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Alternative vegetable cultivation option in semi-arid conditions: the example of broccoli

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Abstract

The present study investigated broccoli cultivation under semi-arid conditions, focusing on the Parthenon F1 and Orantes F1 cultivars. Turkey has made significant advances in vegetable production, particularly in modern agricultural techniques that ensure higher yield eventually income of the growers. This study was conducted at the Adıyaman University Agricultural Practice and Land Management Research Center, with soil analyses performed before planting. Experimental plots were established with four replications, each containing ten plants. The main parameters recorded includes head diameter, head length, plant height, head weight, SPAD readings, vitamin C and nitrogen contents. The obtained results indicated that the Parthenon F1 had a higher average head diameter (11.83 cm) and head length (13.42 cm) compared to the Orantes F1 (8.46 cm and 10.95 cm, respectively). The average plant height for Parthenon F1 was 54.48 cm, while Orantes F1 had an average height of 49.39 cm. The average head weight of Parthenon F1 was significantly higher at 299.07 g compared to Orantes F1's 164.46 g. The SPAD readings were found similar for both cultivars, with Parthenon F1 at 72.86 and Orantes F1 at 72.57. Vitamin C content was higher in Parthenon F1 (111.76 mg/100 g FW) than in Orantes F1 (100.62 mg/100 g FW). However, Nitrogen content was higher in Orantes F1 (4.31%) compared to Parthenon F1 (3.64%). These findings highlight the importance of planting season and variety selection in achieving optimal broccoli production in semi-arid regions. The Parthenon F1 variety, especially when planted in autumn, demonstrated superior results in most parameters. These results suggested that adopting suitable cultivars and adjusting planting seasons can enhance broccoli yield and quality under semi-arid conditions. Further research on different cultivars and cultivation techniques is recommended to improve the sustainability and productivity of broccoli cultivation in semi-arid regions.

Keywords: Broccoli, Semi-arid, Vitamin C, Head weight, SPAD, N Content

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INTRODUCTION

Turkey made significant progress in vegetable production, and the commercially and economically active vegetable sector was established (Balkaya et al., 2023). Under current scenario, with the use of new vegetable species and varieties, as well as advancements in modern agronimical practices and techniques, high productivity per unit area and consequently, higher income is being achieved (Balkaya et al., 2016; Yanmaz et al., 2020; Balkaya et al., 2023). In Turkey, with the increase in productivity in vegetable cultivation areas, the rise in domestic and foreign demand for vegetables, and the investments in industrial vegetable growing which is a different sector a shift has been achieved in vegetable production activities from the small family business model to modern open-field and greenhouse vegetable growing (Yanmaz et al., 2015; Balkaya et al., 2016; Balkaya et al., 2023). Summer vegetables are grown more than winter vegetables. Nowadays, edible vegetables (tomatoes, peppers, eggplants, melons, watermelons, etc.) constitute the most cultivated group, accounting for 80.7% of production. This group is followed by vegetables with edible roots and tubers such as carrots, radishes etc. with 12.2%. Other types of

vegetables (arugula, cabbage, cauliflower, cress, dill, lettuce, spinach, purslane etc.), including broccoli, constitute 7.1% (TUIK, 2022; Balkaya et al., 2023).

According to Turkey's 2023 fresh fruit and vegetable sector report, the production amount of fresh vegetable products in the fresh vegetable production area decreased by 0.2% compared to the previous year, reaching 29 million tons. Vegetable production in open conditions is generally carried out by small landholding families. Depending on these factors, greenhouse vegetable cultivation has also developed in Turkey, with production occurring in many regions. Among vegetables, the significance of winter vegetable production has been better understood in the last 30 years. Broccoli, in particular, has become one of the most important vegetables for healthy diets possessing of various phytonutrients. It's production and consumption has been increasing rapidly in recent years due to its health benefits.

In Turkey, broccoli production increased considerably in 2023, reaching 104,614 tons (TUIK, 2022). It grows well in the climatic conditions of the Aegean, Mediterranean, and Eastern Marmara regions, and it could be successfully grown in semi-arid ecosystems with appropriate irrigation methods and cultivation techniques. Optimal growth occurs at temperatures between 15-20°C, but high temperature can adversely affect its growth and development. There are early, mid-season, and late-season varieties of broccoli, with edible parts available depending on the harvesting time. The vegetation period for these cultivars ranges from 70 to 160 days. Broccoli grows best with a day length of 12-16 hours and in well-drained, rich in organic matter, slightly acidic soils (pH: 6.0-7.5).

