van and Erciş, it had lower WSE (0.50%) because the soil was slopped in that location. The amounts of water conserved and WSE were highest in sandy-loam and smooth soils, while the least amounts were found sandy and also smooth soils. They decreased in slopped soils (Fig. 1). The results of studies by Farahani *et al*. (1998) about water storage efficiency are similar to the results of this study.

After lentil, the highest soil water content was observed in Van (108.6 mm) and least was in Adilcevaz (42.6 mm). The highest WSE was obtained from Erciş (4.90%) while the least was in Adilcevaz (-18.20%) (Table 2). The differences in WSE values could be attributed to the differences in topography rather than precipitation.

Table 1 Precipitation during fallow and fallow efficiency in four locations.

Table 2 shows the water contents in soil depths between 0 and 120 cm were higher in fallow plots than in lentil plots in all locations. Similarly, Güngör (1991), Adak (2001) and Larney and Lindwall (1995) also states that the highest water is obtained from fallow plots. WSE depending on different soil depths varied in locations. The highest amount of water was accumulated in

Table 1: Precipitation during fallow and fallow efficiency in four locations

Locations	Precipitation during fallow (mm)	Soil water-content: Beginning of fallow (mm)	End of fallow (mm)	After lentil (mm)	Consumption of soil water by lentil (%)	Water storage efficiency in W-F-W (%)	Water storage efficiency in W-F-W (%)
Van	312.0	127.7	151.8	108.6	28.5	7.70	-6.10
Erciş	247.3	119.4	142.7	107.3	24.8	9.42	-4.90
Adilcevaz	338.4	104.1	74.3	42.6	42.7	-8.81	-18.20
Gevaş	421.9	96.2	98.3	78.8	19.8	0.50	-4.10

W-F-W: Wheat-Fallow-Wheat and W-L-W: Wheat-Lentil-Wheat rotation system

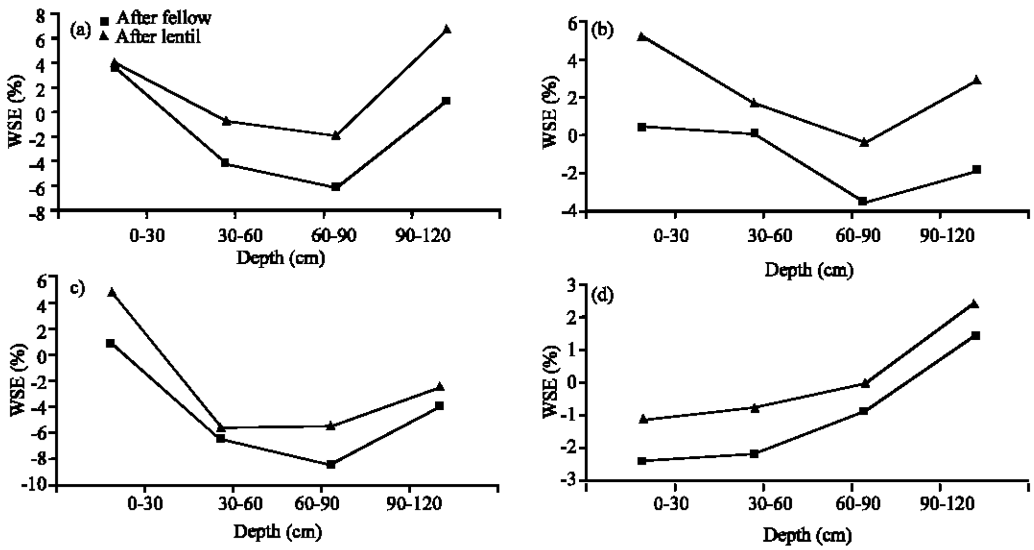

Fig. 1: WSE values in different soil depths in the locations. (a) Van (sandy-loam-clay) (b) Esciş (sandy-loam) (c) Asilcevaz (sandy) (d) Gevas (sandy-loam-clay and slopped)

90-120 cm in Van (6.6%) and Gevaş (2.4%) and in 0-30 cm in Erciş (5.2%) and Adilcevaz (4.7%). After lentil, the highest WSE values were found in 0-30 cm in all locations (Van, Erciş and adilcevaz 3.5, 0.4 and 0.8%), except Gevaş (Fig. 1).

In all locations, except Gevaş, as the soil depth increased after fallow, the WSE started decreasing from 0-30 cm depth and increased again in 60-90 cm. In Gevaş that has slopped land, WSE increased as the soil depth increased (Table 2 and Fig. 1).

Main purpose of fallow is to conserve water to guarantee wheat germination in fall. Therefore, humidity in 0-30 cm soil depth is important at the beginning of growth. But lack of humidity in 30-60 (like in Adilcevaz ve Gevaşta), especially in the cases of decrease in fall rains may cause moisture stress. The decreases in wheat and lentil yields in Adilcevaz and Gevaş could be attributed to this phenomenon. Therefore, the soils of Van (sandy-loam-clay) and Erciş (sandy-loam) seem safer compared to soils of Gevaş (slopped) and Adilcevaz (sandy).

