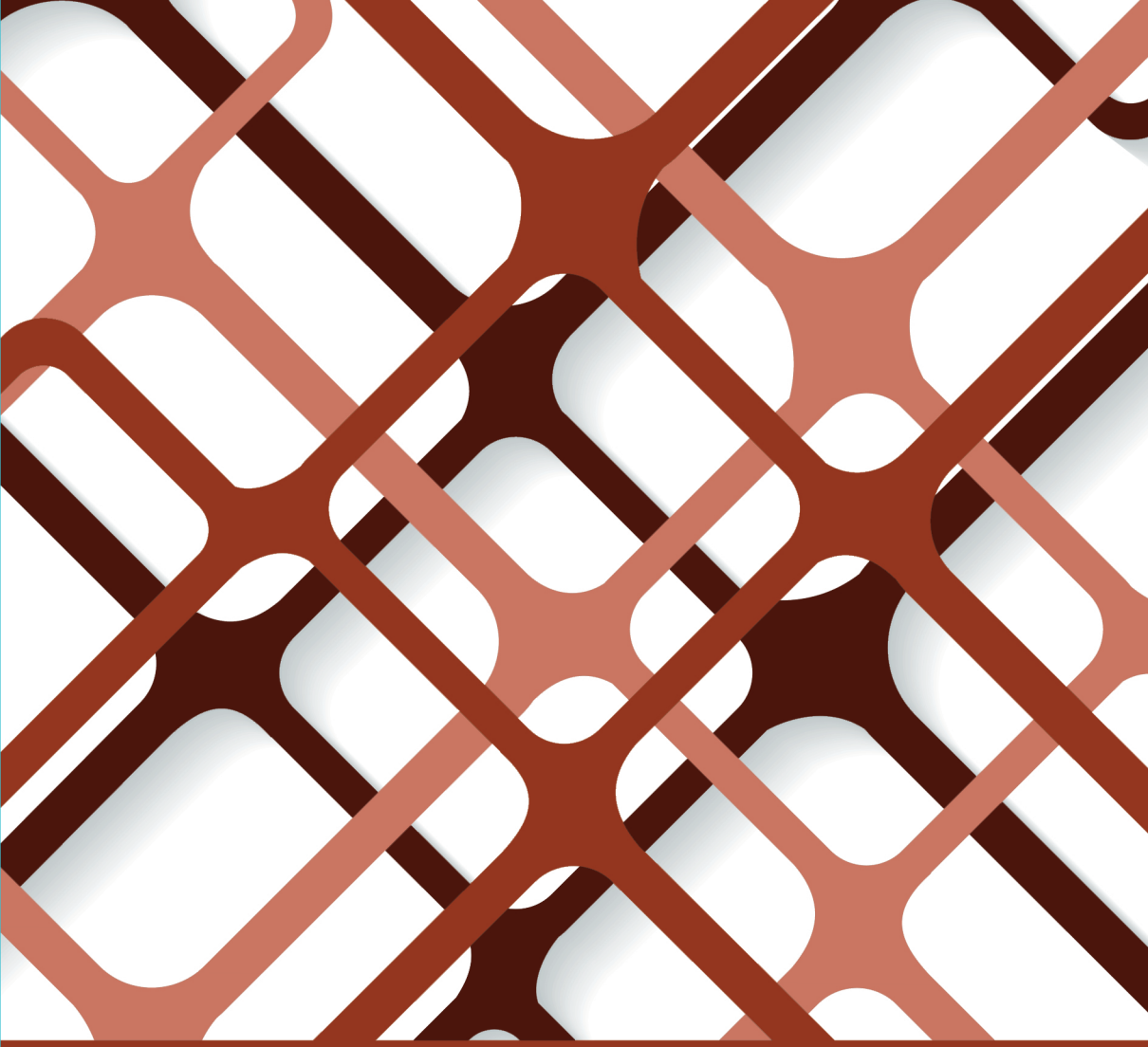

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SEPTEMBER/2021

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PROF. DR. NİGAR YARPUZ BOZDOĞAN
PROF. DR. KORAY ÖZRENK
ASSOC. PROF. DR. ALİ BEYHAN UÇAK

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CONTENTS

Chapter 1

AN OVERVIEW: *MYCOPLASMA BOVIS*

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1. Nomenclature and characteristics

Mycoplasma bovis is classified under the class *Mollicutes* in the phylum *Firmicutes* (Maina, 2019) (Table 1). *Mollicutes* is a special class of bacteria, which lack a cell wall and have a very small genome size (Parker *et al.,* 2018).

Classification	
Domain	Bacteria
Phylum	Firmicutes
Class	Mollicutes
Family	Mycoplasmacetae
Genus	Mycoplasma
Species	M. bovis

Table 1: *Classification of Mycoplasma bovis*

M. bovis is a bacterium, which is devoid of a cell wall and causes pneumonia, mastitis, arthritis, and significantly decreased milk yields, particularly in large herds. Clinical infection with *M. bovis* follows a chronic course, is exhausting, and does not respond to antimicrobial treatment, eventually causing significant economic loss in cattle farming worldwide (Lysnyansky and Ayling, 2016). *M. bovis* has a tight association with the host cells like many other Mycoplasma species (Caswell *et al.,* 2010). The genome of *M. bovis* is of a size of approximately 948 kbp to 1,038 kbp and has a G+C ratio of 27.29% (Maina, 2019). *M. bovis* was first isolated in the USA in 1961, and since then has spread to other countries through animal transport (Karahan *et al.,* 2010). Due to its small genome, *Mycoplasma* depends on the growth of host cells for survival (Maunsell and Donovan, 2009). *M. bovis* has an elaborate genetic system, which encodes variable surface lipoproteins (Vsps) that are antigenic and activate host immune response (Bürki *et al.,* 2015). Vsps are involved in colonization, adhesion, and immune evasion from the host immune system. The main features of Vsps are: (i) an independent phase variation of high frequency between the ON and OFF states of expression, (ii) membrane anchorage via the N-terminal domain, (iii) independent high-frequency size variation and a surface-exposed C-terminal region, (iv) repeating domains throughout the length of the Vsp molecule, and (v) shared epitopes (Bürki *et al.,* 2015). *M. bovis* strains may possess different versions of the Vsp-encoding gene complex, which results in a multitude of phenotypic variations (Perez-Casal *et al.,* 2017). In addition to Vsps, membrane proteins have also

been identified, and their variable expression play an important role in the challenge of realizing the large-scale production of vaccines against *M. bovis* (Gille, 2018). High-frequency antigenic switching is successfully used by *M. bovis* to maintain strain diversity and avoid the host immune system; and hence, contributes to the chronic presentation of the disease (Maina, 2019). *M. bovis* has the ability to weaken the immune response by suppressing lymphocyte proliferation and inhibiting the oxidative burst of neutrophils (Gille, 2018; Srikumaran *et al.,* 2007). The ability of *M. bovis* to produce a biofilm enables it to both stay in the environment long enough and withstand the pressure of desiccation or heat (McAuliffe *et al.,* 2006). *M. bovis* is an important pathogen, which causes various diseases in animals, including pneumonia, mastitis, arthritis, infertility and keratoconjunctivitis (Maina, 2019; Hermeyer *et al.,* 2012). Despite the efforts that have been made by many researchers to control this pathogen and reduce the economic losses caused by it, an effective vaccine is still unavailable (Perez-Casal *et al.,* 2017).

2. Pathology and disease

Mastitis

Mastitis, which can be caused by *M. bovis*, is a major health problem in dairy herds as it reduces both the quantity and quality of milk (Timonen *et al.,* 2017). *M. bovis* is transmitted among animals by milking equipment or milker's hands contaminated with infected milk (Ruegg, 2012). Clinical mastitis is characterized by abnormal udder secretions, altered milk consistency, significantly decreased milk production and unresponsiveness to treatment. Milk consistency may vary from watery to purulent and may appear as sandy or flaky sediments in watery or yellowish fluid (Gille, 2018). Milk is an important transmission vector of mastitis for animals (Junqueira *et al.,* 2020). In order to control *M. bovis*-induced mastitis, it is required to test the entire dairy herd and detect the infected animals (Junqueira *et al.,* 2020). *M. bovis*-induced mastitis is not treatable with antibiotics, and the only means of control is the identification, segregation and culling of infected animals (Junqueira *et al.,* 2020; Timonen *et al.,* 2017; Nicholas *et al.,* 2016). In cases where a large proportion of the herd is infected and immediate culling is not possible, infected animals must be identified and segregated to limit opportunities for transmission. To avoid the transmission of *M. bovis* within a herd, infected animals must be milked last and milking equipment must be fully disinfected between milkings (Nicholas *et al.,* 2016).

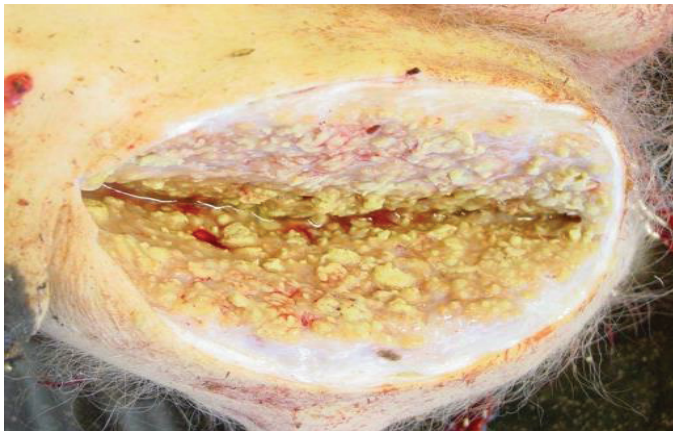

Figure 1: *Purulent mastitis*

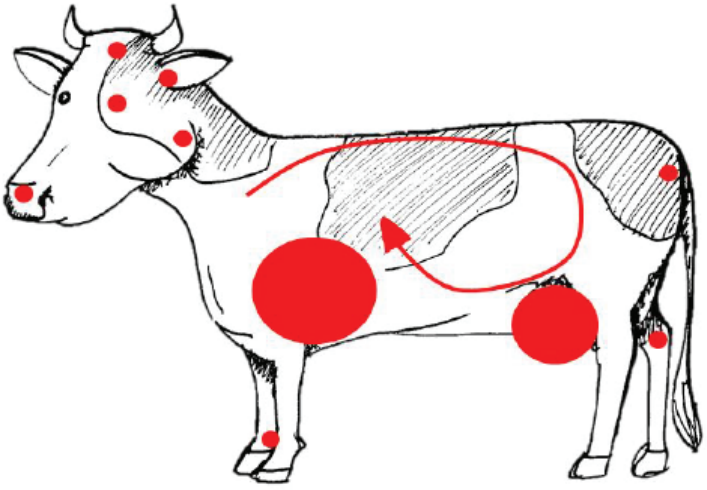

Figure 2: *The most common M. bovis predilection sites (Gille, 2018)*

Pneumonia

Bovine respiratory disease (BRD) (pneumonia or shipping fever), which can be triggered by *M. bovis*, is the leading cause of economic loss in the beef industry worldwide. Clinical signs are generally related to pneumonia and include a runny nose, lethargy, decreased appetite, separation from the herd, a gaunt appearance, sores in the mouth or on the nose, coughing, and an increased respiratory rate (Ward and Powell, 2017).

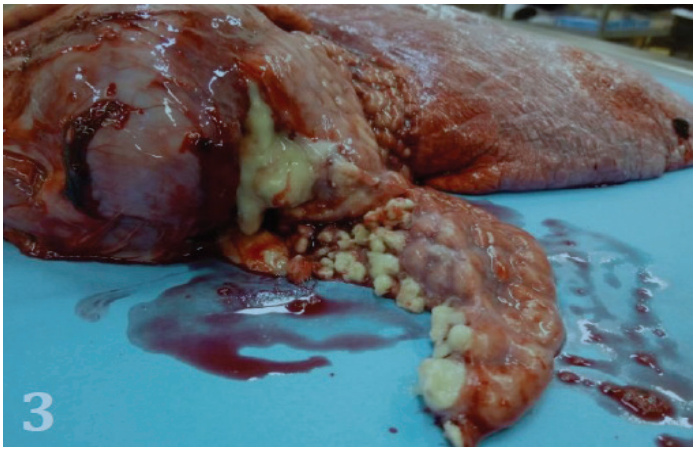

Figure 3: *Pneumonia of the lung (Gille, 2018)*

Severe lung damage occurs from inflammation as the disease progresses, and this damage is irreversible (Ward and Powell, 2017).

Arthritis

Clinical signs associated with arthritis are acute lameness, swelling of the joints and tendon sheaths, and high fever (Hewicker-Trautwein *et al.,* 2002). The shoulders, elbows and knees are also affected. Cartilage erosion also occurs with disease progression, and eventually cartilage is replaced by fibrous connective tissue. Experimental infection is reported to manifest with ulcers on the distal planum of the knees and the secondary laceration of the synovial sac (Gille, 2018). The stifle joint is filled with fluid and fibrin, and the synovium is hyperplastic (Figures 4 and 5) (Gille, 2018; Gagea *et al.,* 2006). *M. bovis*-induced arthritis is generally associated with lesions in the internal organs, including the udder and lungs. Response to treatment is poor, such that infected animals are mostly culled, yet in cases with only one infected joint, arthrodesis can be performed (Gille, 2018).

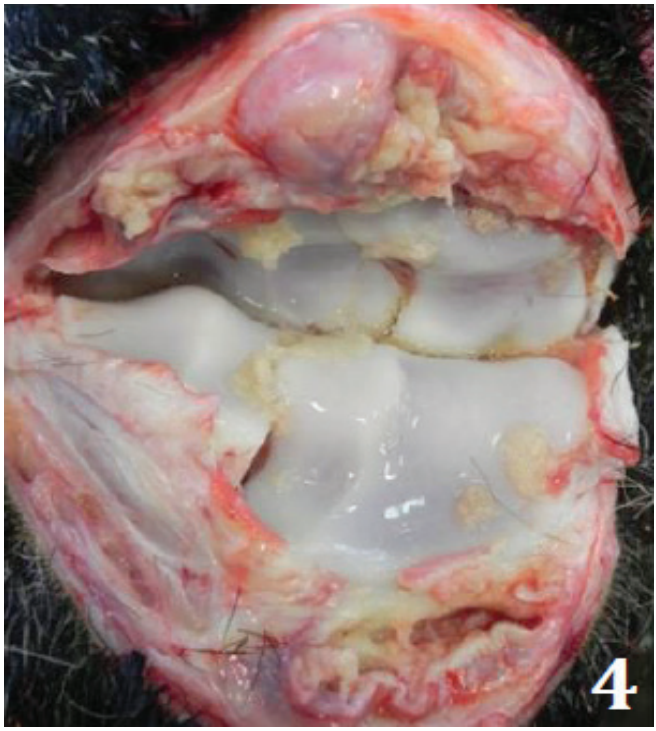

Figure 4: *Fibrinous arthritis caused by M. bovis*

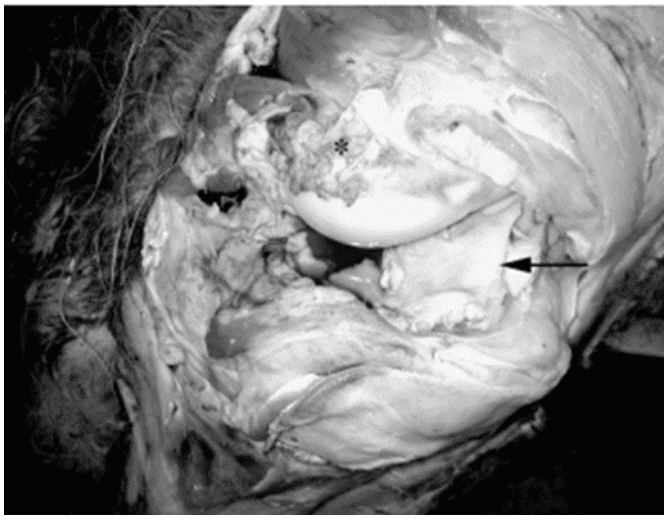

Figure 5: *The stifle joint is filled with fluid and fibrin*

3. Diagnosis

Given the indistinctiveness of the associated clinical symptoms and pathological lesions, laboratory diagnosis is required for the identification *M. bovis* infection (Karahan *et al.,* 2010). Traditionally, *Mycoplasma* species are isolated and identified by culturing samples taken from an infected organ. Known to be incapable of synthesizing amino acids and either completely or partially incapable of synthesizing fatty acids, *M. bovis* is grown on highly enriched media (Parker *et al.,* 2018). As the overgrowth of other faster growing bacteria can compromise the isolation of mycoplasmas by culture, antimicrobials such as thallium acetate or antibiotics are added into the media (Parker *et al.,* 2018). Mycoplasma species are incubated for a period of 7-10 days at 37°C, under 5% CO_2, which results in the growth of micro-colonies that morphologically resemble "fried eggs" under a light microscope (Quinn *et al.,* 2013). Both culture and serology are laboursome, time-consuming and costly, and bear the risk of producing false results due to contamination and cross-reactions (Karahan *et al.,* 2010). Bacteriological and serological methods lack the sensitivity and specificity that would contribute to improving treatment and control strategies for *M. bovis* (Karahan *et al.,* 2010). In recent years, molecular diagnostic methods have become the first choice to identify *M. bovis*. There is a need for rapid and reliable methods to offer an alternative to conventional methods (Salina *et al.,* 2020). When compared to microbiological culture, the polymerase chain reaction (PCR) offers rapid and sensitive results in the detection of Mycoplasma species (Parker *et al.,* 2018). Through the use of species-specific primers, PCR enables the identification of different species (Salina *et al.,* 2020; Parker *et al.,* 2018). Real-time PCR significantly reduces the time required for identifying Mycoplasma species. This technique involves the use of SYBR green dye intercalation and fluorescent reporter probes. By binding to all double-stranded DNA, cyanine SYBR green dye results in a light emission measured at 520 nm wavelength. With the progression of the PCR cycles, the target double-stranded DNA increases in quantity, resulting in a proportionate increase in the amount of light emitted from the dye, and thereby, allows the detection of the PCR products in real-time culture (Parker *et al.,* 2018). As SYBR green is not sequence-specific and binds to all double-stranded DNA, it may increase background signals and decrease specificity, compared to probe-based real-time PCR (Parker *et al.,* 2018; Wong, 2013). The fluorescent reporter probe method, which typically utilizes a hydrolysis probe, offers greater specificity. This technique is based on the binding of the probe to a specific target region, which is internal to the primer binding sites. Cleaving-off and fluorescence of the reporter dye is observed as the PCR cycles progress. An increased

quantity of the PCR product targeted by the probe proportionally increases the fluorescence (Parker *et al.,* 2018; Wong, 2013). While real-time PCR measures the amount of the PCR product by the end of the procedure, the fluorescent reporter probe technique measures amplification as the PCR occurs (Parker *et al.,* 2018).