When growing broccoli in semi-arid regions, drip irrigation can be used as irrigation is of great importance. Fertilizers that generally contain nitrogen, phosphorus, and potassium are ideal for broccoli, as they complement the missing nutritional elements identified through soil analysis. To obtain healthy seedlings, these were grown under controlled conditions. Seeds are sown in trays 26-35 days before transplanting. Seedlings that have reached transplant size transplanted into the field. Generally, the distance between plants in a row was set at 30-50 cm, and the distance between rows was kept 50-80 cm. The formation of side shoots affects these distances. Broccoli heads were harvested while they are tight and green. Delayed harvesting can cause the heads to flower. Semi-arid regions are characterized by low and irregular rainfall. Producing crops in these regions presents many challenges. Factors that make crop production challenging under these conditions include the scarcity of water and water resources, soil problems, evaporation and temperature, plant protection issues (diseases, pests, and weeds), and climatic conditions.

Failure to consistently provide the water needed in agriculture will lead to water scarcity. In these conditions, plants need regular irrigation water for their growth to become regular and, most importantly, to maintain productivity. In these regions, the presence of irrigation systems to compensate for insufficient rainfall ensures efficient crop production and does not negatively affect agricultural output.

Soil structure and fertility play crucial roles in crop production. In semi-arid regions, high temperatures generally lead to increase water loss through evaporation from both soil and plants. This high evaporation rate stresses plants, negatively impacting their growth and yield. Additionally, water scarcity, compounded by its high cost, further affects productivity. Insufficient irrigation exacerbates this issue by depriving plants of the water they need, leading to decreased productivity. Moreover, soils in semi-arid regions often lack organic matter and might be nutrient-deficient, further hindering plant nutrient uptake and resulting in low productivity. Another significant challenge is wind and water erosion. The topsoil is the most productive part for plants, and its loss undesirably impacts agricultural production. Some weeds, diseases, and pests may exhibit increased resistance in semi-arid conditions. Controlling these pests and diseases requires significant effort and cost. Climate change further complicates crop production in semi-arid regions. In vegetable cultivation, the timing of seed sowing or seedling transplanting is very crucial. To address these challenges, various crop production strategies and techniques would be employed including implementing water-saving irrigation techniques, such as drip irrigation, as part of water management practices; using organic fertilizers or cultivation techniques like mulching to enhance soil fertility as part of soil management; selecting drought-resistant and low-water-consumption plant species for resilient crop choices; and employing integrated pest management strategies to reduce reliance on synthetic chemicals. Additionally, training and raising awareness among farmers about farming practices suited to semi-arid conditions are essential components of educational and awareness initiatives.

These strategies can enhance the sustainability of agricultural production in semi-arid conditions, increase crop productivity, and support the livelihoods of people living in these regions. This study focuses on how broccoli cultivation can be effectively carried out in semi-arid conditions.

MATERIALS AND METHODS

Plant Material

The plant materials used in this study were Parthenon F1 and Orantes F1 cultivars. Parthenon F1 is known for its productivity and high quality suitable for both fresh table use and industry. It features compact, dome-shaped heads weighing 400-600 g, with a dark green color, a strong root system, and a harvesting time of approximately 80-85 days after transplanting seedlings. Orantes F1, recommended for fresh consumption and industry, has an

average head weight of 500 g and matures in about 70-75 days. Seeds of the Orantes F1 variety were sown on March 3, 2022, while seeds of the Parthenon F1 variety were planted in peat-filled plastic vials on September 1, 2022. Orantes F1 seedlings were transplanted to the field on April 12, 2022, and Parthenon F1 seedlings were introduced to the field on October 11, 2022. Images of the seedlings at planting size are shown in Figure 1.

a b

Figure 1. Seedlings at planting size of Orantes F1 (a) and Parthenon F1 (b) cultivars.