Table 2 soil water content during, at the beginning and end of fallow on wheat-fallow and wheat-lentil rotation systems.

Wheat yield was significantly affected from fallow-wheat and lentil-wheat rotation systems. All of the yields in fallow treatments were higher than in winter lentil treatments in all locations (Table 3).

The effects of fallow-wheat and winter lentil-wheat rotations systems on biological, grain and straw yield of wheat Adilcevaz location had the lowest biological, grain and straw yield. This could be due to the fact that the soil of Adilcevaz location was sandy; So, water holding capacity of this site was very low (Table 3 and Fig. 2).

Wheat yields in the fallow treatment plots were higher than in the lentil treatment plots. The highest grain yield (1356 kg ha^{-1}) in fallow-wheat rotation system was obtained from Van location that had the highest soil water content (151.8 mm). There was a relationship between soil water content and yield in both fallow-wheat and lentil-wheat rotation systems (Fig. 2). The similar results on the effects of soil structure and topography on yield were reported by Tan *et al.* (1989), Adak (1994), Lyon *et al.* (1998), Eser *et al.* (1999) and Lampulanes *et al.* (2001).

Despite the fact that the fallow-wheat system improves soil water storage efficiency and wheat yield,

Table 2: Soil water content during beginning and end of fallow on wheat-fallow and wheat-lentil rotation systems

Locations	Depth of profile (cm)	Beginning of fallow (mm)	End of fallow (mm)	After winter lentil (mm)	Water storage efficiency (%)	Water storage Efficiency after lentil (%)
Van	0-30	17.3	29.6	28.3	3.9	3.5
	30-60	37.8	35.2	24.4	-0.8	-4.3
	60-90	43.6	37.5	24.4	-2.0	-6.2
	90-120	29.0	49.5	31.5	6.6	0.8
Erciş	0-30	23.1	36.0	24.2	5.2	0.4
	30-60	29.6	33.9	29.8	1.7	0.1
	60-90	35.5	34.4	26.9	-0.4	-3.5
	90-120	31.2	38.4	26.4	2.9	-1.9
Adilcevaz	0-30	12.5	28.3	15.2	4.7	0.8
	30-60	30.1	11.0	8.1	-5.6	-6.5
	60-90	38.2	20.0	9.7	-5.4	-8.4
	90-120	23.3	15.0	9.6	-2.5	-4.0
Gevaş	0-30	19.9	15.3	9.9	-1.1	-2.4
	30-60	28.5	25.0	19.1	-0.8	-2.2
	60-90	28.7	28.7	24.8	0.0	-0.9
	90-120	19.1	29.3	25.0	2.4	1.4

Table 3: The effects of fallow-wheat and winter lentil-wheat rotations systems on biological, grain and straw yield of wheat

		Biological yield (kg ha^{-1})		Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})	
Locations	Previous crops	Lentil	Wheat	Lentil	Wheat	Lentil	Wheat
Van	Fallow	-	5417a	-	1356a	-	4061a
	Winter-lentil	1137	4263b	483	1051b	654	3212b
Erciş	Fallow	-	4957a	-	1236a	-	3721a
	Winter- lentil	1920	3841b	810	948b	1110	2893b
Adilcevaz	Fallow	-	4927a	-	1072a	-	3855a
	Winter- lentil	1157	3294b	452	498b	705	2796b
Gevaş	Fallow	-	5173a	-	1118a	-	4055a
	Winter- lentil	1233	3458b	500	561b	733	2897b

Values having different alphabets are significantly different at $p < 0.05$

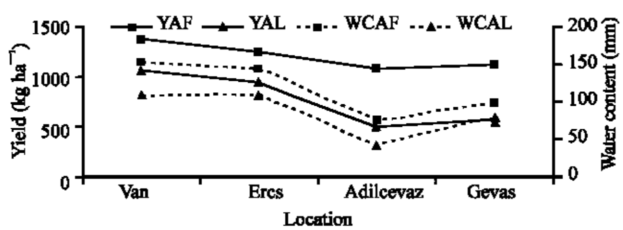

Fig. 2: The relationships between wheat grain yield and the water contents of soils. YAL: Yield after fallow, YAL: Yield after lentil, WCAF: Water content after fallow, WCAL: Water content after lentil

the fallow has not received a great attention in the region. The May-September fallow period is not enough for water accumulation. Therefore, the total water storage efficiency is low. Especially, sandy soil (Adilcevaz) and slopped area (Gevaş) caused decreases in water storage efficiency.