4. The prevalence of *M. bovis* (Epidemiology)

M. bovis was isolated from bovine mastitic milk in the USA (1962), Israel (1964), Canada (1976), Europe (1971-1981) and Japan (1977). Prior to 1992, the Netherlands observed an increased incidence in *M. bovis*-induced bovine diseases (mastitis, pneumonia and arthritis), and the increasing prevalence of this pathogen was first reported in 1992 (ter Laak *et al.* 1992). Based on the sampling of bulk milk tanks, the prevalence of Mycoplasma-induced mastitis was determined to be higher in other European countries, with reports of 1.5% from Belgium and 5.4% from Greece. Mycoplasma-induced mastitis outbreaks have been reported in Austria (Spergser *et al*., 2013), Denmark (Nielsen *et al.,* 2015), Switzerland (Aebi *et al.,* 2015), and the Netherlands (van Engelen *et al.,* 2015). In Israel, between the years 2004-2007, the percentage of herds infected with *M. bovis* was < 1%, but increased to almost 4% in 2008, and ranged from <1% to 3% in the period between 2009-2014 (Nicholas *et al.,* 2016). The herd prevalence of Mycoplasma-induced mastitis has been reported as 55% in Mexico (Miranda-Morales *et al.,* 2008) and 100% in Iran (Ghazaei et al., 2006). While the spread of *M. bovis* is reported to be low in dairy herds in Australia (Morton et al., 2014), New Zealand is considered free from *M. bovis* (McDonald *et al*., 2009). In the USA, the prevalence of Mycoplasma species ranges from <3% of bulk milk tanks in the Midwest and Northeast to 9.4% of the large dairy herds raised in the West (Fox, 2012). In China, *M. bovis*-induced mastitis was first reported in 1983, and the first case of *M. bovis*-induced pneumonia was reported in 2008 (Menghwar *et al*., 2017). The prevalence of *M. bovis*-induced pneumonia has significantly increased, particularly in feedlots, in many countries, including among others the United States of America, France, Mexico, Canada, Northern Ireland and Italy (Margineda *et al*., 2017).

5. Antimicrobial resistance

Antimicrobial resistance is an issue of concern in both human and veterinary medicine (Cai *et al.,* 2019). In the absence of an effective vaccine, only strict control measures and antimicrobial treatment can be used to control *M. bovis* infections (Bokma *et al.,* 2020; Lysnyansky and Ayling, 2016). *M. bovis* is insusceptible to ß-lactams and all antimicrobials targeting the cell wall (Cai *et al.,* 2019). As Mycoplasmas do not synthesize

folic acid, sulfonamides are also ineffective against them (Maunsell *et al.,* 2011). Mycoplasmastatic antimicrobials give the host immune system a chance to fight the infection, but *M. bovis* is equipped with defense mechanisms, including the ability to alter its surface proteins and form biofilms (Lysnyansky and Ayling, 2016; McAuliffe *et al.,* 2006). The control of *M. bovis* infections requires early identification and antimicrobial treatment with macrolides, tetracyclines and some fluoroquinolones (Cai *et al.,* 2019). Tetracyclines, chlortetracyline and doxycycline bind to the 30S ribosomal subunit and block the attachment of aminoacyl-tRNA to the A site, and thereby, inhibit ribosomal protein synthesis (Lysnyansky and Ayling, 2016; Bryskier, 2005a). In field experiments, some antimicrobials have been shown to significantly decrease respiratory diseases caused by *M. bovis* (Bartram *et al.*, 2016). In recent studies conducted in several countries, *M. bovis* has been determined to be less sensitive to various antimicrobial classes targeting protein and DNA synthesis (Bokma *et al.,* 2020).

While high percentages of macrolide resistance have been reported for *M. bovis* isolates, fluoroquinolones still show the highest in vitro antimicrobial activity in the majority of countries (Liu *et al.,* 2020; Becker *et al.,* 2020; Bokma *et al.,* 2020; Cai *et al.,* 2019), except for Spain and Italy (García-Galán *et al.,* 2020). Many studies report differences in the susceptibility of *M. bovis* isolates to antimicrobials, which are attributed to geographical origin, type of livestock production system, year of isolation, isolation site of tested strains, and differences in the antimicrobial preferences of countries (Lysnyansky *et al.,* 2009). The evolution of antimicrobial resistance in *M. bovis* is mainly associated to mutations in chromosomal genes. Today, microbroth dilution methods remain the first choice for the sensitivity testing of Mycoplasma species (Gille, 2018). The small genome size and coding capacity of Mycoplasma species make these bacteria an ideal model for genetic studies. Understanding the antimicrobial resistance mechanisms of *M. bovis* will contribute to the future development of genetic diagnostic assays for the rapid detection of resistant strains (Kong *et al.,* 2016). Many studies have reported low sensitivity to various commercial antimicrobials and highlighted the development of resistant strains all over the world (Sulyok *et al.,* 2014; Ayling *et al.,* 2014; Lerner *et al.,* 2014; Gautier-Bouchardon *et al.,* 2014).

6. Prevention and control

Several studies have aimed to develop an effective vaccine for the reduction of the incidence of *M. bovis*, but the majority are of no avail (Dudek *et al.,* 2016). Although some small-scale trials appear to have succeeded in achieving protection against *M. bovis* and elevating *M.*

bovis-specific antibody titers, large-scale studies targeted at developing commercial vaccines have produced either no or small protective impact (Mulongo *et al.,* 2013). The diverse expression of variable surface lipoproteins can be held accountable for this restricted efficiency of vaccines (Dudek et al., 2016). The introduction of asymptomatic infected animals is the biggest threat for the spread of infection to *M. bovis*-free herds (Gille, 2018; Maunsell *et al.*, 2011). *M. bovis* can be easily transmitted from infected to uninfected animals (Maunsell *et al.*, 2011). If new cattle are sourced, serological tests, nasal swabs and milk analysis should be performed during their quarantine period (Gille, 2018).

The introduction and purchase of biological materials (milk, feces, colostrum) should be avoided, due to their inherent infectious potential. Also all transportation devices and farming equipment used on farms should be thoroughly disinfected. Animal merchants, milk truck drivers, veterinarians and equipment in contact with cattle should be perceived as hygienic risks (Gille, 2018). Due to treatment failure on dairy farms, many experts have advised the culling of all animals that test positive for *M. bovis* by PCR or culture (Nicholas *et al.*, 2016). If culling is not feasible, infected animals must be identified, segregated and milked last. Individual udder preparation and milking hygiene are particularly important in preventing the spread of infection during milking. Throughout the milking process, gloves should be worn, and gloves should be disinfected between cattle (Gille, 2018). Teats should be dipped in 1% iodine for the removal of biological and organic materials, and all milking equipment should be disinfected with a sanitizer. Poor ventilation in barns and the housing of calves and cattle together, appear to increase the prevalence of mastitis. Several precautions can be taken to reduce the risk of transmitting infection to young calves (Gille, 2018). It is preferable to feed calves with milk alternatives or pasteurized milk, and pasteurization can be performed at 65°C for 1 hour to eliminate the risk of infection (Gille, 2018; Maunsell *et al.,* 2012). Individual housing is another successful measure to avert infection, and feed or milk buckets should not be alternated between animals. Healthy animals should not be housed together with chronically sick cattle to avoid the spread of infection in the herd (Maunsell *et al.,* 2011). Euthanasia is an option for chronically sick cattle, and enables both reducing infection and protecting animal welfare (Gille, 2018; Caswell *et al.,* 2010). Given that *M. bovis* can remain in the environment for a period ranging from days to months, the environment must be well sterilized with 0.5% sodium hypochlorite or 2% chlorhexidine. *M. bovis* is susceptible to desiccation, so after disinfection, leaving the environment to dry may decrease contamination (Justice-Allen *et al.,* 2010).

Conclusion

In conclusion, research points out to not only an increasing occurrence of resistance in *M. bovis*, but also the emergence of resistant strains at an alarming rate. Infections are getting out of control and becoming harder to treat while vaccine-based protection is unavailable. Thus, it is imperative to raise public awareness to avoid the overuse and misuse of antibiotics.

References

Ayling, R. D., Rosales, R. S., Barden, G., & Gosney, F. L. (2014). Changes in antimicrobial susceptibility of Mycoplasma bovis isolates from Great Britain. Veterinary Record, 175(19), 486-486.

Aebi, M., van den Borne, H.P., Bart, A., Steiner, A., Pilo, P., Bodmer, M., 2015. *Mycoplasma bovis* infections. in Swiss dairy cattle: A clinical investigation. Acta Veterinaria Scandinavica 57, 10-21

Bartram, D. J., H. Moyaert, B. H. Vanimisetti, C. P. Ramage, D. Reddick, and M. R. Stegemann. 2016. Comparative efficacy of tulathromycin and tildipirosin for the treatment of experimental *Mycoplasma bovis* infection in calves. Veterinary Medicine and Science 2(3):170-178.

Bryskier A. (2005a). Tetracyclines, in *Antimicrobial Agents, Antibacterials and Antifungals*, ed Bryskier A. (Washington, DC: ASM Press;), 642–651.

Bokma, J., Gille, L., De Bleecker, K., Callens, J., Haesebrouck, F., Pardon, B., & Boyen, F. (2020). Antimicrobial Susceptibility of Mycoplasma bovis Isolates from Veal, Dairy and Beef Herds. *Antibiotics*, *9*(12), 882.

Bürki, S., Frey, J., & Pilo, P. (2015). Virulence, persistence and dissemination of Mycoplasma bovis. *Veterinary microbiology*, *179*(1-2), 15-22.

Becker, C. A., Ambroset, C., Huleux, A., Vialatte, A., Colin, A., Tricot, A., ... & Tardy, F. (2020). Monitoring Mycoplasma bovis diversity and antimicrobial susceptibility in calf feedlots undergoing a respiratory disease outbreak. *Pathogens*, *9*(7), 593.

Caswell, J. L., K. G. Bateman, H. Y. Cai, and F. Castillo-Alcala. 2010. Mycoplasma bovis in respiratory disease of feedlot cattle. Veterinary Clinics of North America: Large Animal Practice 26(2):365-379.

Cai, H. Y., McDowall, R., Parker, L., Kaufman, E. I., & Caswell, J. L. (2019). Changes in antimicrobial susceptibility profiles of Mycoplasma bovis over time. *Canadian Journal of Veterinary Research*, *83*(1), 34-41.

Dudek, K., D. Bednarek, R. D. Ayling, A. Kycko, E. Szacawa, and T. A. Karpińska. 2016. An experimental vaccine composed of two adjuvants gives protection against *Mycoplasma bovis* in calves. Vaccine 34(27):3051-3058.

Fox, L.K., 2012. Mycoplasma mastitis: Causes, transmission, and control. Veterinary Clinics of North America: Food Animal Practice 28, 225-237. Gille, L. (2018). Mycoplasma bovis: Sources of infection, prevalence and risk factors (Doctoral dissertation, Ghent University, Ghent, Belgium).

Ghazaei, C., 2006. Mycoplasmal mastitis in dairy cows in the Moghan region of Ardabil State, Iran. Journal of the South African Veterinary Association 77, 222-223.

García-Galán, A., Nouvel, L. X., Baranowski, E., Gómez-Martín, Á., Sánchez, A., Citti, C., & de la Fe, C. (2020). Mycoplasma bovis in Spanish cattle herds: Two groups of multiresistant isolates predominate, with one remaining susceptible to fluoroquinolones. *Pathogens*, *9*(7), 545.

Gagea, M. I., Bateman, K. G., Shanahan, R. A., Van Dreumel, T., McEwen, B. J., Carman, S., ... & Caswell, J. L. (2006). Naturally occurring Mycoplasma bovis—associated pneumonia and polyarthritis in feedlot beef calves. *Journal of Veterinary Diagnostic Investigation*, *18*(1), 29-40.

Gautier-Bouchardon, A. V., Ferré, S., Le Grand, D., Paoli, A., Gay, E., & Poumarat, F. (2014). Overall decrease in the susceptibility of Mycoplasma bovis to antimicrobials over the past 30 years in France. *PLoS One*, *9*(2), e87672.

Hermeyer, K., Buchenau, I., Thomasmeyer, A., Baum, B., Spergser, J., Rosengarten, R., Hewicker-Trautwein, M., 2012a. Chronic pneumonia in calves after experimental infection with *Mycoplasma bovis* strain 1067: characterization of lung pathology, persistence of variable surface protein antigens and local immune response. Acta Veterinaria Scandinavica 54, 9.

Hewicker-Trautwein, M., M. Feldmann, W. Kehler, R. Schmidt, S. Thiede, F. Seeliger, P. Wohlsein, H. J. Ball, I. Buchenau, J. Spergser, and R. Rosengarten. 2002. Outbreak of pneumonia and arthritis in beef calves associated with *Mycoplasma bovis* and Mycoplasma californicum. Veterinary Record 151

Junqueira, N. B., Salina, A., Oliveira, G. C., Mettifogo, E., Joaquim, S. F., Guimarães, F. F., ... & Langoni, H. (2020). Detection of clinical bovine mastitis caused by Mycoplasma bovis in Brazil. The Journal of dairy research, 87(3), 306-308.

Justice-Allen, A., J. Trujillo, R. Corbett, R. Harding, G. Goodell, and D. Wilson. 2010. Survival and replication of Mycoplasma species in recycled bedding sand and association with mastitis on dairy farms in Utah. Journal of Dairy Science 93(1):192-202.

Karahan, M., Kalin, R., Atil, E., & Çetinkaya, B. (2010). Detection of Mycoplasma bovis in cattle with mastitis and respiratory problems in eastern Turkey.

Liu, Y., Xu, S., Li, M., Zhou, M., Huo, W., Gao, J., ... & Han, B. (2020). Molecular characteristics and antibiotic susceptibility profiles of Mycoplasma bovis associated with mastitis on dairy farms in China. *Preventive Veterinary Medicine*, *182*, 105106.

Lysnyansky, I., & Ayling, R. D. (2016). Mycoplasma bovis: mechanisms of resistance and trends in antimicrobial susceptibility. *Frontiers in microbiology*, *7*, 595.

Lysnyansky, I., Mikula, I., Gerchman, I., & Levisohn, S. (2009). Rapid detection of a point mutation in the parC gene associated with decreased

susceptibility to fluoroquinolones in Mycoplasma bovis. *Antimicrobial Agents and Chemotherapy*, *53*(11), 4911-4914.

Lerner, U., Amram, E., Ayling, R. D., Mikula, I., Gerchman, I., Harrus, S., ... & Lysnyansky, I. (2014). Acquired resistance to the 16-membered macrolides tylosin and tilmicosin by Mycoplasma bovis. *Veterinary microbiology*, *168*(2-4), 365-371.

Maunsell, F. P. and A. Donovan. 2009. Mycoplasma bovis infections in Young Calves. Veterinary Clinics: Food Animal Practice (25):139-177.

Maina, T. (2019). Understanding the interaction between mycoplasma bovis and bovine respiratory macrophages (Doctoral dissertation, University of Saskatchewan).

McAuliffe L., Ellis R. J., Miles K., Ayling R. D., Nicholas R. A. J. (2006). Biofilm formation by mycoplasma species and its role in environmental persistence and survival. *Microbiology* 152, 913–922. 10.1099/mic.0.28604-0.

Maunsell, F., M. B. Brown, J. Powe, J. Ivey, M. Woolard, W. Love, and J. W. Simecka. 2012. Oral Inoculation of Young Dairy Calves with *Mycoplasma bovis* Results in Colonization of Tonsils, Development of Otitis Media and Local Immunity. PLoS One 7(9):e44523.

Maunsell, F. P., Woolums, A. R., Francoz, D., Rosenbusch, R. F., Step, D. L., Wilson, D. J., & Janzen, E. D. (2011). Mycoplasma bovis infections in cattle. *Journal of Veterinary Internal Medicine*, *25*(4), 772-783.