Site Discription

The current research was conducted at the Adıyaman University Agricultural Application and Land Management Research Center (ADYÜTAYAM), Before planting, land preparation and soil analyses were conducted. The experimental area has a clay soil structure with a pH of 7.5, 1.38% organic matter, 2.10% calcium carbonate, and is non-saline. The experiments were set up with 4 replications, each containing 10 plants. During the trial, three hoeings were performed for earthing up and weed control purposes. No plant protection products were used throughout the trial. Fertilization included 90 g of P-Smart, 25 g of K-Smart, and 100 g of urea applied to each sub-plot after planting. The average temperature, total rainfall, and humidity values between September 2022 and February 2023 are presented in Table 1.

Table 1. Climate data of the experimental area

Year/Month 2022	Avarage Teperature ^{0}C	Average Humidity (%)	Total rainfall (mm)
September	27.67	21.21	0.4
October	21.11	30.93	8.2
November	12.96	69.20	165.0
December	9.29	73.55	24.6
2023			
January	6.69	61.95	37.6
February	5.16	52.34	88.4

Recorded Parameters

Head width (cm), head height (cm), head weight (g), plant height (cm), yield (kg/da), and SPAD values were recorded in the plants. Vitamin C (mg/100 g FW) and N (%) contents were examined in the heads. The diameter of the main head was determined by measuring with a ruler. Head width was determined by measuring the diameter of the cut heads with a ruler. The height of the head was determined by measuring the part from the cut section to the top of the head with a ruler. Plant height was determined by measuring the plant from the soil surface to its top with a tape measure. Yield was obtained by collecting all the heads harvested in each plot replication wise. The SPAD readings were taken with the Konica Minolta SPAD-502 Plus device before 11 o'clock in the morning when the heads reached maturity. Vitamin C analysis (ascorbic acid) and the amount of Vitamin C (L-ascorbic acid) were measured by the spectrophotometric method according to Pearson and Churchill (1970).

RESULTS AND DISCUSSION

The measurements in Table 2 are given as the average of the measurements made from 5 plants in the sub-plots.

The main head diameter of the Parthenon F1 variety (11.83 cm) was measured higher than that of the Orantes F1 variety (8.46 cm) (Table 2). Similarly, in other studies, main head diameter values reported for broccoli include 17.85 cm (Alan and Sönmez, 2012), 9.93 cm (Yılmaz and Şahin, 2014), 12.44-13.15 cm (Sharif, 2008), 7.50-10.30 cm (Ouda and Mahadeen, 2008), 9.30-12.40 cm (Tan et al., 1999), 11.70-15.70 cm (Aslan, 2018), and 8.3-9.7 cm (Kaymak et al., 2023). The main head height of the Parthenon F1 variety (13.42 cm) was measured higher than that of the Orantes F1 variety (10.95 cm) (Table 2). Figure 2 shows the average curd diameter and length

measurements. The averages of the Parthenon F1 variety yielded higher results due to variety characteristics. In studies, main head height values measured in broccoli range from 11.28-16.23 cm (Alan and Sönmez, 2012), 11.2-16.8 cm (Yoldaş and Eşiyok, 2004), 10.50-14.53 cm (Ece and Güler, 2017), and 6.8-10.7 cm (Kaymak et al., 2023). It is well known that ecological conditions are crucial for broccoli cultivation (Günay, 1984) and for the adaptation of different varieties to semi-arid conditions (Ece and Güler, 2017). The differences in main head diameter and height are believed to be related to the planting season, aside from variety characteristics. These studies indicated that main head measurement values vary depending on factors such as planting time, planting density, fertilization, and irrigation practices. According to various literature sources, including Ece and Güler (2017), the adaptation of different broccoli varieties to ecological factors plays a significant role in cultivation.

Table 2. Measures parameters of broccoli cultivars.

Parametres & Cultivars	Replication	Mean Head width (cm)	Mean Head length (cm)	Mean Plant Heigh t (cm)	Mean Head Weight (g)	Mean SPAD reading	Mean Vitamin C	N Rate (%)	Yield (kg/da)
Orantes F1	1	8.32	10.79	48.64	166.920	73.56	100.16	3.80	968.225
	2	8.80	11.36	50.62	163.610	71.38	102.54	4.62	958.313
	3	8.28	10.70	48.90	162.840	72.78	99.15	4.52	955.424
	Mean Values	8.46	10.95	49.39	164.455	72.57	100.62	4.31	960.654
Parthenon F1	1	11.44	13.18	53.36	294.700	74.14	117.36	3.80	1.708,17
	2	11.88	13.54	55.02	299.590	70.32	108.22	3.54	1.731,33
	3	12.16	13.54	55.07	302.920	74.12	103.86	3.40	1.749,38
	Mean Values	11.83	13.42	54.48	299.070	72.86	111.76	3.64	1.729.63