The traditional fallow-crop rotation is not economically feasible for the region. Instead of this, use of annual legumes (with low water consuming crops such as lentil and chickpea) with should take place to protect soil from erosion. Growing lentil in fallow years should be considered to improve other aspects such as deep biological process of soil, thus increasing permeability and water holding capacity of soil, optimization of N, weed control and increasing farmer's additional income.

ACKNOWLEDGMENT

This study was funded by The Scientific and Technical Research Council of Turkey (TOGTAG-TARP-1956 project).

REFERENCES

Aase, J.K. and J.L. Jr. Pikul, 2000. Water use in a modified summer fallow system on semiarid Northern Great Plains. Agric. Water Manage., 43: 345-357.

Adak, M.S., 1994. Effects of different previous crops and fallow on wheat yield, some yield components and protein ratio in Haymana conditions. University of Ankara. Publication, No. 1373, pp: 29.

Adak, M.S., 2001. Determination of soil water content after fallow, winter and spring sown lentil in dry farming areas. Turk. J. Agric. For., 25: 257-263.

Bonfil, D.J., I. Mufradi, S. Klitman and S. Asido, 1999. Wheat grain yield and soil profile water distribution in a no-till arid environment. Agron. J., 91: 368-373.

Connor, D.J. and R.S. Loomis, 1991. Strategies and tactics for water limited agriculture in low rainfall Mediterranean climates. In: Proceedings of the Improvement and Management of Winter Cereals under Temperature, Drought and Salinity Stresses Symposium, 26-29 October 1987. ICARDA-INIA, Cordoba, MAPA-INIA, Madrid, Spain

Eser, D., M.S. Adak and A. Biesantz, 1999. Effect of fallow, winter lentil, nitrogen fertilization and different soil tillage on wheat yield in the dry farming areas of Central Anatolia. Turk. J. Agric. Forest., 23: 567-576.

Farahani, H.J., G.A. Peterson, D.G. Westfall, L.A. Sherrod and L.R. Ahuja, 1998. Soil water storage in dryland cropping systems: The significance of cropping intensification. Soil Sci. Soc. Am. J., 62: 984-991.

Gan, Y.T., P.R. Miller, B.G. McConkey, R.P. Zentner, F.C. Stevenson and C.L. McDonald, 2003. Influence of diverse cropping sequences on durum wheat yield and protein in the semiarid northern Great Plains. Agron. J., 95: 245-252.

Godwin, R.J., 1990. Agricultural engineering in development: Tillage for crop production in areas of low rainfall. FAO, Rome, Italy, pp: 124.

Güngör, O., 1991. Take Advantage of Farming of Lentil in Order to Decrease the Amount of Fallow in Konya Ecological Conditions. Publication of Konya Village. Affairs Research Institute, No. 146, pp: 73

Kacar, B., 1995. Chemical Analysis of Plant and Soil: III. University of Ankara, Foundation of Education, Research and Improvement Publications: No. 3, pp: 66-67.

Lampurlanes, J., P. Angas and C. Cantero-Martinez, 2001. Root growth, soil water content and yield of barley under different tillage systems on two soils in semiarid conditions. Field Crops Res., 69: 27-40

Lampurlanes, J., P. Angás and C. Cantero-Martínez, 2002. Tillage effects on water storage during fallow and on barley root growth and yield in two contrasting soils of the semi-arid Segarra region in Spain. Soil Tillage Res., 65: 207-220.

Larney, F.J. and C.W. Lindwall, 1995. Rotation and tillage effects on available soil water for winter wheat in a semi-arid environment. Soil Tillage Res., 36: 111-127.

Lyon, D.J., W.W. Stroup and R.E. Brown, 1998. Crop production and soil water storage in long-term winter wheat-fallow tillage experiments. Soil Tillage Res., 49: 19-27.

Montgomery, D.C., 1991. Design and Analysis of Experiments. John Wiley and Sons, New York, pp: 649.

Miller, P.R., B.G. McConkey, G.W. Clayton, S.A. Brandt, J.A. Staricka, A.M. Johnston, G.P. Lafond, B.G. Schatz, D.D. Baltensperger and K.E. Neill, 2002. Pulse crop adaptation in the northern Great Plains. Agron. J., 94: 261-272.

Miller, P.R., Y. Gan, B.G. McConkey and C.L. McDonald, 2003. Pulse crops for the northern Great Plains. I. Grain productivity and residual effects on soil water and nitrogen. Agron. J., 95: 972-979.

SAS, 1996. SAS User's Guide Statistics. Version: 6.11 SAS Institute. Cary, NC.

Tan, A., Ö. Kurt and A. Karagöz, 1989. Production of grass on the fallow area (In Turkish with English abstract). Publication of Central Field Crops Institute. No. 17, Ankara

Thomson, B.D., K.H.M. Siddique, M.D. Barr and J.M. Wilson, 1997. Grain legume species in low rainfall Mediterranean-type environments. I. Phenology and seed yield. Field Crops Res., 54: 173-187.