Morton, J., Malmo, J., House, J., Mein, G., Izzo, M., Penry, J., 2014. *Mycoplasma bovis* in Australian dairy herds. Australian Veterinary Journal 92, 322-323.

Parker, A. M., Sheehy, P. A., Hazelton, M. S., Bosward, K. L., & House, J. K. (2018). A review of mycoplasma diagnostics in cattle. *Journal of veterinary internal medicine*, *32*(3), 1241-1252.

Nielsen, P.K., Petersen, M.B., Nielsen, L.R., Halasa, T., Toft, N., 2015. Latent class analysis of bulk tank milk PCR and ELISA testing for herd level diagnosis of *Mycoplasma bovis*. Preventive Veterinary Medicine 121, 338-342.

Spergser, J., Macher, K., Kargl, M., Lysnyansky, I., Rosengarten, R., 2013. Emergence, re-emergence, spread and host species crossing of *Mycoplasma bovis* in the Austrian Alps caused by a single endemic strain. Veterinary Microbiology 164, 299-306.

McDonald, W.L., Rawdon, T.G., Fitzmaurice, J ., Bolotovski, I., Voges, H., Humphrey, S., Fernando, K., Canagasebey, Y., Norton, R.N., McIntyre, L., 2009. Survey of bulk tank milk in New Zealand for *Mycoplasma bovis*, using species-specific nested PCR and culture. New Zealand Veterinary Journal 57, 44-49.

Miranda-Morales, R.E., Rojas-Trejo, V., Segura-Candelas, R., Carrillo-Casas, E.M., Sánchez- Gonzalez, M.G., Castor, R.S., Trigo-Tavera, F.J., 2008.

Prevalence of pathogens associated with bovine mastitis in bulk tank milk in Mexico. Annals of the New York Academy of Sciences 1149, 300-302.

Mulongo, M., T. Prysliak, and J. Perez-Casal. 2013. Vaccination of feedlot cattle with extracts and membrane fractions from two *Mycoplasma bovis* isolates results in strong humoral immune responses but does not protect against an experimental challenge. Vaccine 31(10):1406-1412.

Menghwar, H., He, C., Zhang, H., Zhao, G., Zhu, X., Khan, F. A., ... & Guo, A. (2017). Genotype distribution of Chinese Mycoplasma bovis isolates and their evolutionary relationship to strains from other countries. *Microbial pathogenesis*, *111*, 108-117.

Margineda, C. A., Zielinski, G. O., Jurado, S. B., Ferrella, A., Mozgovoj, M., Alcaraz, A. C., & López, A. (2017). Mycoplasma bovis pneumonia in feedlot cattle and dairy calves in Argentina. Brazilian Journal of Veterinary Pathology, 10.

Nicholas, R. A., L. K. Fox, and I. Lysnyansky. 2016. Mycoplasma mastitis in cattle: To cull or not to cull. Vet. J. 216:142–147.

Perez-Casal, J., T. Prysliak, T. Maina, M. Suleman, and S. Jimbo. 2017. Status of the development of a vaccine against *Mycoplasma bovis*. Vaccine 35(22):2902-2907.

Quinn PJ, Markey BK, Leonard FC, Fanning S, Maguire D. (2013) Veterinary Microbiology and Microbial Disease. 2nd ed. Hoboken: Wiley.

Ruegg, P. L. 2012. New perspectives in udder health management. Vet. Clin. North Am. Food Anim. Pract. 28:149–163.

Salina, A., Timenetsky, J., Barbosa, M. S., Azevedo, C. M., & Langoni, H. (2020). Microbiological and molecular detection of Mycoplasma bovis in milk samples from bovine clinical mastitis. Pesquisa Veterinária Brasileira, 40(2), 82-87.

Sulyok, K. M., Kreizinger, Z., Fekete, L., Hrivnák, V., Magyar, T., Jánosi, S., ... & Gyuranecz, M. (2014). Antibiotic susceptibility profiles of Mycoplasma bovis strains isolated from cattle in Hungary, Central Europe. *BMC veterinary research*, *10*(1), 1-8.

Timonen, A. A., Katholm, J., Petersen, A., Mõtus, K., & Kalmus, P. (2017). Within-herd prevalence of intramammary infection caused by Mycoplasma bovis and associations between cow udder health, milk yield, and composition. Journal of dairy science, 100(8), 6554-6561.

van Engelen, E., Dijkman, R., Holzhauer, M., Junker, K., van Wuyckhuise, L., Gonggrijp, M., 2015. Typing of *Mycoplasma bovis* from arthritis outbreaks in dairy herds. Progress in Human and Animal Mycoplasmology. Proceedings of European Mycoplasma Meeting, Pendik, Istanbul, Turkey, 3-5 June 2015, p. 25

Ward, H., & Powell, J. (2017). *Bovine Respiratory Disease*. Cooperative Extension Service, University of Arkansas, United States Department of Agriculture, and county governments cooperating.

Wong, L. J. C. (2013). Next Generation Sequencing (pp. 19-36). New York: Springer.

Chapter 2

DETERMINATION OF PLANT WATER CONSUMPTION OF SESAME (*SESAMUM INDICUM* L.) USING PENMAN-MONTEITH AND WATER BUDGET METHODS

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1. INTRODUCTION

Sesame (*Sesamum indicum* L.) is an important oil plant belonging to the Sesamum genus of the Pedaliaceae family of the Personatae order (Arıoğlu 2007). The name comes from the Arabic word "simsim." Sesame is can grow in tropical, subtropical climate zones and regions with suitable microclimate characteristics (Tan 2011). Sesame can mature in 90 to 120 days, can reach 2 meters in height, and is a plant with a strong tap root system that goes to 40-50 cm depth and can spread to the sides by 15-70 cm. Roots can go to a depth of 100-150 cm depending on the type of soil and water retention. Sesame is an oil plant that maturates from bottom to top, branches or non-branches, as well as the capsules are cracked or not cracked. Due to the low productivity of the varieties whose capsules do not crack, varieties with cracked capsules are commonly cultivated in the world. The leaves of sesame plants can be green, narrow and segmented. Leaf margins may be serrated or toothed. Depending on the number of flowers formed, they can be single or triple encapsulated, and the capsules can have two or four carpels (Ilısu 1973). The leaf structure, branching and capsule formation of a sesame plant are shown in Figure 1. Sesame cultivation may become more widespread as a second crop especially in irrigated areas of the Southeast provinces, depending on improvement in the mechanization in harvesting of sesame.

Figure 1. Leaf structure, branching and capsule formation of sesame plant

The world sesame cultivation area in 2019 was 12.82 million ha, production was 6.54 million tons and average yield was 510 kg ha^{-1} (FAO, 2019). Turkey ranks 38th in the world sesame producing countries with a sesame cultivation area of 24855 ha, 9th in average yield with 679 kg ha^{-1} and 34th in production with 16893 tons sesame production (Anonymous 2019). In the last 24 years, sesame cultivation area and sesame production in Turkey significantly decreased. The production in 1989 was 97600 ha, while decreased to 24855 ha in 2019. Therefore, sesame production decreased considerably in parallel with the decrease in cultivation. Average yield recently has increased, however, the increase was not sufficient (Anonymous 2019).

Leaf formation (bottom-up) of sesame plant is shown in Figure 2. Irrigation water applied is efficiently used in drip irrigation system used for sesame plants (Figure 3).

Figure 2. Leaf formation during young vegetative period of sesame plants

Water, which is indispensable for living organisms and nature, is one of the most basic needs of plants. In addition to maintaining the vital activities of plants, water is absolutely necessary in areas such as

agriculture, industry and transportation. (Akın and Akın 2007). Most of (75%) the annual usable surface and ground water assets are being used for irrigation in the agriculture. Therefore, plants will be most affected by the water scarcity caused by global climate change (Saltürk 2006).

Effective use of water resources is becoming increasingly important in Turkey as well as in the world. Therefore, water losses during transporting the irrigation water to fields and distributing to plant root zone should be decreased as much as possible to meet plant-water requirement at the desired level (Bayramoğlu 2013).

Figure 3. Irrigation of sesame with drip irrigation system

Plant water consumption can be determined by direct or indirect methods, using climate parameters. The direct methods require a long time and a high labor, while indirect methods are simpler and faster (Kaya 2011). Climate parameters and weather data are used to determine the results of a study, carried out to evaluate the efficiency of FAO56 Penman-Monteith method, revealed that the meadow plants had a high level of similarity with the ETo value. Since FAO56 Penman-Monteith method clearly combines both physiological, physiological and aerodynamic parameters, the researchers recommend to use FAO56 Penman-Monteith method in estimation of ET0 value. In the first stage of the method

development, difficulties were encountered as many climate data were included in the equation. However, the predictions were improved over time with the use of benchmark plants and new studies carried out (Allen et al., 1998).

The aim of this study was to determine the plant water consumption of sesame (*Sesamum indicum* L.) genotype in 2019 by Penman – Monteith method using both the plant water budget and the climate data. The studies carried out to determine the plant water consumption in the region with the aforementioned methods are rare. Therefore, the study contains important data that can be used by all scientists and farmers in the region.

2. MATERIAL and METHOD

The study was carried out during the sesame growing period of Siirt province in 2019. The altitude of the experimental area is 894 m, and the study area is located between 37° 58' N and 41° 50' E latitudes. In this region, the continental climate zone is dominated by cold and rainy winters and hot and dry summers, and the four seasons are experienced with their most distinctive features. The average temperature is 26 ºC in summer and 2.7 ºC in winter. The highest annual relative humidity was recorded in January (70.2%) and lowest in August (26.9%). The annual average relative humidity is 50.41%. The annual total average precipitation is 669.2 mm, and the monthly precipitation varies between 103.6 mm and 1.3 mm (Anonymous 2019).

The average field capacity (FC) of soil in the study area was 433 mm (0-90 cm), the wilting point (WP) was 312 mm, and available water holding capacity was 121 mm. Soil bulk density was determined as 1.40 gr cm^{-3}. Electrical conductivity of the irrigation water was 0.34 dS m^{-1} and pH value was 7.21.

Water distribution in the study in which the drip irrigation method was used, was provided by using soft PE lateral pipelines with a working pressure of 4 atm and an outer diameter of 16 mm. No deep infiltration or runoff was allowed to occur. The moisture content of the effective root depth (90 cm) was determined by gravimetric method before each irrigation. Moisture values determined as dry weight percent were converted to depth (Equations 1 and 2).

$d= (Pw-Pw_{AW})*As*D/100$..... (1)

Where; d is the moisture content at the depth (mm); Pw is the field capacity (%); Pw_{AW} is the moisture content of each soil layer (%), and As is the bulk density of soil ($g/cm^{3)}$ and D is the depth of a soil layer (mm). The volume of water to be applied was calculated using the following equation (Equation 2). Total amount of water (dT) for the effective root depth was calculated by adding the water content for each layer (Equation 2).

$d_T=d_{(0-30)}+ d_{(30-60)} + d_{(60-90)}$ ..... (2)

Monthly and seasonal evapotranspiration values were calculated using the soil moisture content (90 cm) water budget method and moisture content values measured at the beginning and end of the harvest during the growing season (Zeleke and Wade 2012). The water balance equation (Equation 3) was used to calculate the water consumption of the plants (Zeleke and Wade 2012).

$ET_a= P + I – R_f – D_p \pm \Delta S$ .....(Equation 3)

Where; ET_a is the evapotranspiration (mm), P is the precipitation (mm), I is the amount of irrigation water (mm), R_f is surface runoff (mm), D_p is deep infiltration (mm) and ΔS (mm) is water changes at plant root depth. The droplet flow rate was lower than the infiltration rate of the soil, therefore, we assumed no surface runoff occurs. Since the amount of irrigation water was applied up to the field capacity, we assumed that no deep infiltration occurs.

2.1 Plant Water Consumption

The concept called 'Evapotranspiration' and abbreviated as ET in many national and international sources is accepted as the terminological definition of 'Plant Water Consumption' in Turkish. Basically, ET refers to evaporation from soil and plant. In general, evaporation refers to the movement of liquid water from the environment to the atmosphere by evaporation. Evaporation of water from many surfaces, especially soil and open water surfaces, is called 'evaporation'. The energy must penetrate the water to occur the evaporation. The source of this energy in nature is mostly solar radiation and air temperature. The evaporated water moves in the direction of vapor pressure difference between the surface

and the atmosphere surrounding this surface. After evaporation, the atmosphere surrounding the surface where evaporation occurs may become saturated with water, and evaporation may stop if this air does not move. At this stage, air movement occurs through the wind. Evaporation takes place entirely depending on solar radiation, air temperature, air humidity and wind speed (Bayramoğlu 2013). In addition to these factors, when the surface where evaporation occurs is soil, the amount of soil surface shaded by the above-ground plant parts and the water content in soil depth exposed to evaporation are also very important on the amount of evaporation.

2.2 Determination of Plant Water Consumption

Crop water consumption can be measured directly or estimated using climate data. Although direct measurement methods provide reliable results, they are quite expensive and time consuming. Therefore, direct measurement of plant water consumption is only carried out for calibrating the prediction equations from the climate data and determining the local plant coefficients.

Numerous equations have been developed to estimate plant water consumption using climate data. Some of these equations were developed by using several climatic factors, and are easy to apply, however, they can give reliable results for long periods. Others are rather complex equations that were developed considering many climatic factors affecting plant water consumption, and reliable results can be obtained even for short periods.

In practice, the common method of estimating plant water consumption is to define a potential plant water consumption where only climatic factors are effective, and to develop empirical equations that can be used to calculate potential plant water consumption. Then, the potential plant water consumption values are corrected using plant coefficients, which are the function of plant type and plant development stages (Güngör et al., 2004; Kırnak and Gençoğlan, 2001).

$$\mathbf{ET=Kc*ETp} \qquad (1.1)$$

In the equation, ET is the plant water consumption (mm/day), Kc is the plant coefficient and ETp is the potential water consumption (mm/day).

However, a standard definition of potential plant water consumption has not yet carried out and the interpretation causes some confusions. Therefore, the concept of "comparative (benchmark) plant water consumption" has been widely used instead of potential plant water consumption. For this purpose, initially a benchmark plant with certain conditions is determined and empirical equations are developed that can be used to estimate the water consumption of benchmark plant. Then, the equations are corrected with the plant coefficients as a function of plant species and plant growth stage, so that the equations can be used to estimate water consumption for other plants.

$$ET=Kc*ETo \quad (1.2)$$

In the equation; ET is plant water consumption (mm/day), Kc is plant coefficient, and ETo is Benchmark plant water consumption (mm/day).

In practice, meadow plants, sesame, clover and similar plants are used to compare the plants. In the case of meadow plants, the comparison of plant water consumption is as follows; the plant water consumption in a large area covered with meadow plants with 8-10 cm high, uniform (Persian: same, uniform) height, effectively growing, fully covering the area and adequately irrigated.

The study will focus on the Penman-Monteith modification, which provides results for short periods.

3.3 Penman-Monteith

Penman developed the formula for evaporation from the open water surface in 1948 using climate data (insolation, temperature, humidity, pressure, and wind speed). This method was further improved by Monteith for plants in 1976 by adding aerodynamic and surface resistance factors. In 1990, experts came together and generated the FAO Penman-Monteith method. Although this method is named differently in different countries, it has been commonly used as FAO56-PM with the concept of "reference plant water consumption" instead of potential water consumption (Koç and Güner 2005; İlhan and Utku 1998; Allen et al., 1998). In the Penman-Monteith Method, the water consumption (ETc) of the plants can be determined after correcting the reference crop water consumption with the single crop coefficient (kc) or the double crop

coefficient (ke + kcb). In addition, the change in plant water consumption due to various stresses caused by drought, salinity, disease and other factors can also be determined by using the stress coefficient (ks) (Yürekli 2010; Allen et al., 1998; Gençoğlan et al., 1999; Uçak et al., 2016).

3.4 Penman-Monteith Method for Benchmark Crop Water Consumption

In this method, the benchmark plant water consumption is estimated with the following equation.

$$ET = \frac{\delta}{\delta+\gamma^*}(R_n - G)\frac{1}{\lambda} + \frac{\gamma}{\delta+\gamma^*}\frac{900}{T+275}u_2(e_a - e_d) \quad (1.3)$$

The equations used in the calculation of some terms in this equation are given below.

$$\delta = \frac{4098e_a}{(T+237.3)^2} \quad (1.4)$$

$$\lambda = 2.501 - 2.361 \times 10^{-3}T \quad (1.5)$$

$$\gamma = 0.0016286\frac{P}{\lambda} \quad (1.6)$$

$$\gamma^* = \gamma(1 + 0.34u_2) \quad (1.7)$$

$$R_n = R_{n_s} - R_{nl} \quad (1.8)$$

$$R_{n_s} = 0{,}75R_s \quad (1.9)$$

$$R_{n_l} = 2{,}451f(T)f(e_d)f\left(\frac{n}{N}\right) \quad (1.10)$$

$$R_5 = \left(0.25 + 0.50\frac{n}{N}\right)R_a \quad (1.11)$$

$$e_d = e_a\frac{RH}{100} \quad (1.12)$$

$$u_2 = u_z\left(\frac{2}{z}\right)^{0.2} \quad (1.13)$$

$ET =$ the reference plant water consumption(mm/day),

$\delta =$ Slope of wapor pressure, $kPa/°C$

$\gamma^* =$ Modified psychrometric constant , $kPa/°C$

$\gamma =$ Psychrometric constant , $kPa/°C$

$P =$ Atmosheric pressure , kPa

$R_n =$ Net radiation on plant surface , $\frac{MJ}{M2}/g\ddot{u}n$

$R_a =$ the short − wave radiation reaching the earth surface, $\frac{MJ}{M2}/g\ddot{u}n$

(This can be taken directly from Table 1.2.)