In the trial, measurements of plant height parameters showed that Parthenon F1 resulted in higher measurements compared to Orantes F1, with average heights of 54.48 cm and 49.39 cm, respectively (Table 2). Plant height is influenced by factors such as climate, soil properties, planting density, transplanting date, and fertilization (Francescangeli et al., 2006; Singh et al., 2017; Solunke et al., 2011; Singhal et al., 2009). In various studies, broccoli plant heights have been measured as 54.80 cm, 53.70 cm, 59.87 cm, 71.52 cm, and 61.4 cm (Hafiz et al., 2015; Singhal et al., 2009; Meena et al., 2023; Yılmaz and Şahin, 2014; Yıldırım and Geyik, 2019). These variations are largely attributed to planting time and fertilization factors. In this study, autumn planting has been observed to yield better results.

The main head weight measured 166.640 g in initial spring cultivation in Adıyaman, whereas it measured 299.070 g in autumn cultivation (Table 2). Despite differences in variety characteristics, planting season has proven to be a crucial parameter in semi-arid conditions. Considering these results, trials with different varieties suitable for autumn planting have been established. In various studies, average head weights of different broccoli varieties have been measured as 547-678 g (Alan and Sönmez, 2012), 204-389 g in the Aegean region (Eşiyok, 1996), 536-729 g in Konya conditions (Karakaya, 2006), 380-560 g (Bozokalfa et al., 2009), 81-295 g (Kaymak et al., 2023), and 273.32-350.97 g (Moniruzzaman et al., 2007). The distribution of average curd weight (g) values in the trial is shown in Figure 4. Furthermore, the average head weight was measured in the Parthenon F1 variety, influenced by both variety characteristics and autumn planting.

When examining SPAD measurements (Table 2), it is evident that measurements for both varieties are similar, as shown in Figure 3. The SPAD readings in broccoli plants grown under semi-arid conditions were recorded as 72.56 and 72.86 (Table 2 and Figure 3). Kaymak et al. (2023) recorded a SPAD reading value of 87.6. SPAD readings underscore the importance of fertilization. In another study (Taşcı and Kuzucu, 2023), SPAD readings were measured at 70.20 in broccoli plants treated with chemical fertilizer. Vidigal et al. (2021) recorded SPAD reading values ranging from 64.28 to 71.33, emphasizing the impact of fertilizer applications. Kaymak et al. (2023) highlighted nitrogen's role as a constituent of amino acids and the chlorophyll molecule, explaining why SPAD readings are lower in control applications in various studies (Sattel et al., 1998; Taşcı and Kuzucu, 2023; Kaymak et al., 2023).

Toivonen et al. (1994) reported that climatic conditions strongly influence the vitamin C content in broccoli heads. Koh et al. (2009) found that vitamin C levels in broccoli range between 57.35–131.35 mg/100 g FW. In this study, the average vitamin C content was measured as 100.62 mg/100 g FW for the Orantes F1 variety and 111.76 mg/100 g FW for the Parthenon F1 variety (Table 2). The data obtained generally fall within the upper range of these reported values, likely due to variety characteristics and favorable post-harvest storage conditions. Kurilich et al. (1999) reported that vitamin C levels in 50 broccoli subspecies varied depending on the variety, ranging from 54.0 to 119.8 mg/100 g FW. Vitamin C content is an important parameter that changes with storage duration. Analyses of vitamin C at different storage periods (Carvalho and Clemente, 2004) found that levels in broccoli stored at 1°C decreased within 15 days, with the most significant decline occurring between days 12 and 15.

In the experiment, nitrogen content (% N) measured was 4.31 for the Orantes variety and 3.61 for the Parthenon

variety. Yılmaz and Şahin (2017) measured an average % N content of 2.27 in broccoli heads. Yoldaş et al. (2008) reported % N values ranging from 3.06 to 5.08 in broccoli heads also they reported the variation is attributed to fertilizer applications; the lowest measurement was obtained from the control treatment, while the maximum N content in the heads was measured with the application of 450 kg N ha−1. In another study, % N values in broccoli leaves ranged from 3.18 to 3.87 (Ouda and Mahadeen, 2008). The effect of organic fertilizers on % N content is reported to improve both the mineralization of these fertilizers and the physical and chemical properties of the soil (Ouda and Mahadeen, 2008).

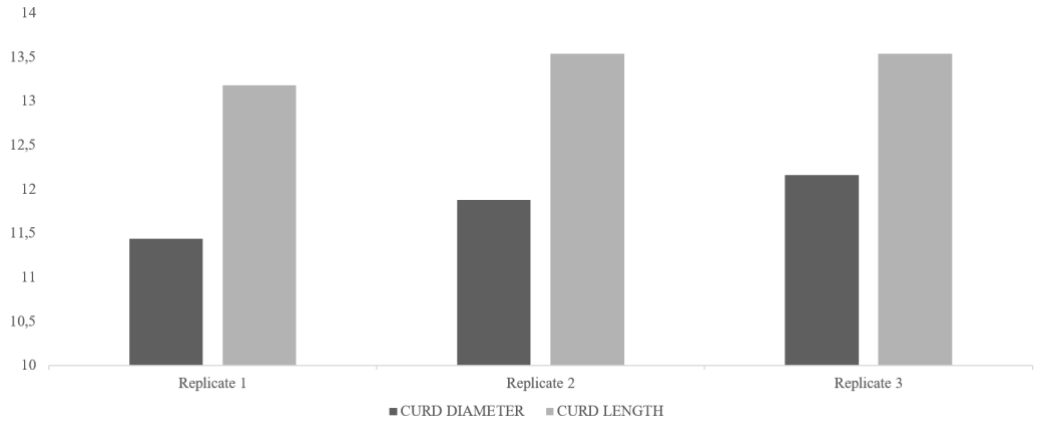

Figure 2. Average curd diameter and curd length values of broccoli cultivars.

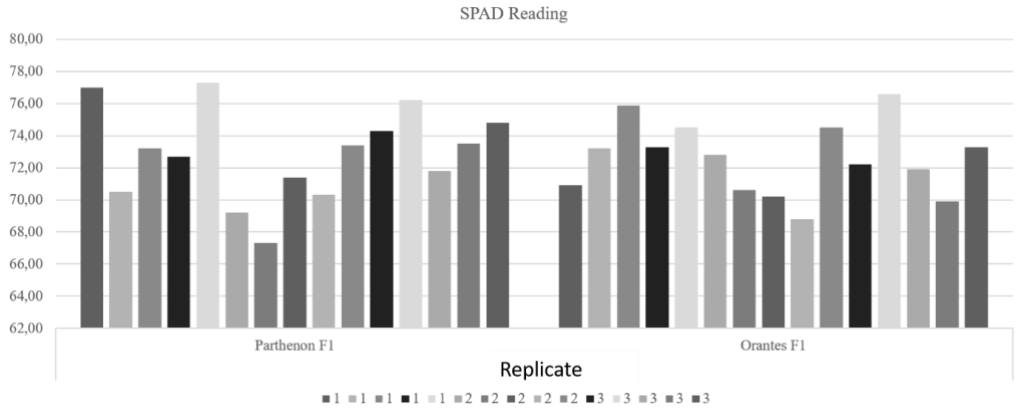

Figure 3. SPAD Reading Parameters measured in Parthenon F1 and Orantes F1.

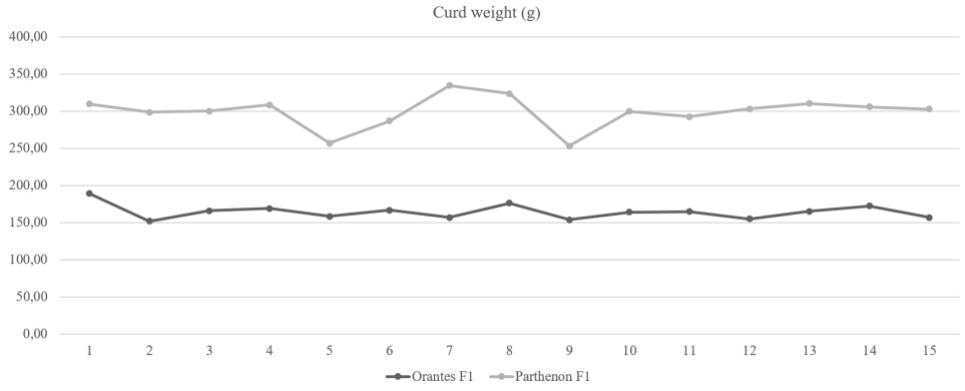

Figure 4. Head weights of broccoli cultivars in semi-arid conditions.