$R_s =$ Radiation reaching the outer surface of the atmosphere , $\frac{MJ}{M2}/day$

$R_{n_s} =$ short − wave net radiation reaching the earth, $\frac{MJ}{M2}/day$

$R_{n_l} =$ long − wave net radiation reaching the earth, $\frac{MJ}{M2}/day$

$f(T) =$ Temperature function (This can be taken directly from Table 1.3)

$T = Temperature, ° C$

$f(e_d)$
$= \ Wapor\ pressure\ function\ (This\ can\ be\ directly\ taken\ from\ Table$ 1.4)

$e_d = \ Actual\ vapor\ pressure\ at\ average\ air\ temperature, kPa$

$e_a = Saturated\ vapor\ pressure\ at\ average\ air\ temperature, kPa$

($This\ can\ be\ directly\ taken\ from\ Table$ 1.5)

$f\left({}^{n}/_{N}\right)$: $Insolation\ rate\ function$

($This\ can\ be\ directly\ taken\ from\ Table$ 1.6)

n = Insolation period, h

N = Possible maximum insolation duration, h ($This\ can\ be\ directly\ taken\ from\ Table$ 1.7)

G = Heat flow in the soil, MJ/m^2/day

(This can be ignored as the average temperature of soil does not change much in successive periods)

$\lambda = Latent\ heat\ of\ evaporation, \frac{MJ}{kg}$

$\left(2.45 \frac{MJ}{kg}\ can\ be\ used\ as\ an\ average\ value \right)$

$u_2 = Equivalent\ of\ wind\ speed\ at\ 2\ m\ altitude, m/s$

$u_z =\ wind\ speed\ measured\ at\ z\ m\ altitude, \frac{m}{s}$

z = The altitude at which the wind speed is measured, m

(In Turkey, meteorological bulletins usually provides wind speed values measured at 10 m altitude) and

RH = Average relative humidity, %

In terms of pressure units;

1 mb = 0.1 kPa

and in terms of radiation units;

1 cal/cm^2/day =0.041868 MJ/m^2/day = 0.01706 mm/day.

Table 1. Radiation values reaching the outer surface of the atmosphere, Ra

Latitude	Months							
	March	April	May	June	July	August	September	October
44	26.0	33.6	39.5	42.2	40.7	36.0	29.2	21.3
42	27.0	34.3	39.7	42.4	40.9	36.8	29.9	22.3
40	27.9	35.0	39.7	42.4	40.9	37.3	30.6	23.5
38	28.9	35.5	40.2	42.2	40.9	37.5	31.4	24.5
36	29.7	36.0	40.2	42.2	40.9	37.7	32.1	26.0
34	30.4	36.3	40.4	41.9	41.2	38.0	32.8	26.5

(MJ/m2/day).

Table 2. Temperature function, f (T).

T, $\circ C$	2	4	6	8	10	12	14	16	18
f(T)	11.4	11.7	12.0	12.4	12.7	13.1	13.5	13.8	14.2
T,$\circ C$	20	22	24	26	28	30	32	34	36
f(T)	14.6	15.0	15.4	15.9	16.3	16.7	17.2	17.7	18.1

e_d, kPa	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2
f(e_d)	0.23	0.22	0.20	0.19	0.18	0.16	0.17	0.14	0.13
e_d, kPa	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0
f(e_d)	0.12	0.12	0.11	0.10	0.09	0.08	0.08	0.07	0.06

Table 3. Vapor pressure function f (e_d).

Table 4. Saturated vapor pressure at average air temperature,e_a.

T, ∘ C	1	2	3	4	5	6	7	8	9
e_a, kPa	0.66	0.71	0.76	0.81	0.87	0.93	1.00	1.07	1.15
T, ∘ C	10	11	12	13	14	15	16	17	18
e_a, kPa	1.23	1.31	1.40	1.50	1.61	1.70	1.82	1.94	2.06
T, ∘ C	19	20	21	22	23	24	25	26	27
e_a, kPa	2.20	2.34	2.49	2.64	2.81	2.98	3.17	3.36	3.57
T, ∘ C	28	29	30	31	32	33	34	35	36
e_a, kPa	3.78	4.01	4.24	4.49	4.76	5.03	5.32	5.62	5.94

Table 5. Insolation rate function, f (n/N).

n/N	0.00	0.05	0.10	0.15	0.20	0.25	0.30
f(n/N)	0.10	0.15	0.19	0.24	0.28	0.33	0.37
n/N	0.35	0.40	0.45	0.50	0.55	0.60	0.65
f(n/N)	0.42	0.46	0.51	0.55	0.60	0.64	0.69
n/N	0.70	0.75	0.80	0.85	0.90	0.95	1.00
f(n/N)	0.73	0.78	0.82	0.87	0.91	0.96	1.00

Table 6. Possible maximum insolation duration, N (h/day)

Latitude	Months							
	March	April	May	June	July	August	September	October
44	11.9	13.4	14.7	15.4	15.2	14.0	12.6	11.0
42	11.9	13.4	14.6	15.2	14.9	13.9	12.6	11.1
40	11.9	13.3	14.4	15.0	14.7	13.7	12.5	11.2
35	11.9	13.1	14.0	14.5	14.3	13.5	12.4	11.3
30	12.0	12.9	13.6	14.0	13.9	13.2	12.4	11.5

3.5 General Climate Characteristics of Siirt Province

The region is under the influence of dry and hot tropical air masses settled in the Basra low pressure center during the summer season. The highest temperature during a day rises above 40 °C. In addition, during this period, the dry and hot winds called "samyeli", generated by the expansion of the Basra low pressure center towards Anatolia, cause both excessive evaporation and dust storms. In addition, dusty and polluted air coming from the Syrian and Arabian deserts affect the Siirt region. In winter, Siirt region is under the influence of precipitation fronts coming from the Central Mediterranean region. Frontal activities that cause these precipitations continue until April (Atalay and Mortan 2003). Experimental field has the similar climatic conditions.

The annual average temperature of the experimental field based on the climate data between 1938 and 2017 is 16.1 °C. The cold temperature during winter months due to external factors affecting Turkey, increase rapidly as of March and reach over 25°C in May and June (Table 1). The average temperature of experimental area in summer (June, July, and August) is not higher than 26°C, and in winter (December, January, February) is not lower than 2.7°C. There is a 27.8°C temperature difference (amplitude) between the average temperature of January (2.7°C), the coldest month and July (30.5°C), the hottest month. High seasonal temperature difference is one of the causes for continental climate in the experimental area.

The average temperature of Siirt province in summer is 28.8°C and 3.8°C in winter. The temperature values in the experimental area are higher than in many regions of Turkey. The latitude of the experimental area is an important factor affecting the temperature. The experiment area is located in the south part of Turkey. Sun rays reach the experimental area at a steeper angle compared to many other regions of Turkey. In addition, landforms have an impact on the temperature values of the experimental area.

The basin where the experiment was conducted is located on the outskirts of the Southeastern Taurus Mountains of the Taurus mountain range. Therefore, the effect of cold air coming from the north is not observed much. In the south, there are no obstacles to prevent the effects of hot

weather. Another important factor that affects the temperature is the dominant continental climate in the regions where air gets hot quickly. Therefore, summers are very hot and winters are very cold. Low altitude and cloudiness are other factors that affecting the temperature values in the region. The distribution of precipitation also varies according to the seasons. The season with the highest precipitation is spring with 40%, followed by winter with 38%. The precipitation in both seasons accounts for 78% of the total precipitation. The precipitation in the autumn season is 20% of annual rainfall and followed by the summer season with 2%. Snowfall in the region is very low and occurs in December, January and February.

The average wind speed, which differs greatly by months, is 1.2 m/s for 1938-2018. However, the highest average wind speed is 0.6 m/sec in March, April, May, June, July, August and September, and the lowest value is 0.3 m/sec in November, December and January. The fastest wind in a year was recorded in October (5.8 m/sec) and the lowest wind speed (2.4 m/sec) was recorded in December and March. The number of wind blows in the spring months is 42,487 which ranks the first with 26% followed by summer and winter with 25% and autumn with 24%.

Table 7. Long term meteorological data of Siirt province (1938-2019).

Parameter	Maximum Temperature (°C)	Minimum Temperature (°C)	Average Relative Humidity (%)	Average Total Precipitation (mm)	Maximum Precipitation (mm)	Average Evaporation(mm)	Average Insolation Time (Hour)
Duration of Observation (Year)	**79**	**79**	**78**	**78**	**79**	**79**	**57**
January	**19.7**	**-19.3**	**71.9**	**34.6**	**53.4**	**12.0**	**3.6**
February	**20.6**	**-16.5**	**67.1**	**29.4**	**53.2**		**4.4**
March	**28.5**	**-13.3**	**62.0**	**24.1**	**63.0**	**33.0**	**5.4**
April	**32.9**	**-4.1**	**58.0**	**22.4**	**71.4**	**84.0**	**6.5**
May	**36.2**	**2.0**	**50.7**	**21.2**	**68.1**	**186**	**9.0**
June	**40.2**	**8.2**	**34.6**	**15.5**	**16.7**	**284.8**	**11.7**
July	**44.4**	**13.1**	**27.4**	**13.5**	**22.2**	**368.0**	**12.2**
August	**14.4**	**46.0**	**26.4**	**13.3**	**12.2**	**351.8**	**11.4**
September	**39.9**	**8.5**	**31.2**	**14.4**	**37.5**	**254.3**	**9.9**

October	**36.6**	**0.3**	**46.7**	**49.7**	**70.8**	**137.6**	**7.2**
November	**25.8**	**-14.1**	**62.4**	**82.5**	**102.9**	**53.0**	**5.2**
December	**24.3**	**-14.6**	**70.6**	**94.5**	**71.8**	**13.1**	**3.6**
Annual	**46**	**-19.3**	**50.8**	**719.8**	**102.9**	**1753.6**	**7.5**

In addition, the latitude degree, average temperature, wind speed, average relative humidity, insolation duration and atmospheric (actual) pressure values for the period of the region and plant water consumption calculated were taken from Siirt Province 15th Regional Meteorology Directorate station.

3.6 Siirt Province Climate Data for the Study Year (2019)

In the calculation of plant water consumption with the aforementioned methods, the average wind speed, relative humidity, temperature, atmospheric (actual) pressure and insolation duration starting from 18 June 2019 till the end of harvest time in 29 October 2019 (June, July, August, September and October) were obtained from Siirt Meteorology Directorate.

Table 8. Average wind speed in Siirt province (m/sec) (2 m).

Month / Year	June	July	August	September	October	Mean
2020	1.3	1.3	1.3	1.1	1.0	**1.2**

Table 9. Average relative humidity in Siirt province (%).

Month / Year	June	July	August	September	October	Mean
2020	26.6	25.2	23.4	22.1	26.3	**24.72**

Table 10. Average temperature in Siirt (°C).

Month / Year	June	July	August	September	October	Mean
2020	27.2	31.6	30.6	29.0	21.7	**28.0**

Table 11. Average atmospheric (actual) pressure in Siirt province (hPa).

Month / Year	June	July	August	September	October	Mean
2020	907.8	905.7	904.6	911.5	916.1	**909.1**

Table 12. Average isolation duration in Siirt province (h).

Month / Year	June	July	August	September	October	Mean
2020	346.3	333.7	328.3	284.9	266.1	**311.8**

3.7.1 Research data

- **Latitude of Siirt province:** 38° 42 '
- **Time :** June, July, August, September, October in 2019
- **Mean temperature, T:** 28.0°C
- **Wind speed measured at 10 m altitude, u_{10}:** 1.2 m/s
- **Average relative humidity, RH:** %24.7
- **Duration of Insolation, n:** 10h 39 min
- **Atmospheric pressure (actual pressure),** P : 909 mb = 90.9 kPa

3.7.2 Determination of plant water consumption of sesame according to Penman-Monteith modification method

1) The saturated vapor pressure at the average air temperature is determined.

	March	April	May	June	July	August	September	October	Mean
T, ∘ C	1	2	3	4	5	6	7	8	9
e_a, kPa	0.66	0.71	0.76	0.81	0.87	0.93	1.00	1.07	1.15
T, ∘ C	10	11	12	13	14	15	16	17	18
e_a, kPa	1.23	1.31	1.40	1.50	1.61	1.70	1.82	1.94	2.06
T, ∘ C	19	20	21	22	23	24	25	26	27
e_a, kPa	2.20	2.34	2.49	2.64	2.81	2.98	3.17	3.36	3.57
T, ∘ C	28	29	30	31	32	33	34	35	36
e_a, kPa	3.78	4.01	4.24	4.49	4.76	5.03	5.32	5.62	5.94

Table 13. Saturated vapor pressure at average air temperature, e_a.

For T = 28.0 °C $\boldsymbol{e_a}$ **3.78 kPa**

2) The actual vapor pressure at average air temperature is calculated.

$$e_d = e_a \frac{RH}{100} = 3.78 * \frac{24,7}{100} = \mathbf{0.9\ kPa}$$

3) The slope of the vapor pressure curve is calculated.

$$\delta = \frac{4098 e_a}{(T+237.3)^2} = \frac{4098*3.78}{(28+237,3)^2} = \mathbf{0.220\ kPa/°C}$$

4) Psychometric constant is calculated.

$$\gamma = 0.0016286 \frac{P}{\lambda} = 0.001 * \frac{90.9}{2,45} = \mathbf{0.0604\ kPa/°C}$$

5) Equivalent of wind speed at 2 m altitude;

$$u_2 = u_z \left(\frac{2}{z}\right)^{0.2} = \mathbf{1.2 m/s}.$$

6) The modified psychometric constant is calculated.

$$\gamma^* = \gamma(1 + 0.34u_2) =$$

$$0.0604 * (1 + 0.34 * 1.2) = \mathbf{0.085\ kPa/°C}$$

7) Duration of possible maximum insolation is calculated.

Table 14. Duration of possible maximum insolation, N(h/day).

Latitude	Months							
	March	April	May	June	July	August	September	October
44	11.9	13.4	14.7	15.4	15.2	14.0	12.6	11.0
42	11.9	13.4	14.6	15.2	14.9	13.9	12.6	11.1
40	11.9	13.3	14.4	15.0	14.7	13.7	12.5	11.2
35	11.9	13.1	14.0	14.5	14.3	13.5	12.4	11.3
30	12.0	12.9	13.6	14.0	13.9	13.2	12.4	11.5

By interpolating;

38° 42 ' altitude and

- For June N = 14.8 h
- For July N = 14.5 h
- For August N = 13.6 h
- For September N = 12.46 approximately 12.5 h and
- For October N = 11.24 approximately 11.2 h.

  The average of these values is calculated: 13.32 h approximately 13.3 is used.

8) Insolation rate is calculated.

n = 10 h 39 min = 10.45 h

$$\frac{n}{N} = \frac{10.45}{13.3} = \mathbf{0.78}$$

9) Radiation values reaching the outer surface of the atmosphere is calculated.

Table 15. Radiation values reaching the outer surface of the atmosphere,

Latitude	Months							
	March	April	May	June	July	August	September	October
44	26.0	33.6	39.5	42.2	40.7	36.0	29.2	21.3
42	27.0	34.3	39.7	42.4	40.9	36.8	29.9	22.3
40	27.9	35.0	39.7	42.4	40.9	37.3	30.6	23.5
38	28.9	35.5	40.2	42.2	40.9	37.5	31.4	24.5
36	29.7	36.0	40.2	42.2	40.9	37.7	32.1	26.0
34	30.4	36.3	40.4	41.9	41.2	38.0	32.8	26.5

Ra(MJ/m^2/day).

38° 42 ' latitude and

- For June Ra = 42.2 MJ/$m2/day$
- For July Ra =40.9 MJ/$m2/day$
- For August Ra = 37.5 MJ/$m2/day$
- For September Ra = 31.4 MJ/$m2/day$
- For October Ra = 24.5 MJ/$m2/day$

The average of these values are calculated: 35.3 MJ/$m2/day$

10) The short-wave radiation reaching the earth is calculated.

$$R_s = \left(0.25 + 0.50\frac{n}{N}\right) R_a$$

= (0.25+0.50*0.78)*35.3 = **22.6 MJ/$m2/day$**

11) Short-wave net radiation is calculated.

$$R_{n_s} = 0{,}75R_s$$

= 0.75*22.6 = **16.9 MJ/$m2/day$**

12) The temperature function is determined.

Table 16. Temperature function, f(T).

T, ∘ C	2	4	6	8	10	12	14	16	18
f(T)	11.4	11.7	12.0	12.4	12.7	13.1	13.5	13.8	14.2
T,∘ C	20	22	24	26	28	30	32	34	36
f(T)	14.6	15.0	15.4	15.9	16.3	16.7	17.2	17.7	18.1

For T = 28°C, then f (T) = **16.3**

13) The Vapor pressure function is determined.

e_d, kPa	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2
f(e_d)	0.23	0.22	0.20	0.19	0.18	0.16	0.17	0.14	0.13
e_d, kPa	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0
f(e_d)	0.12	0.12	0.11	0.10	0.09	0.08	0.08	0.07	0.06

Table 17. Vapor pressure function, f(e_d).

$$for\ e_d = 0.8\ kPa, then\ \mathrm{f}(e_d) = 0.22,$$

$$for\ e_d = 1.0\ kPa,\ \ if\ \mathrm{f}(e_d) = 0.20, then\ interpolation\ is\ carrid\ out,$$

$$for\ e_d = 0.9\ kPa, then\ \mathrm{f}(e_d) = \mathbf{0.23}$$

14) The insolation rate function is determined.

Table 18. Insolation rate function, f(n/N).

n/N	0.00	0.05	0.10	0.15	0.20	0.25	0.30
f(n/N)	0.10	0.15	0.19	0.24	0.28	0.33	0.37
n/N	0.35	0.40	0.45	0.50	0.55	0.60	0.65
f(n/N)	0.42	0.46	0.51	0.55	0.60	0.64	0.69
n/N	0.70	0.75	0.80	0.85	0.90	0.95	1.00
f(n/N)	0.73	0.78	0.82	0.87	0.91	0.96	1.00

f(n/N) = 0.78 is calculated for n/N =0.75,

f(n/N) = 0.82 is calculated for n/N =0.80

f(n/N) = **0.80** is calculated for n/N =0.78**.**

15) The long-wave net radiation is determined.

$$R_{n_l} = 2{,}451 f(T) f(e_d) f\left(\frac{n}{N}\right)$$

= 2.451*16.3*0.23 = **9.19 MJ/*m2/day***

16) The net radiation on the plant surface is determined.

$$R_n = R_{n_s} - R_{nl}$$

= 16.9- 9.19 = **7.71 MJ/*m2/day***

17) Benchmark plant water consumption is calculated.

$$ET = \frac{\delta}{\delta+\gamma^*}(R_n - G)\frac{1}{\lambda} + \frac{\gamma}{\delta+\gamma^*}\frac{900}{T+275}u_2(e_a - e_d) =$$

$$\frac{0{,}220}{0{,}220+0{,}085} * (7.71 - 0) * \frac{1}{2.45} + \frac{0.0604}{0.220+0.085} * \frac{900}{28+275} * 1.2 * (3.78 - 0.9) =$$ **8.0 mm/day**.

3.8 Determination of Plant Water Consumption by Water Budget Method

Crop water consumption is calculated with the following water balance equation:

ET = I + P –Dp ± ΔSW (1)

In this equation;

ET, plant water consumption (mm);

I, total irrigation water applied (mm);

P, amount of precipitation (mm);

Dp, deep penetration (mm), and

ΔSW, changes in soil water storage between sowing and harvesting (mm). P, Rf and Dp do not occur, therefore, all are considered zero

The P value is determined from the precipitation gauge in the Meteorology observatory, and the ΔS value is determined from the humidity measurements in the profile. Briefly, water use efficiency and water consumption are calculated. The deep infiltration losses (Dp) were accepted as zero, since water is applied at field capacity during irrigation and the dripper flow rate was lower than the infiltration rate of soil. In addition, the surface flow values (Rf) are not taken into account as it was insignificant. The plant water consumption calculated by the water budget method was 238.6 mm/month.

4. RESULTS

The plant water consumption of the sesame genotype was determined using the data obtained from the 15th Regional Directorate of Siirt. The data were integrated into the Penman-Monteith modification, and the Reference Plant Water Consumption for 2019 was calculated as 8.00

mm/day, and the plant water consumption for the water balance was calculated as 238.6 mm/month.

Daily plant water consumption determined using modified Penman – Monteith method was 8 mm/day. The plant water consumption determined using the water budget method was as 7.95 mm/day. Modified Penman – Monteith method which was used to determine the plant water consumption provided very close result to the actual value. The results showed that this method can be used in studies to be carried out in the region.

5. CONCLUSION AND RECOMMENDATIONS

Climatic change, which has recently emerged as a serious threat due to global warming, causes the depletion of limited water resources in our country. The results of this study, which was carried out to further encourage sesame cultivation in the region, revealed that the difference between the actual water consumption and the calculated water consumption was insignificant. On the other hand, the amount of water to be used by crops and irrigation projects in areas where water consumption is intense should be determined based on long and short period's actual climate data. In this respect, the necessary calculations for the irrigation program of the sesame can be carried out by using the Penman-Monteith equation, which is a method that provides more realistic results in estimation of plant water consumption by using more meteorological data. Suitable irrigation programs should be prepared based on the climatic conditions of each region to conserve water resources. Therefore, the plant water consumption between the irrigation intervals of crops grown should be calculated and an irrigation program should be prepared, considering the climatic data of a region.

6. REFERENCES

Akın, Mutluhan, ve Galip Akın. «Suyun Önemi Türkiye'de Su Potansiyeli.» *Ankara Üniversitesi Dil ve Tarih Coğrafya Fakültesi Dergisi* 47, no. 2 (2007): 105-118.

Allen, R. G., L. S. Pereira, D. Raes, ve M. Smith. «Crop Evapotranspiration (guidelines for computing crop water requirements).» *FAO Irrigation and Drainage*, 1998: 56.

Anonim. *Siirt İli Coğrafi Bilgileri.* 5.baskı. İstanbul: İnkılap, 2019.

—. *T.C. Tarım ve Köyişleri Bakanlığı. Tohumluk Tescil ve Sertifikasyon Merkezi Müdürlüğü.* 2019. http://www.Ttsm.gov.tr/ (erişildi: 05 20, 2020).

Arıoğlu, Halis. *Yağ Bitkileri Yetiştirme ve Islahı.* Adana: Çukurova Üniversitesi Ziraat, 2007.

Atalay, İbrahim, ve Kenan Mortan. *Türkiye Bölgesel Coğrafyası.* İstanbul: İnkılap, 2003.

Bayramoğlu, Elif. *Trabzon İlinde İklim Değişikliğinin Mevsimsel Bitki Su Tüketimine Etkisi:.* Kastamonu: Kastamonu Üniversitesi, 2013.

Gençoğlan, Cafer, ve Atilla Yazar. «Çukurova Koşullarında Yetiştirilen I. Ürün Mısır Bitkisinde İnfrared Termometre Değerlerinden Yararlanılarak Bitki Su Stresi İndeksi (CWSI) ve Sulama Zamanının Belirlenmesi.» *Tr. J. of Agriculture and Forestry*, no. 23 (1999): 87-95.

Güngör, Yetkin, A. Zeki Erözel, ve Osman Yıldırım. *Sulama.* Ankara: Ankara Üviversitesi Ziraat Fakültesi Yayınları, 2004.

İlhan, A. İ., ve M. Utku. «GAP Sulama Alanında Bitki Su Tüketimi ve Bitki Su Gereksinimi,.» *Tarım Orman Meteorolojisi Sempozyumu* . İstanbul: İTÜ, 1998.

Ilısu, Kamil. *Yağ Bitkileri ve Islahı.* İstanbul: Çağlayan Kitapevi, 1973.

Kaya, S. «Yarı-Kurak İklim Koşullarında Farklı Yöntemlerle Hesaplanan Refereans Evapotranspirasyon Değerlerinin Karşılaştırılması.» *Bingöl Üniversitesi Fen Bilimleri Dergisi* 1, no. 1 (2011): 58-60.

Kırnak, H, ve Gençoğlan, C. «Use of crop water stress index for scheduling irrigation in second crop corn.» *Ziraat Fakültesi Dergisi* 5, no. 3 4 (2001): 67-75.

Koç, T., ve Ü. Güner. «Mevcut Sulama Projelerinin Fao Kriterleriyle Yeniden Değerlendirilmesi: Tavas Ovasi Örneği,.» *Dumlupınar Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 2005: 93-106.

Saltürk, Metin. «Problem of Water in the Middle East and Analysis of the Problem within the Perspective of Turkey.» *Journal of Security Strategies*, no. 3 (2006): 21-38.

Tan, Ahmet. «Susam Agroskop Tarım.» *Gıda- Hayvancılık Dergisi*, 2011: 25-29.

Uçak, Ali Beyhan, A. Öktem, C. Sezer, R. Cengiz, ve Behcet İnal. «Determination of Arid and Temperature Resistant Sweet Corn (Zea mays saccharata Sturt) Lines.» *Intennational Journal of Environmental & Agriculture Research (IJOEAR)* 2, no. 7 (2016): 79-88.

Yürekli, Kadir. «Kayseri İlinde Mevsimsel Bitki Su Tüketimindeki (ETo) Değişimin Saptanması.» *Tarım Bilimleri Araştırma Dergisi* , 2010: 21-25.

Zeleke, K.T., Wade, L.J., 2012. Evapotranspiration estimation using soil water balance. Weather and Crop Data, Rijeka, Croatia, pp. 41-58.

Chapter 3

ECOSYSTEM APPROACH TO SUSTAINABLE AQUACULTURE

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Introduction

Beyond their aesthetic and recreational value, seas and intracontinental surface water resources are of vital and economic importance for living organisms. Intracontinental water resources are regarded as limited resources and their conservation is of prominent importance considering their roles in meeting the need for urban drinking water and industrial water use, the growing demand for animal protein in aquaculture, and their recreational potential. Thus, planning within the framework of serious, effective, and long-term programs is needed.

Aquaculture production is done via hunting and cultivation worldwide. It includes production for use in fish feed, fish oil, and non-food purposes in addition to human consumption. Hunting is one of the oldest production activities and maintains its social and economic importance worldwide. The developing technology, increasing population, and demand for animal food in the last century have added to the pressure on fishery, leading to the realization that fishery resources are renewable but not unlimited.

Aquaculture products are valuable food resources that meet an important portion of the need for animal protein and their resources should be managed in a balanced manner between their preservation and use for their effective and efficient use in the future. Aquaculture resources and their management are great global issues, which stem from their control and monitoring and the lacking in the efficient management of fishing fleets. The increases in the number of fishing fleets and technological capacity in developed and developing countries have brought along serious problems in the allocation of limited resources and fishery revenues. Authorities on the fishery industry have declared sustainable production possible only through the management of the resources with effective management plans. In contrast with hunting, aquaculture production is a globally growing sector. Aquaculture production has grown by 12-fold with an annual increase of 8.8% worldwide in the last 30 years (FAO, 2018). The Food and Agriculture Organization of the United Nations (FAO) has declared the aquaculture sector as a rapidly developing and continuously growing sector in all food sectors.

According to the data of FAO, production via hunting in the seas peaked in 1996 and showed a relatively constant progress in the following years. In recent years, sea and inland water hunting have decreased while aquaculture have continuously increased and showed the greatest growth among all food production (OECD, 2016). In 2017, the global water product production was 172.7 million tons, which comprised 92.5 million tons of products from hunting (53.6%) and 80.1 million tons of products from aquaculture (46.4%). Of the production from hunting in 2017, 80.6

million tons were from seas and 11.9 million tons were from inland waters while 30.6 million tons of the aquaculture production were form seas and 49.5 million tons of the aquaculture production were from inland waters. According to the FAO, the ratio of biologically sustainable global fish stock was 90% in 1974 and decreased to 68.6% in 2013. Among the examined stocks in 2013, 31.4% were subject to overfishing and biologically non-sustainable, 58.1% were subject to fishing at the maximum sustainability level, and only 10.5% of the stock was under low fishing pressure (FAO, 2016).

The technological and industrial developments, increasing population, and changing needs have led to the overuse, exhaustion, and pollution of natural resources. Water resources are negatively affected by industrial and domestic pollution and housing. In addition to the damage caused by anthropogenic activities, the uncontrollable changes such as the global climate change and global warming affect water product production.

Various factors including the climate change, changing environmental factors, the destruction caused by human activities in natural habitats, population increase, and over and unconscious fishing negatively affect natural fish stocks. Despite the measures taken against this problem, production through hunting is thought to no longer increase and aquaculture is believed to become the only source of the increase in production. Moreover, the number and capacity of the facilities has increased along with the increase in the production of global water product cultivation and large-scale facilities are founded in the seas worldwide.

Sea product culture has a great and growing potential considering the large sea area that exceeds the area required to meet the need for sea products (Gentry et al., 2017a). Sea product culture essentially includes valuable sea fish production while also producing seaweed, bivalve mollusk, and crustaceans (Bostock et al., 2010; FAO, 2018). Historically, sea product cultivation has developed near coastal waters (i.e., tidal areas, estuaries, and sheltered bays) to benefit from still waters and have easy access to fishing cages (Gentry et al., 2017b). However, despite the competition with other activities (fishing, energy production, protection areas, tourism, military activities, and transportation) for area in the coastal regions, the sector is expected to grow while improving its efficiency with the developing aquaculture technology (Marra, 2005). The growth and expansion of the aquaculture sector will continue and, thus, the future of aquaculture should be planned and organized to reduce the conflict with other activities and apply a sustainable and progressive ecosystem approach to aquaculture (Soto et al., 2008; Sanchez-Jerez et al., 2016).

Criteria for Aquaculture Areas

Area planning for aquaculture is based on two grounds.

(1) Potential regions that are determined for the development of water product cultivation (Areas that are declared appropriate for sustainable cultivation activities by the current management/authority in regions where predetermined criteria are met).

(2) Areas other than the determined potential regions that are identified by businesses for cultivation (Areas that are officially reported to be in conformity with criteria for cultivation area but should be approved by authority/management for production).

Within the scope of production in potential regions or areas that are identified by businesses, the determination of optimum criteria with respect to the properties of production areas and compliance with the criteria during the production activities are needed for sustainable cultivation.

To identify appropriate areas for production, culture fish regions should examine the species to be cultivated and systems within the framework of certain requirements (water quality, temperature, depth, distance to coasts, flow) and criteria within the scope of current legislation, which include environmental (protection areas, closeness to sensitive habitats), social (visual impact, anthropogenic activities, employment), and economic (access to roads and other services) concerns (Figure 1).

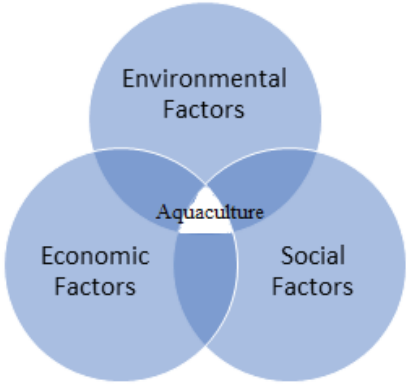

Figure 1. *Sustainable Aquaculture Goals*

The production area should have properties that are appropriate for the water demands of species. This is the first prerequisite for a production area. The area will not be preferred if it is not suitable for the efficient production of the species of interest. In aquaculture, especially in optimum feeding, certain water parameters are known to be effective, with

temperature, dissolved oxygen, salinity, pH, and water quality being the leading parameters (Figure 2).

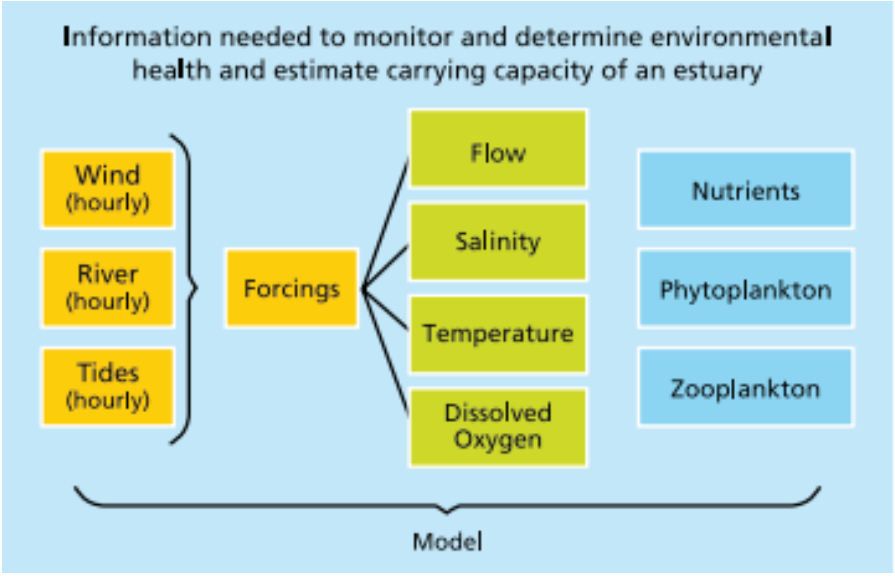

Figure 2. *An illustration of the concept of flushing time (Valle-Levinson, 2013)*

In addition, water exchange amount, turbidity, algae bloom, fouling organisms, natural diseases, and pollution (heavy metals, pesticides, petrol, and its derivatives) and are other properties that require consideration during the determination of potential production areas.

Weak flow systems usually do not allow transportation of organic waste materials in large amounts. Thus, the location of the reference station that will be used to monitor the aquaculture-originated pollution is also important (Okumuş et al., 2004).