CONCLUSION

Broccoli, which is important for human health, is not very selective in terms of soil requirements. Depending on the variety characteristics, broccoli plants can be grown in high quality in areas where soil organic matter is high or where plant nutrition is provided. Broccoli is sensitive to drought, loses its crown quality in case of sudden

heat increase and forms scattered crowns, but it has been observed that it can adapt to the environment as well as cauliflower and can be resistant to temperature changes. It has been observed that broccoli can be economically cultivated in Adıyaman when planted in the autumn season. It is believed that promoting alternative vegetable cultivation such as broccoli in Adıyaman, among the GAP (Southeastern Anatolia Project) provinces, could address the deficiency in seedling production facilities in the region. Broccoli is grown in a very small portion of home gardening in Adıyaman during the winter season. The limited growth and yield of broccoli are thought to result from inadequate application of fertilizers, lack of appropriate cultural control methods, and management practices. The expansion of broccoli cultivation and analysis of its growth parameters are of great importance. Harvest strategies, optimal number for selective hand harvesting per date, and the harvestable head count per date (biological aspects) impact both current market supply and price conditions (economic aspects). Price fluctuations during harvesting are also crucial for economic viability and therefore need to be analyzed economically (Lindemann-Zutz et al., 2016). Vegetable cultivation can enhance productivity in semi-arid conditions through techniques such as drip irrigation, mulching, and appropriate fertilization methods. Additionally, sustainable agricultural practices can be supported through integrated pest management techniques. Experiments should be conducted on fertilizer types and dosages in semi-arid conditions, leveraging the significant benefits of nitrogen on plant measurement parameters such as head diameter, head weight, and above ground biomass. In semi-arid regions, these methods can make broccoli cultivation economically and ecologically advantageous. These studies demonstrate that with irrigation programs, particularly during periods of low rainfall, and using fertilizers high in nitrogen content, alternative vegetable cultivation such as broccoli can be successfully conducted while mitigating water stress.

Compliance with Ethical Standards

Peer-review

Externally peer-reviewed.

Declaration of Interests

The authors state there is no competing interest.

Author contribution

Designed and performed the experiment: Bayram C.A., Formal data analysis and writing: Bayram C.A.

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REFERENCES

Alan, Ö., & Sönmez, K. (2012). Determination of Agricultural Characteristics and Possibilities of Growing Some Broccoli Varieties (*Brassica oleracea* L. var. italica) in Eskisehir Ecological Conditions. Selcuk Journal of Agriculture and Food Sciences, 26(3), 29-35.

Aslan, M. H. (2018). Effect of different water levels and nitrogen dozes on yield and yield components of broccoli (*Brassica oleraceae* var. italica) plant in semiarid climate conditions (Doctoral dissertation).

Balkaya, A., Sarıbaş, S., & Özgen, T. (2016). Türkiye' de kışlık sebze türlerinin tarımsal üretimdeki yeri ve önemi. Türktob Dergisi, 5 (20): 8–12. (in Turkish)

Balkaya, A, Karaağaç, O., Atasoy S. (2023). Geçmişten Geleceğe Türkiye'de Lahanagil Sebzelerinin Üretimi, Sorunlari Ve Çözüm Önerileri. İKSAD yayınevi " Farklı Yönleriyle Lahanagiller Üzerine Bilimsel Çalışmalar. 1. Bölüm, 3-36. (in Turkish)

Bozokalfa, M.K., Duman, İ., Yolageldi, L., Turhan, G., Turhan, K. (2009) Brassicaeae ve Solanaceae familyası sebzelerinin münavebeli yetiştiriciliğinde türlerin karşılıklı etkileşimlerinin verim ve kalite özelliklerine etkisi, Anadolu Tarım Bilimleri Dergisi, 19 (1), 47- 62. (in Turkish)

Carvalho, Paulo de Tarso., & Clemente, E. (2004). The influence of the broccoli (*Brassica oleracea* var. itálica) fill weigth on postharvest quality. Food Science and Technology, 24, 646-651.