High-capacity production in the seas is carried out using cage systems in which modern technologies are used. The cage systems are affected by the oceanographic properties of the seas. The technological developments in recent years have led to the use of high-resistance materials that will sustain minimum damage from the oceanographic factors. During the determination of the production area, efforts are made to minimize the negative effect of weather conditions on the systems while the structure of the ground on which the systems will be established emerges as an important factor. Furthermore, properties such as flow rate and direction, depth, distance to coast in the production area are important criteria that will affect both production activities and environmental properties. The direction of the flow is an important parameter for cage systems and the

systems are planned in consideration of it. Flow rate should be at levels that will not cause excessive energy consumption by fish and squeezing of fish into nets while allowing the transport of wastes and oxygen during the water exchange in the cages. The environmental problems especially in bays and gulfs where depths are low have forced the producers to be more precautious about depth. Within this framework, cage systems, which are mostly established in bays and gulfs, are moved to deeper waters/open seas thanks to technological developments (Figure 3). This offer advantages in reaching the desired production volume with its advantages in high stocking, environment, and production. The production in deeper waters should be encouraged both for production and sustainable environment. Another important criterion is the distance of the production area to the coasts. There is usually a linear relationship between depth and distance to coast, but the depths of regions that can be regarded as far away from the coast in areas with different bottom structures were found to be not suitable for production. Therefore, depth and distance to coast should be evaluated separately. Flow rate/direction, depth, and distance to coast should have values that allow the natural disposal of the wastes that originate from the production area in the sea environment. However, the values can vary depending on the production area.

Figure 3. *Fish farm cages*

The ecological assessment of the region is another important factor in the determination of the production area. The region is not appropriate for production if it is ecologically sensitive. The properties of ecological sensitive areas are determined considering the presence of endemic species, presence of seagrass area, and identification of endangered flora and fauna that have been protected by international treaties. Ecological sensitive areas should be declared marine protection areas and marked on sea maps to protect them from any negative impact.

Cage systems are believed to cause pollution in regions in which they are established. The aquaculture sector has made intensive efforts to extinguish these negative beliefs about the sector. Regions that are far from residential areas are especially preferred to avoid this conflict (Figure 4). Moreover, production is done in regions that are away from residential areas to avoid urban and industrial pollution and conflict with different sectors on the use of coasts (tourism areas).

Figure 4. *Salmon culture*

Environmental Factors in Aquatic Environments

Organisms in waters are not only affected by materials and properties that directly affect the waters but also are endangered by the aquatic life that is indirectly affected by these factors. Nutrients of aquatic organisms, other organisms that hunt them or hunted by them, and organisms that

protect their territories are examples to this concern (Munsuz and Ünver, 1995).

Natural cleaning in the surface waters is needed for the continuation of vital functions in the aquatic environments. This occurs through the increase in oxygen concentration and decrease in carbon dioxide concentration after contact with atmospheric oxygen, leading to increased pH.

The majority of the discharges due to anthropogenic factors affects coastal regions and not open seas or oceans. Pollutants can be grouped as persistent, non-persistent, and continuous pollutants. Persistent pollutants that especially threaten life in the seas in the long-term comprise inorganic and certain organic materials. These pollutants accumulate in organisms and are transferred from one organism to another and, thus, can halt the reproduction of some organisms or fundamentally affect reproduction in a water body and can cause esthetic issues in addition to their negative impact on organisms. Continuous pollutants are very similar to persistent pollutants but grouped under a different category especially due to their biological accumulation in species and transfer from one species to another in increasing amounts. This group includes heavy metals such as mercury, cadmium, and lead (Sunlu and Türkman, 1987). At this stage, heavy metals such as mercury and persistent and continuous pollutants can cause bioaccumulation and biomagnification in organisms. (Figure 5). In this case, consumption of fish, which is an important resource for nutrient requirements, can threaten public health. Figure 6 shows the transport of pollutants from their source to the food chain and receivers.

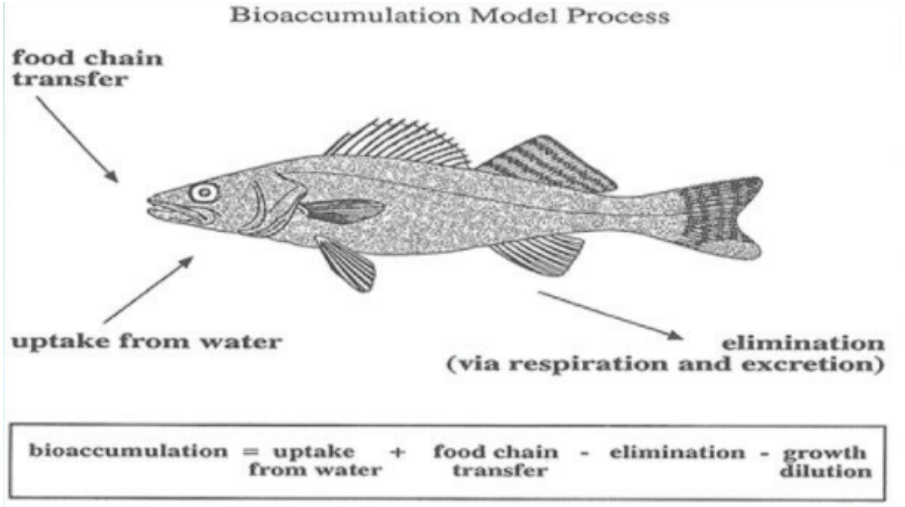

Figure 5. *Bioaccumulation (Yarsan and Yipel, 2013; Mishra, 2018)*

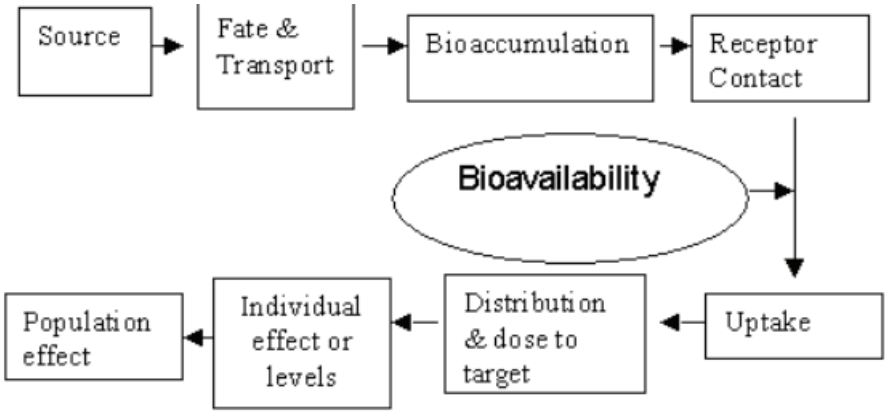

Figure 6. *The transport of pollutants from their source to the receiver (Powers et al., 2003; Lioy, 1990; Burger and Gochfeld, 1996)*

The threat posed by bioaccumulation and bioconcentration to human health is at severe levels (Figure 7). Organometallics and organic chemicals threaten human health. Humans are exposed to these materials through the consumption of meat, fish, plants, drinking water, soil, and plants etc. (USGS, 2015). Because of consumption of contaminate fish and shrimps, peoples are exposed to cancer 200 times greater that minimum cancer risk (Kar et al., 2011; Mishra, 2021).

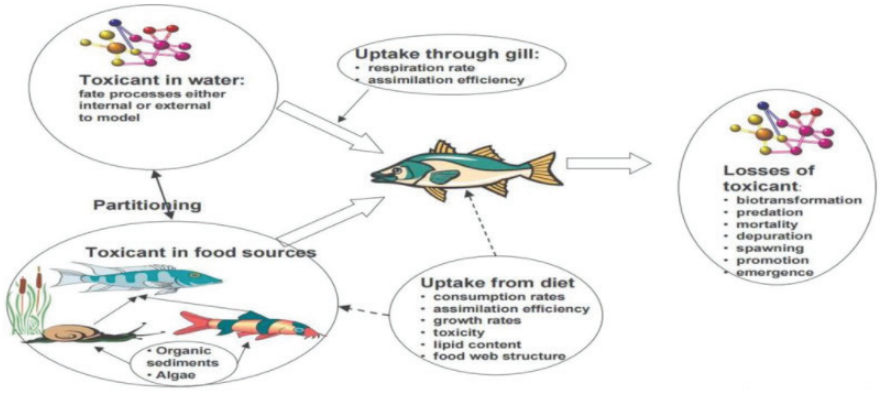

Figure 7. *Components of bio-concentration (Imhoff et al., 2004; Mishra, 2018)*

Therefore, compliance with the relevant legislation on especially the discharge of persistent pollutants into the marine ecosystem is important in the sustainability of the fishing industry. The sustainability of fish farming and production can be achieved through the optimization of environmental factors (the cease of the discharge due to agricultural areas, industrial discharge, point source discharge into marine environments), production

planning by prioritizing social factors, and optimum planning of economic engineering.

On the other hand, non-persistent pollutants are biodegradable and unstable and, thus, are converted into simpler, more stable, and inorganic products in time and their accumulation in living organisms and transfer from one organism to another is much lower than that of persistent and continuous pollutants (Uslu and Türkman, 1987).

Environmental Impact of Aquaculture

The effect of any activity in the water environment on the natural environments is inevitable to some degree. The effect is on environmental parameters and organisms. Thus, firstly, on which factors aquaculture activities will have an effect should be determined. The factors and their impact levels determine the upper limits of the criteria for aquaculture monitoring activities.

The increases in the number of businesses, capacities, and areas around the world bring along the increase in environmental impact in addition to the increase in production amounts. Therefore, production models that are limited by certain criteria are needed for sustainable cultivation activities. However, these are not standard models and should be evaluated considering all properties of the production areas and cultivation methods. The production areas worldwide show different physical, chemical, and geographical properties. Thus, all properties of production areas should be considered when planning production.

Today, the growth rate and capacity of facilities that cultivate fish using cages is growing significantly, leading to increases in aquaculture worldwide. Production amount depends on various factors (such as production method, species, stocking intensity, production area, feed quality). Depending on their capacities, businesses want to produce at a maximum amount and earn economic gain. Therefore, the goal of the businesses is to obtain the maximum yield from determined areas. Businesses carry out studies on the production amount they can possibly obtain from the production area during the project. Studies have shown a positive correlation between the increase in production per unit area and environmental impact. The calculation of the maximum production amount for a production area, that is, determination of the carrying capacity, is needed. Moreover, the necessary legal measures should be taken to prevent from the exceeding of the determined capacity under no circumstances. The beginning point of the environmental impact is the total amount of the production area. The exceeding of the load that can be disposed of by the natural environment during production activities can cause greater cumulative issues over the years.

Feed is the leading issue that should be examined with regard to production and environmental impact in aquaculture. Feed is the leading factor that affect production area and has the greatest share among the operating costs. Thus, the amount and properties of the feed that is used in the production area are of importance in terms of economy and environmental impact. Feed emerges as the main factor of production as it is desired to have qualities that can meet the feeding and growth requirements of the species of interest. Therefore, feed properties and composition differ. Various raw materials are used in feed production, which include macronutrients comprising protein, fat, and carbohydrates that meet the energy requirement of fish, micronutrients that include various vitamins and minerals, and other additives. Producers prefer high-quality feeds. The parameters that determine the physical and chemical quality of fish feeds include raw materials, feed formulation, feed production technology, and the quality control strategy used during production.

Certain criteria should be considered to reduce the fish feed-caused environmental impact on the production area (Cho et al., 1994);

-***Digestibility during the selection of raw materials:*** Raw materials with high digestibility coefficients should be preferred. Raw materials should have high energy but low cellulose contents and should not contain any non-nutritious materials.

-***Balanced feed formulation***: The feeds that will be produced in compliance with the natural feeding conditions of the species should have ration formulations that allow maximum energy and maximum protein availability.

-***Feed production technology:*** The most appropriate technology and method that provide physical and chemical quality, improve digestion, hinder dispersion in water, and consumed by fish without any losses should be employed in fish feed production for aquaculture. Today, the advanced extrusion technology, which is more efficient in fish farming and can reduce environmental impact, is used in feed production.

-Balancing of the nutrient amount: The Carbon:Nitrogen:Phosphorus (C:N:P) balance, which is needed depending on the species and developmental/growth stage of fish, should be controlled during feed production. Studies have used this approach to approximately determine the mole fraction between dissolved phosphate, nitrate, and carbonate in water. The same ratios are also observed in algae protoplasm. Phosphate, nitrate, and carbonate are eliminated from water in upper layers to which light can enter and used in algae biosynthesis at a ratio of 106/16/1. In deeper waters, phosphate, nitrate, and carbonate release carbon at the same ratios (Uslu and Türkman, 1987). As can be seen, the ecosystem

has a circle outside anthropogenic factors. In the reciprocal relationship between consumer and producer organisms, as is the case in respiration and photosynthesis, stable conditions emerge during the production and disintegration of organic materials in a balanced ecosystem. In a healthy ecosystem, the balance yields a constant amount of excess oxygen. The stability between production via photosynthesis, F=dP/dt (F=organic material production rate; P= algae biomass) and heterotrophic respiration (S=organic material disintegration rate) can be described using a simplified stochiometric chemical equation:

$106CO_2 + 16NO_3^- + HPO_4^+ + 122H_2O + 18H^+ +$ (trace elements; energy) ……. $C_{106}H_{263}O_{110}N_{16}P + 138O_2$ (algae protoplasm)

The complex dynamic between photosynthesis and respiration is created by various organisms. A simple stochiometric formulation of such a complex event reflects the "minimum law" of Justus Liebig. The phosphorus and nitrogen that are dissolved in sea water due to assimilation through photosynthesis are consumed in a balanced manner. Regardless of temporary or environmental factors, nitrogen and phosphorus determine the scale of organic production in many seas together. (Uslu and Türkman, 1987). As is phosphorus, nitrogen is a necessary and important nutrient in the growth of algae and other organisms. However, the removal of compounds containing nitrogen phosphorus before their release into the receiver environment is of great importance (Duran and Demirer, 1997).

Furthermore, the protein:energy balance of feeds should be adjusted in accordance with the energy requirement of the fish species. The N/P requirement should be determined considering the fish species and its developmental stage and the availability of N/P in the raw materials should be established. The N and P resources of plant origin may be preferred instead of excessive N and P in feed rations (Cho et al., 1994; Hardy and Gatlin, 2002).

Feeding method is another factor in fish cultivation. It is of great importance both in terms of cost and environment. To minimize the production-induced environmental impact, ideal feeding methods should be developed along with the improvement of the physical and chemical properties of feeds. An ideal feeding method can be developed by calculating the total feed amount and considering feeding frequency and feeding technique.

Two methods are applied in the feeding of fish: feeding until the fish are full or limited feeding. The easiest and most expensive method is feeding until fish are full. The maximum fish amount that can be consumed by fish in observable production areas are released into the medium. It

is a completely observation-based method. On the other hand, in limited feeding, the optimum feeding rates given in feed recipes and supported by information about water temperature, fish weight, and stock amount are fed to fish. Compliance with the recommended ratio is advisable for optimum growth. However, the ratios on feed recipes do not always allow optimum growth and, thus, the feeding ratio should be applied at the appropriate feeding intervals that are given in tables by considering the species, genetic origin, feed content, and the properties of the water and production area. Feeding frequency is determined by considering water temperature and developmental period. Depending on the feed digestion duration of fish, fry should be fed more frequently. Furthermore, the timing of feeding before sunrise and sundown is important in terms of feed conversion.

Past experiences usually determine the daily and meal-based feed amount in businesses. The total feed amount should be calculated with respect to the water temperatures that are in reference to the amounts of stocked fish in cages. During the calculations, feed conversion rate (FCR)[1] for fish species should be considered (Skalli and Robin, 2004).

(1) Feed Conversion Rate (FCR) = Total amount of feed consumption, g/Total weight gain, g

FCR is used as a growth parameter and gives information about feed quality, digestion, and conversion. Thus, FCR should be calculated during and at the end of each production period.

Uncareful and unconscious applications in the production areas cause feed and economic losses. They also cause increases in the waste amount in the media. Ideal feed and feeding method should be applied to especially minimize feed-originated waste amount.

Feeding is not only about fish feeding; it also uses scientific data, experience, and record-keeping. Businesses generally do not attach the necessary importance to scientific data. We should remember that fish feeding only involves feeding fish at the sufficient amount and the minimization of feed loss will prove beneficial both economically and environmentally.

Impact on the Benthic Area

The growth of cage facilities both in terms of their numbers and capacity has brought along certain environmental impacts in addition to the increase in production areas. Scientific studies examine the environmental impact of cage fishing under three sections comprising general, water column, and benthos (Başçınar, 2011). Depending on production amount, water properties, and other factors, cage fishing can cause enrichment in organic materials in the water column and benthic environment in its

impact area and changes in the qualitative and quantitative properties of benthic organisms (Barg, 1992; Heryadi et al., 2019; Prihadi et al., 2020).

The benthos-related environmental impact of fishing activities is noteworthy (Karakassis and Hatziyanni, 2000; Kalantzi and Karakassis, 2006). Especially bioindicator species are commonly used to monitor the changes in water quality and environment.

Feed- and fish stool-originated wastes are accumulated in the sea bottom of fish production areas, which can affect the structure of the sediment and, thus, benthic habitats. The sediment type on the bottom of caging areas are highly affected by geochemical and biological variables and different sediment types are highly effective factors in the changes in the structure of benthic populations (Kalantzi and Karakassis, 2006). In addition to the physiochemical properties of sediments and water column, the low oxygen concentrations forming on the bottom due to the disintegration of organic materials can cause changes in various parameters (Pearson and Rosenberg, 1978). Figure 8 shows the impact of wastes that form due to the feeding activities and stools in production areas on water column.

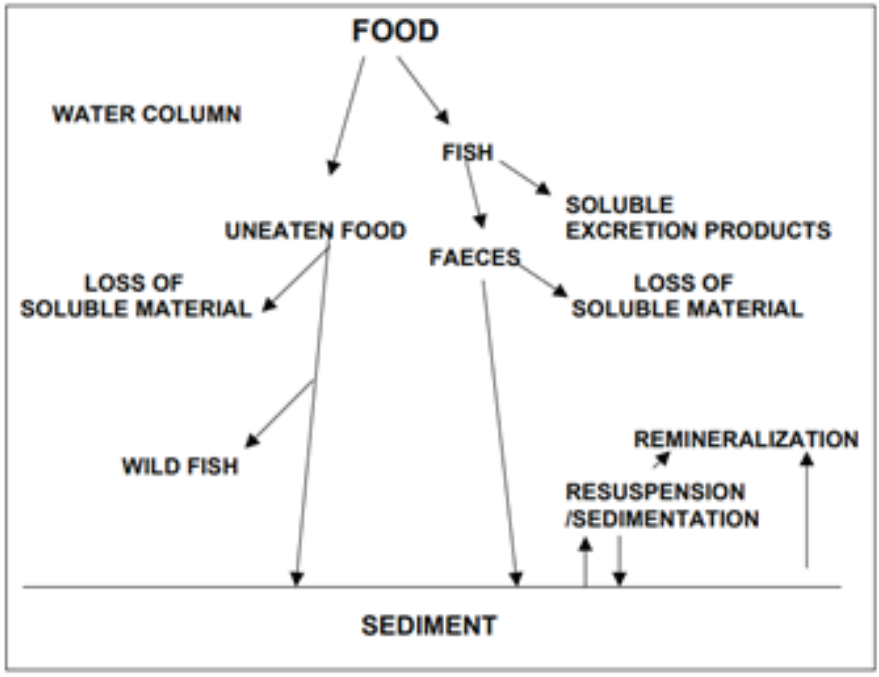

Figure 8. *The impact of waste materials that are released during intensive fish farming (Gowen, et al., 1990)*

Feed consumed by fish is discharged in a water-soluble form and as feces while non-consumed feed precipitate into the sediment in the water-soluble form. The impact of feed emerges as the depletion of oxygen in deep waters, increases in the total sulfite amount in the sediment, temporary sediment disruptions, and significant decreases in the biomass in benthic habitats (Tsutsumi et al., 1991). The changes in benthic fauna occur in the number of species, population and biomass (Drake and Arias, 1997).

Along with organic enrichment, important changes in parameters such as abundance, dominancy, and species diversity in the composition of microbenthic invertebrate populations under the cages can occur (Pearson and Rosenberg, 1978) (Figure 9). The number and diversity of species in benthic environments are at their lowest levels under the cages and increase as the distance from the cages increases (Karakassis and Hatziyanni, 2000; Vita and Marin, 2007).

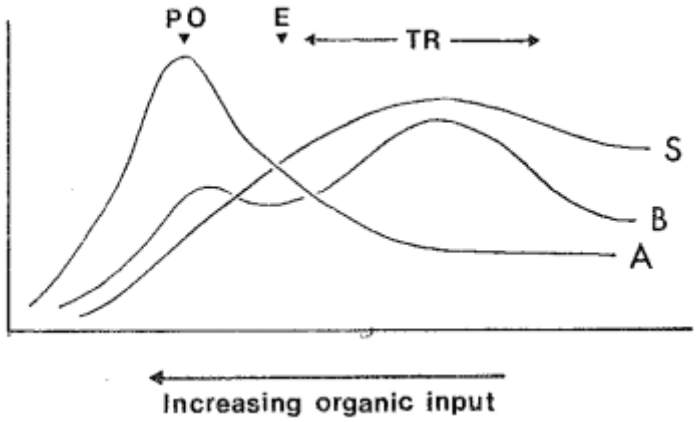

Figure 9. *Generalized SAB diagram, based on previous figure, of changes across a gradient of organic enrichment. S: species number; A: total abundance; B: total biomass; PO: peak of opportunists; E: ecotone point; TR: transition zone (Pearson and Rosenberg, 1978)*

Another indicator of organic pollution is the organic carbon content in the sediment. Pearson and Rosenberg (1978) qualitatively explained the relationship between total organic carbon and species diversity. Total organic carbon content is correlated with benthic diversity and can be used as an indicator in benthic ecosystems (Hyland et al., 2005; Albayrak et al., 2006; Kalantzi and Karakassis, 2006).

The main potential impact of aquaculture on biological diversity involves trophic change, but serious impact occurs locally within the few hundred meters of the impact area and ecosystem renewal can continue,

albeit slowly, when production ends. The invertebrate macro fauna under or around the cages is the most affected by the impact of the cultivation areas. The relative decrease or change in macro fauna are ecologically important, but extinction or broad impact on populations are not expected (Okumuş et al., 2004).

Carrying Capacity of the Production Field and Waste Spread

Cage fishing has important global, regional, and local environmental impact (Folke and Kautsky, 1989; Naylor et al., 2000; Folke and Kautsky, 2021). Considering the disturbance of the sustainability of aquaculture activities due to the environmental issues caused by production areas, the determination of the Carrying (Assimilation) Capacity[2] of the activity area is important.

(2) Carrying Capacity= [150 + 80 * (Fish Production Area - 1) * Distance to the Shore Coefficient *Depth Coefficient* F (Karakassis et al., 2013)

Fish farm area: The area planned for fish production/ the area of fish production(hectare)

Distance to the shore coefficient: 4.2 (for production in gulfs and bays)

Depth coefficient: 1.31 for 21-35 m; 2.76 for 36-50 m; 3.96 for areas deeper than 50 m

F=M / (G1+G2) * M / (L1+L2)

M: The narrowest openness of the bay to the sea

G1+G2: Sum of the topographic axes of the bay

L1+L2: The distance of the two points of the axis (M) that determines the openness of the bay to the fish farm

Not calculating the carrying capacity of production areas can cause serious disadvantages in the number of cage facilities, increase in production capacity, and other users of the area, leading to environmental issues.

An environmental impact assessment is usually carried out to avoid the exceeding of the ecological carrying capacity by the planned production area (Aguilar-Manjarrez et al., 2017). In addition to the calculation of the assimilation capacity in production areas, cumulative impact assessment of the production areas should be performed (David et al., 2015). Within this scope, the impact area of all production areas should be determined with regard to their wastes (Chary et al., 2021). The most important effects of the fish farming activities using net cages in the seas are due to the non-consumed feed by fish and the feces of fish after the consumption of feeds.

To determine the dispersion of these wastes in marine environments, the surface area, stool sedimentation rate, flow rate, and water depth should be considered.

The dispersion distance of the wastes in the production area is calculated using the equation[3]:

(3) $d = \frac{D * Cv}{V}$ (Gowen et al., 1989).

d= Dispersion distance

D= Water depth (average production area)

Cv= Flow rate

V= Sedimentation rate of excessive feed/stool

Scientific studies have shown that stool sedimentation rate of fish greatly vary depending on the properties of feeds and marine properties but accepted to be 0.1-1 m/s (FAO, 2010).

Conclusion

Aquaculture has been rapidly growing in parallel with the technological developments worldwide. This rapid development has increased the number of production areas and production amount. Countries that still carry out water product cultivation tend to increase their production areas and production amounts. This is predicted to continue worldwide. Thus, the monitoring of the impact on areas where such production is carried out is inevitable.

The waters used in production are important resources and their quality should be maintained for multivariate reasons. Efforts should be exerted to maintain the stability of the chemical compositions of waters that are critical for life. Natural waters have self-cleaning and buffering capacities for certain pollutants, but if the photosynthesis and respiration activities of living things are disrupted by anthropogenic factors, natural waters cannot self-clean, in other words, natural purification will no longer be possible. This negatively affects the vital functions of all living things and all fishing/aquaculture activities, starting with the smallest living thing in the aquatic ecosystem. It is of critical importance to maintain the stable state between photosynthesis and respiration, which are activities of living organisms in the aquatic environment. Efforts should be made to ensure that these processes are not disturbed by any anthropogenic factors and that the balance is sustainable. The temporary or random disturbance of the respiration and photosynthetic balance leads to various chemical and biological changes in the waters, which, in turn, can cause pollution. This means that the ecosystem can no longer maintain its old systematic process

and sustain continuity of life, leading to a process and result that negatively affect living organisms in the aquatic environment.

Within this scope, production areas should be managed within the framework of legislation with an ecosystem approach and control-monitoring activities should be to carried out. The ecosystem approach can lead to the formation of independent criteria for different production areas. Monitoring the ecosystem criteria is needed for the sustainable development of aquaculture. The monitoring of the environmental impact of the production area is of importance both ecologically and managerially. Monitoring with an ecosystem approach will ensure the early detection of the potential effect of production on the environment and taking the necessary precautions.

The assessment of the production area is of utmost importance to determine the effect of aquaculture activities on the natural environment and living organisms in its impact area. The assessment and the following monitoring studies before the use of an area for cage fishing can offer useful information.

Therefore, in the studies on the reduction of the environmental impact of the production areas:

-Ecological assessment of production areas,

-Determination of the physicochemical properties of the waters in production areas,

-Determination of different factors that can affect the ecological structure and water properties in the production area,

-Determination of the ecosystem approach criteria of the production area,

-Calculation of the maximum carrying capacity of the production area,

-Determination of the impact area of aquaculture,

-Determination of the impact of the cultivation activities during the production season with respect to certain criteria,

-Calculation of the cumulative impact of production areas in terms of based on certain criteria,

-Ensuring modern aquaculture applications, and

-Determination of alternative areas in case of an ecological concern are needed.

The preservation of the quality of the waters in production areas is important in terms of both the environment and production continuity in

aquaculture. Thus, aquaculture management with an ecosystem approach oriented to the protection of the waters in the production areas is needed. The sustainability of aquaculture production, which is the food and animal protein source that is growingly needed in parallel with the increasing population worldwide, in hinged upon these principles. The use of aquaculture methods with an ecosystem approach in all production areas will provide both environmental monitoring and production continuity.

REFERENCES

Aguilar-Manjarrez, J., Soto, D. & Brumment, R. (2017). Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Report ACS113536. Rome, FAO and World Bank Group, Washington, DC. 395 pp.

Albayrak, S., Balkıs, H., Zenetos, A., Kurun, A. & Kubanç, C. (2006). Ecological quality status of coastal benthic ecosystems in the Sea of Marmara. Marine Pollution Bulletin, 52: 790-799.

Barg, U.C. (1992). Guidelines for the promotion of environmental management of coastal aquaculture development. FAO Fisheries Technical Paper. p 122-322.

Başçınar, N.S. (2011). Kafes balıkçılığının bentik ortama etkisi. Yunus Araştırma Bülteni. 2: 23-27.

Bostock, J., McAndrew, B., Richards, R., Jauncey, K., Telfer, T., Lorenzen, K., Little, D., Ross, L., Handisyde, N., Gatward, I. & Corner, R. (2010). Aquaculture: global status and trends. Philosophical Transactions of the Royal Society B: Biological Sciences, 365: 2897–2912.

Burger, J. & Gochfeld, M. (1996). Ecological and human health risk assessment: a comparison. Pp. 127-148 in Interconnections between human and ecosystem health. (DiGuilio, R.T. and Monosson, E., eds). Chapman and Hall, London.

Chary, K., Callier, M.D., Coves, D., Aubin, J., Simon, J. & Fiandrino, A. (2021). Scenarios of fish waste deposition at the sub-lagoon scale; a modelling approach for aquaculture zoning and site selection. ICES Journal of Marine Science, Doi:10.1093/icesjms/fsaa238.

Cho. C.Y., Hynes, J.D., Wood, K.R. & Yoshida, H.K. (1994). Development of high-nutrient-dense, low-pollution diets and prediction of aquaculture wastes using biological approaches. Aquaculture, 124: 293-305.

David, G.S., Carvalho, E.D., Lemos, D., Silveira, A.N. & Dall'Aglio-Sobrinhoe, M. (2015). Ecological carrying capacity for intensive tilapia (*Oreochromis niloticus*) cage aquaculture in a large hydroelectrical reservoir in Southeastern Brazil. Aquacultural Engineering 66 (5):30-40.

Drake, P. & Arias, A.M. (1997). The effect of aquaculture practices on the benthic macroinvertebrate community of a lagoon system in the Bay of Cadiz (Southwestern Spain). Estuaries, 20: 677-688.

Duran, M. & Demirer, G.N. (1997). Su Arıtımında Temel İşlemler, Ankara, 1997. 202 s.

FAO (2010). Site selection and carrying capacities for inland and coastal aquaculture, http://www.fao.org/3/a-i3322e.pdf.

FAO (2016). The State of World Fisheries and Aquaculture 2016, Contributing to Food Security and Nutrition for All, Rome. 200 pp.

FAO (2018). The State of World Fisheries and Aquaculture 2018-Meeting the sustainable development goals. Licence: CC by-NC-SA 3.0 IGO. FAO, Rome. 227 pp. http://www.fao.org/publications/card/en/c/I9540EN (last accessed 30 December 2020).

Folke, C. & Kautsky, N. (1989). The role of ecosystems for a sustainable development of aquaculture. Ambio 18: 234–243.

Folke, C. & Kautsky, N. (2021). Aquaculture and ocean stewardship, Ambio https://doi.org/10.1007/s13280-021-01528-8.

Gentry, R.R., Froehlich, H.E., Grimm, D., Kareiva, P., Parke, M., Rust, M., Gaines, S.D. & Halpern, B.S. (2017a). Mapping the global potential for marine aquaculture. Nature Ecology & Evolution, 1:1317–1324.

Gentry, R.R., Lester, S.E., Kappel, C.V., White, C., Bell, T.W., Stevens, J. & Gaines, S.D. (2017b). Offshore aquaculture: spatial planning principles for sustainable development. Ecology and Evolution, 7: 733–743.

Gowen, R.J., Bradbury, N.B. & Brown, J.R. (1989). The use of simple models in assessing two of the interactions between fish farming and the marine environment. In: De Pauw, N. et al. (Ed.) Aquac. Biotechnol. Prog., 2: 1071-1080.

Gowen, R.J., Rosenthal, H., Makinen, T. & Ezzi, I. (1990). Environmental impacts of aquaculture activities. AQUACULTURE EUROPE´89-BUSINESS JOINS SCIENCE, N. De Pauw and R. Billard (Eds). E.A.S. Special Publication No. 12 Belgium, 1990.

Hardy, R.W. & Gatlin, D.M. (2002). Nutritional strategies to reduce nutrient losses in intensive Aquaculture. In: Cruz-Suarez, L:E., Ricque-Marie, D., Tapia-Salazar, M., Gaxiola-Cortes, M.G., Simoes, N. (Eds), Advances en Nutricion Acuicola VI. Memorias del VI Simposium International de Nutricion Acuicola. 3 al 6 de Septiembre del 2002. Cancun, Quintana Roo, Mexico.

Heryadi, H., Yanto, S., Fadillah, R. & Suwoyo, H.S. (2019). The Utilization of Super Intensive Pond Waste as a Media Plant of Mustard Greens (*Brassica rapa var. parachinensis*). Jurnal Pendidikan Teknologi Pertanian, 5(2):52-57.

Hyland, J., Balthis, L., Karakassis, I., Magni, P., Petrov, A., Shine, J., Vestergaard, O. & Warwick, R.M. (2005). Organic carbon content of sediments as an indicator of stress in the marine benthos. Marine Ecology Progress Series, 295: 91-103.

Imhoff, J.C., Clough, J., Park, R.A. & Stoddard, A. (2004). Evaluation of Chemical Bioaccumulation Models of Aquatic Ecosystem, US Environmental Protection Agency, National Exposure Research Laboratory, Office

of Research and develompent Athens, Georgia:Ecosystem Research Division. http://www.hspf.com/pdf/FinalReport2018.pdf

Kalantzi, I. & Karakassis, I. (2006). Benthic impacts of fish farming: Meta-analysis of community and geochemical data. Marine Pollution Bulletin. 52:484-493.

Kar, S., Maity, J.P., Jean, J.S., Lui, C.C., Lui, C.W. Bundschuh, J. & Lu, H.Y. (2011). Health risk for human intake of aquaculturl fish: Arsenic boaaccumulation and contamination, J. Environ Sci Health A Tox Hazard Substances Environ Eng. 46 (11), 1266-1273, doi: 10.1080/10934529-2011.598814.

Karakassis, I. & Hatziyanni, E. (2000). Benthic disturbance due to fish farming analyzed under different levels of taxonomic resolution. Marine Ecology Progress Series, 203: 247-253.

Karakassis, I., Papageorgiou, N., Kalantzi, I., Sevastou, K. & Koutsikopoulos, C. (2013). Adaptation of fish farming production to the environmental characteristics of the receiving marine ecosystems: a proxy to carrying capacity. Aquaculture 408-409:184–190. https://doi.org/10.1016/j.aquaculture.2013.06.002.

Lioy, P.J. (1990). Assessing total human exposure to contaminants. Environ. Sci. Technol. 24:938- 945.

Marra, J. (2005). When will we tame the oceans? Nature, 436: 175–176.

Mishra, B. (2018). Bioaccumulation of Mercury, College of Agriculture, Food Science, and Funtable Systems KYSU Kentucy State.

Munsuz, N. & Ünver, İ. (1995). Su Kalitesi, Ankara Üniversitesi Ziraat Fakültesi, Yayın No: 1389 Ankara, 1995. 335 s.