Ece, A., & Güler, S. (2017). Kızılırmak'ta (Çankırı) ikici ürün olarak kullanılabilecek alternatif sebze türlerinin belirlenmesi. Tekirdağ Ziraat Fakültesi Dergisi, 14(1). (in Turkish)

Eşiyok, D. (1996). Bornova Koşullarında Yetiştirilmeye Uygun Brokkoli Çeşitlerinin Belirlenmesi Üzerine Bir Araştırma. Ege Üniversitesi Ziraat Fakültesi Dergisi, 33(1): 55-62. Bornova-İzmir. (in Turkish)

Francescangeli, N., Sangiacomo, M. A., & Martí, H. (2006). Effects of plant density in broccoli on yield and radiation use efficiency. Scientia Horticulturae, 110(2), 135-143.

Günay, A. (1984). Özel Sebze Yetiştiriciliği, Cilt: III, Çağ Matbaası, Ankara. (in Turkish)

Hafiz, M. A., Biswas, A., Zakaria, M., Hassan, J., & Ivy, N. A. (2015). Effect of planting dates on the yield of broccoli genotypes. Bangladesh Journal of Agricultural Research, 40(3), 465-478.

Karakaya, Z. (2006). Yaz Sezonunda Yetiştirilen Brokkolide (*Brassica oleracea* L. var. italica) Bazı Organik Maddelerin Bitki Gelişmesi, Verim ve Kaliteye Etkileri. Selçuk Üniversitesi Ziraat Fakültesi Fen Bilimleri Enstitüsü. Yüksek Lisans Tezi, 57s. (in Turkish)

Kaymak, H. Ç., Tıraşcı, S., & Kaşka, M. (2023). Assessing Chicken Manure's Competitiveness with Inorganic

Nitrogen in Broccoli Production. Akademik Ziraat Dergisi, 12(2), 169-176.
Koh, E., Wimalasiri, K. M. S., Chassy, A. W., & Mitchell, A. E. (2009). Content of ascorbic acid, quercetin, kaempferol and total phenolics in commercial broccoli. Journal of Food Composition and Analysis, 22(7-8), 637-643.
Kurilich, A. C., Tsau, G. J., Brown, A., Howard, L., Klein, B. P., Jeffery, E. H., ... & Juvik, J. A. (1999). Carotene, tocopherol, and ascorbate contents in subspecies of Brassica oleracea. Journal of Agricultural and Food Chemistry, 47(4), 1576-1581.
Lindemann-Zutz, K., Fricke, A., & Stützel, H. (2016). Prediction of time to harvest and its variability in broccoli (*Brassica oleracea* var. italica) Part I. Plant developmental variation and forecast of time to head induction. Scientia Horticulturae, 198, 424-433.
Meena, A. K., Gupta, A., Kumar, M., Thakur, V., Rangu, T., & Ahmad, M. (2023). Effect of Bio-Fertilizers On Growth, Quality, Yield and Economics of Broccoli (*Brassica oleracea* L. Var. Italica). International. Journal of Agricultural and. Statistical Sciencies, Vol, 19(2), 753-758.
Moniruzzaman, M., Rahman, S. M. L., Kibria, M. G., Rahman, M. A., & Hossain, M. M. (2007). Effect of boron and nitrogen on yield and hollowstem of broccoli. Journal of Soil and Nature, 1(3), 24-29.
Ouda, B. A., & Mahadeen, A. Y. (2008). Effect of fertilizers on growth, yield, yield components, quality and certain nutrient contents in broccoli (*Brassica oleracea*). International Journal of Agriculture and Biology, 10(6), 627-632.
Pearson, D., & Churchill, A. A. (1970). The Chemical Analysis of Foods. Gloucester Place.
Sattel, R., Dick, R., Luna, J., McGrath, D., & Peachey, E. (1998). Common vetch (*Vicia sativa* L.). Citeable URL:https://ir.library.oregonstate.edu/concern/open_educational_resources/nz806009x
Sharif, A. A. (2008). Effect of Spacing and Potassium on Growth and Yield Of Broccoli (*Brassica oleracea* L. var. italica) (Doctoral dissertation, Dept. Of Agricultural Extension & Information System).
Singh, G., Sarvanan, S., Rajawat, K. S., Rathore, J. S., & Singh, G. (2017). Effect of different micronutrients on plant growth, yield and flower bud quality of broccoli (*Brassica Oleracea* var. Italica). Current Agriculture Research Journal, 5(1), 108-115.
Solunke, B. G., Wagh, A. P., Dod, V. N., & Nagre, P. K. (2011). Effect of dates of planting and spacing on growth and yield of broccoli. Asian Journal of Horticulture.6(2), 294-296.
Tan, D.K.Y., Wearing, A.H. Rickert, K.G. and Birch, C.J. (1999). Broccoli yield and quality can be determined by cultivar and temperature but not photoperiod in south-east Queensland. Australian Journal of Experimental Agriculture, 39: 901–907
Tascı, F.G., & Kuzucu, C.O. (2023). The effects of vermicompost and green manure use on yield and economic factors in broccoli. Horticulturae, 9, 406.
Toivonen, P. M., Zebarth, B. J., & Bowen, P. A. (1994). Effect of nitrogen fertilization on head size, vitamin C content and storage life of broccoli (*Brassica oleracea* var. italica). Canadian Journal of Plant Science, 74(3), 607-610.
Türkiye İstatistik Kurumu (TÜİK) (2022). Bitkisel Üretim, 2022. Erişim adresi: https://data.tuik.gov.tr/ (in Turkish)
Vidigal, S. M., Puiatti, M., Lopes, I. P. D. C., & Sediyama, M. A. N. (2021). Nitrogen content, SPAD index and production of single head broccoli. Horticultura Brasileira, 39(1), 52-57.
Yıldırım, D. E. (2017). Trabzon ili brokoli yetiştiriciliğinde farklı dikim zamanlarının bitki gelişimi ve verimi üzerine etkileri (Doctoral dissertation). (in Turkish)
Yıldırım, E., & Gedik, A. (2019). Effect of planting times on growth and yield of different cultivars in broccoli cultivation. Journal of Alatarim, 18(2), 125-134.
Singhal, P., Srivastava, B. K., Singh, M. P., & Singh, P. K. (2009). Effect of date of planting and spacing on the performance of broccoli. Indian Journal of Horticulture, 66(1), 137-140.
Yanmaz, R., Balkaya, A., Akan, S., Kaymak, H.Ç., Sarıkamış, G., Ulukapı Önal, K., Karaağaç, O., Güvenç, İ., Kurtar, E.S., & Açıkgöz Eryılmaz, F. (2020). Türkiye ZMO IX. Türkiye Ziraat Müh. Teknik Kongresi. Bildiriler Kitabı. Cilt 1, 585-607. (in Turkish)
Yanmaz, R., Duman, İ., Yaralı, F., Demir, K., Sarıkamış, G., Sarı, N., Balkaya, A., Kaymak, H.Ç., Akan, S., & Özalp, R. (2015). Sebze üretiminde değişimler ve yeni arayışlar. Türkiye ZMO VIII. Türkiye Ziraat Müh. Teknik Kongresi. Bildiriler Kitabı. Cilt 1, 579-605. (in Turkish)
Yılmaz, M., & Şahin, S. (2014). Yeşil gübrelemede kullanılan bakla (*Vicia faba* L.) bitkisinin brokoli verimi üzerine etkilerinin belirlenmesi. Journal of Agricultural Faculty of Gaziosmanpaşa University, (1), 86-95. (in Turkish)
Yoldas, F., Ceylan, S., Yagmur, B., & Mordogan, N. (2008). Effects of nitrogen fertilizer on yield quality and nutrient content in broccoli. Journal of Plant Nutrition, 31(7), 1333-1343.
Yoldaş, F. ve Eşiyok, D. (2004). Dikim Sıklığı, Ekim ve Dikim Zamanlarının Brokkoli'de Verim ve Kalite Parametreleri Üzerine Etkisi. Ege Üniversitesi Ziraat Fakültesi Dergisi, 41(2):37-48. (in Turkish)