Naylor, R.L., Goldburg, R.J., Primavera, J.H., Kautsky, N., Beveridge, M.C.M., Clay, J., Folke, C., Lubchenco, J., Mooney, H. & Troell, M. (2000). Effect of aquaculture on world fish supplies. Nature 405, 1017–1024. https://doi.org/10.1038/35016500.

OECD (2016). Review of Fisheries: Policies and Summary Statistics 2015, OECD Publishing, Paris, 110 pp.

Okumuş, İ., Atasaral, Ş. & Kaçabaş, M. (2004). Su ürünleri yetiştiriciliğinde çevresel etki değerlendirme ve izleme, Ulusal Su Günleri, 6-8 Ekim 2004, İzmir.

Pearson, T.H. & Rosenberg, R. (1978). Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. H.Barnes, (ed.), Oceanographic Marine Biology Annual Review, 16. Aberdeen University Press, Aberdeen, 229311 pp.

Powers, CW., Barnes, D., Burger, J., Duffy, L.K., Eichelberger, J., Friedlander, B., Gochfeld, M., Jewett, S. & Kosson, D. (2003). Amchitka Independent Assessment Science Plan, June 24, 2003, 168 p.

Prihadi, T.H., Widiyati, A., Hermawan, M., Permana, N., Radona, D. & Aubin, J. (2020). Fish culture technology using double net system for hybrid grouper (brown marbled grouper *Epinephelus fuscoguttatus* × giant grouper *Epinephelus lanceolatus*) and rabbitfish (*Siganus canaliculatus*). IOP Conf. Series: Earth and Environmental Science 521: 012003, doi:10.1088/1755-1315/521/1/012003.

Sanchez-Jerez, P., Karakassis, I., Massa, F., Fezzardi, D., Aguilar-Manjarrez, J., Soto, D., Chapela, R., Avila, P., Macias, C., Tomasetti, P., Marino, G., Borg, A., Franičević, V., Yucel-Gier, G., Fleming, A., Biao, X., Nhhala, H., Hamza, H., Forcada, A. & Dempster, T. (2016). Aquaculture's struggle for space: the need for coastal spatial planning and the potential benefits of Allocated Zones for Aquaculture (AZAs) to avoid conflict and promote sustainability. Aquaculture Environment Interactions, 8: 41–54.

Skalli, A. & Robın, J.H. (2004). Requirement of n-3 long chain polyunsaturated fatty acids for European seabass (*Dicentrarchus labrax*) juveniles: growth and fatty acid composition. Aquaculture, 240: 399-415. doi:10.1016/j.aquaculture.2004.06.036.

Soto, D., Aguilar-Manjarrez, J., Brugère, C., Angel, D., Bailey, C., Black, K., Edwards, P., Costa-Pierce, B., Chopin, T., Deudero, S., Freeman, S., Hambrey, J., Hishamunda, N., Knowler, D., Silvert, W., Marba, N., Mathe, S., Norambuena, R., Simard, F., Tett, P., Troell, M. & Wainberg, A. (2008). Applying an ecosystem-based approach to aquaculture: principles, scales and some management measures. In D. Soto, J. Aguilar-Manjarrez and N. Hishamunda (eds). Building an ecosystem approach to aquaculture. FAO/Universitat de les Illes Balears Expert Workshop. 7–11 May 2007, Palma de Mallorca, Spain. FAO Fisheries and Aquaculture Proceedings. No. 14. Rome, FAO. pp. 15–35.

Tsutsumi, H., Kikuchi, T., Tanaka, M., Higashi, T., Imasaka, K. & Miyazaki, M. (1991). Bentic faunal succession in coue orginaclly polluted by fish farming. Marine Pollution Bulletin, 23: 233-238.

USGS (2015). Bioaccumulative contaminants, Human Health, http://health.usgs.gov /bioacc_cont

Uslu, O. & Türkman, A. (1987). Su Kirliliği ve Kontrolü, T.C. Başbakanlık Çevre Genel Müdürlüğü Yayınları Eğitim Dizisi, 364 s.

Valle-Levinson, A. (2013). Some basic hydrodynamic concepts to be considered for coastal aquaculture. In L.G. Ross, T.C. Telfer, L. Falconer, D. Soto & J. Aguilar-Manjarrez, eds. Site selection and carrying capacities for inland and coastal aquaculture, pp. 147–158. FAO/Institute of Aquaculture, University of Stirling, Expert Workshop, 6–8 December 2010. Stirling, the United Kingdom of Great Britain and Northern Ireland. FAO Fisheries and Aquaculture Proceedings No. 21. Rome, FAO. 282 pp.

Vita, R. & Marin, A. (2007). Environmental impact of capture-based bluefin tuna aquaculture in benthic communities in the western Mediterranean. Aquaculture Research, 38: 331-339.

Yarsan, E. & Yipel, M. (2013). The important terms of Marine Pollution "Biomarkers and Biomonitoring, Bioaccumulation, Bioconcentration, Biomagnification". J Mol Bomark Diagn S1:003. Doi: 10.4172/2155-9929.51-003.

Chapter 4

TRADITIONAL KNOWLEDGE OF MEDICINAL PLANTS IN YUSUFELI (ARTVIN) REGION

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1. INTRODUCTION

The existence of mankind also started diseases. Traditional treatment methods against these diseases are matured by taking advantage of nature and past experiences. Traditional methods are also synthesized with cultural, religious and philosophical structures of societies (Arslan et al., 2016). The last treatment applied in folk medicine is medication. Most of the folk medicines given in names such as "home remedies" and "old women medicines" are experimental practices that have come to the end of long experience. Folk medicine, which has a wide application area in Anatolia, is being used by means of rational and magical methods, usually by a very large population in rural areas (Şar, 2008).

Ethnobotanical studies on human-plant relationships in Turkey have benefited from the use of drugs or drug mixtures from wild plants in the nature or from cultivated species in the treatment of diseases more commonly in rural areas (Akbulut, 2015; Kalankan et al., 2015; Mükemre et al., 2015; Polat et al., 2015; Akbulut and Bayramoğlu, 2014; Akbulut and Özkan, 2014; Hayta et al., 2014; Akbulut and Bayramoğlu, 2013; Saraç et al., 2013; Çakılcıoğlu et al., 2010). The following factors can be listed among the reasons widely use of traditional remedies in Turkey consist of the high ratio of rural population working on agriculture and farming; transmission from generation to generation, and easy access and uses to these plants in rural areas (Şar, 1982).

Recently, there has been an increase in demand for such plants. Some of them are being traded in domestic and foreign markets as raw or semi-finished products under the name of non-wood forest product (Özkan and Akbulut, 2012). It is said that the number of plants used for treatment purposes in Turkey is between 350 and 1000 (Özgen et al., 2004; Başer, 2001; Koyuncu, 1990). This number is increasing with new studies and new plant uses are being determined (Akbulut and Karaköse, 2016).

The use of organic products as much as in rural areas has also begun to take an important place in urban life. Especially when it comes to the last stage from the medical point of view and when it is not possible to return to medical treatment, mankind is looking for healing from natural products as a last hope. People from all segments of society are inclined to use traditional herbs in some way. Although these treatment systems are not evidence-based by some scientists, it is known that many people prefer these methods today. For this reason, in order to provide a more effective and reliable use of traditional treatment systems, it is important for the health professionals to have adequate and necessary knowledge in this area and to give importance to traditional medicine as well as modern medicine (Arslan et al., 2016).

2. MATERIALS AND METHODS

The material of the study includes plants that are used by the locals for medicinal purposes which were collected during the 2014 vegetation period. A total of 60 days of survey was done in this study. In the scope of the study, face-to-face surveys were conducted with the people living in Yusufeli city centre, Öğdem village, Altıparmak village, Erenköy, Köprügören village, Pancardağı highlands (Figure).

Face-to-face interviews were made during the study to determine the plant species as a result of which the local names, parts used, usage objectives and usage types were determined for the plants that are used for ethnobotanical purposes in the region. The collected plant species were pressed, dried and recorded in the KATO herbarium. The study entitled "Flora of Turkey and the East Aegean Islands" (Davis, 1965-1985; Davis, 1988; Güner et al., 2000) was used for the identification of plant species. The scientific names of plants were controlled according to List of Turkey Plants (Vascular Plants) (Güner et al., 2012).

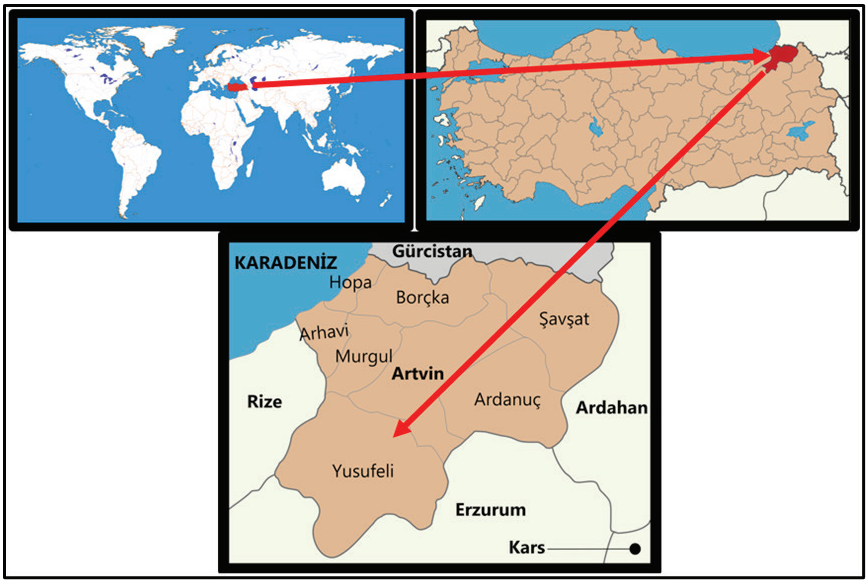

Figure. *Location of study area (https://tr.wikipedia.org/wiki/Artvinin_ilceleri)*

3. RESULTS AND DISCUSSIONS

As a result of study, in Yusufeli province and some villages, 26 plant species were used for medicinal purposes by local people. Rosaceae family with 6 taxa has become the most abundant family in the study area. This

family is followed by Polygonaceae, Lamiaceae, Euphorbiaceae and Asteracea.

Adoxaceae

Plant species: *Sambucus nigra* L.

Local name: Mürver

Plant part used: Leaves

Traditional uses: Painkiller

Preparation: Leaves are heated, used for painkiller (external use).

Location: Köprügören köyü

Amaranthaceae

Plant species: *Beta vulgaris* L. var. *vulgaris*

Local name: Pazı

Plant part used: Leaves, branches

Traditional uses: Rheumatism

Preparation: Leaves are heated, used for rheumatism (external use). Leaves and branches used for making meal.

Location: Altıparmak köyü

Amaryllidaceae

Plant species: *Galanthus woronowii* Losinsk.

Local name: Kardelen

Plant part used: Tuber

Traditional uses: Antipyretic, Sedative

Preparation: Root tea (decoction) used for antipyretic, sedative.

Location: Altıparmak köyü

Apiaceae

Plant species: *Ferula orientalis* L.

Local name: Çaşır

Plant part used: Fresh root

Traditional uses: Diabetes, stomach ache, intestinal parasitic, anaemia, orexigenic, wound healing

Preparation: Eaten regularly for diabetes, stomach ache, intestinal

parasitic, anaemia, orexigenic. Root powder used for wound healing.

Location: Öğdem köyü

Araliaceae

Plant species: *Hedera helix* L. f. *helix*

Local name: Sarmaşık

Plant part used: Flowers, leaves

Traditional uses: Blood stopper, making yeast

Preparation: Powder prepared from flowers, drink with water for blood stopper. Leaves used for making yeast.

Location: Altıparmak köyü

Asteraceae

Plant species: *Helichrysum armenium* DC. subsp. *armenium*

Local name: Ölmez çiçek

Plant part used: Flowering branches

Traditional uses: Diuretic, Kidney stone

Preparation: Dried flowers and branches (decoction) used for diuretic and kidney stone.

Location: Öğdem köyü

Plant species: *Taraxacum buttleri* Soest

Local name: Keklikotu

Plant part used: Root

Traditional uses: Somniferous, liver purifier, diabetes, immune system booster

Preparation: Root (decoction) drink one teacup for somniferous, liver purifier, diabetes, immune system booster.

Location: Erenköy

Buxaceae

Plant species: *Buxus sempervirens* L. subsp. *sempervirens*

Local name: Şimşir

Plant part used: Leaves, branch bark

Traditional uses: Antipyretic, constipation, diarrhea, liver diseases

Preparation: Leaves (infusion) used for antipyretic, constipation, diarrhea, liver diseases. Leaves and branch bark (infusion) used for liver diseases.

Location: Öğdem köyü

Crassulaceae

Plant species: *Sedum pallidum* M.Bieb.

Local name: Dam koruğu

Plant part used: Leaves

Traditional uses: Wound healing

Preparation: Leaves (salve) used for wound healing (external use).

Location: Altıparmak köyü

Euphorbiaceae

Plant species: *Euphorbia* sp. (Zehirli)

Local name: Sütleğen

Plant part used: Latex, seed

Traditional uses: Malaria, jaundice, wart, fungal, wound healing

Preparation: Oil from milk and seeds used for malaria, jaundice, wart, fungal, wound healing.

Location: Altıparmak köyü

Plant species: *Mercurialis annua* L.

Local name: Yer fesleğeni

Plant part used: Flowers, leaves

Traditional uses: Uterine swelling

Preparation: Leaf and flower are boiled and steamed for uterine swelling.

Location: Altıparmak köyü

Fabaceae

Plant species: *Trifolium pratense* L. var. *pratense*

Local name: Üçgül

Plant part used: Aerial parts

Traditional uses: Against poisoning, diuretic, anti-vomiting

Preparation: Aerial parts (decoction) drink for poisoning. Used for diuretic, anti-vomiting.

Location: Öğdem köyü

Lamiaceae

Plant species: *Mentha longifolia* (L.) L. subsp. *longifolia*

Local name: Eşek nanesi

Plant part used: Leaves

Traditional uses: Heart and stomach strengthening, cholesterol stabilizer

Preparation: Leaves (infusion) drink one teacup three times a day for heart and stomach strengthening. Leaves (infusion) drink one teacup three times a day for cholesterol stabilizer.

Location: Öğdem köyü

Plant species: *Thymus praecox* Opiz subsp. *caucasicus* (Willd. ex Ronniger) Jalas

Local name: Adi kekik

Plant part used: Leaves, flowers, branches

Traditional uses: Inflammatory wound healing, acne treatment, oral health

Preparation: Aerial parts (infusion) drink one teacup two times a day for inflammatory wound healing, acne treatment. Infusion with leaves (mouthwash) for oral health.

Location: Erenköy

Malvaceae

Plant species: *Malva sylvestris* L.

Local name: Ebeci

Plant part used: Leaves

Traditional uses: Cough, antipyretic, sedative, lose weight

Preparation: Waited leaves in water one night used for cough, antipyretic (external use). Leaves (infusion) used for sedative, lose weight.

Location: Erenköy

Pinaceae

Plant species: *Picea orientalis* (L.) Peterm.

Local name: Doğu ladini

Plant part used: Resin (Pis)

Traditional uses: Abscess, stomach diseases, inflammatory wound healing

Preparation: External use for abscess and inflammatory wound healing, chewed for stomach diseases.

Location: Öğdem köyü

Plantaginaceae

Plant species: *Plantago major* L. subsp. *major*

Local name: Siğlen

Plant part used: Leaves

Traditional uses: Abscess, hematischesis

Preparation: Leaves are softened in hot water, used abscess and hematischesis (external use).

Location: Köprügören köyü

Polygonaceae

Plant species: *Polygonum bistorta* L. subsp. *carneum* (K.Koch) Coode & Cullen

Local name: Kurtpençesi

Plant part used: Whole plant

Traditional uses: Diuretic, diarrhea, mumps disease

Preparation: Dried whole plant (infusion) for diuretic and diarrhea. Leaves and flowers (salve) used mumps disease.

Location: Altıparmak köyü

Plant species: *Rumex acetosella* L.

Local name: Sitibiga

Plant part used: Leaves, root

Traditional uses: Gum bleeding, antipyretic

Preparation: Leaves eaten fresh for gum bleeding. Roots (decoction) used for antipyretic.

Location: Öğdem köyü

Rosaceae

Plant species: *Alchemilla* sp.

Local name: Aslanpençesi

Plant part used: Leaves, branches

Traditional uses: Diabetes, myolysis, oedema

Preparation: Leaves and branches (decoction) used for diabetes. Leaves used for making salads.

Location: Altıparmak köyü

Plant species: *Fragaria vesca* L.

Local name: Yabani çilek, çilek otu

Plant part used: Fruits, leaves, seeds

Traditional uses: lose swelling, oral health, jaundice

Preparation: Fruits used for making jam. Leaves (infusion) used for losing swelling. Infusion with leaves (mouthwash) for oral health. Seeds (decoction) used for jaundice (oral administration).

Location: Öğdem köyü

Plant species: *Potentilla erecta* (L.) Räusch

Local name: Beşparmak otu

Plant part used: Whole plant

Traditional uses: Tooth ache, skin beauty, constipation

Preparation: Root can be chewed for toothache. Flowers (decoction) used for skin beauty. Flowering branches and leaves (decoction) used for constipation (oral administration).

Location: Köprügören köyü

Plant species: *Rosa canina* L.

Local name: Kuşburnu

Plant part used: Fruits, leaves

Traditional uses: Colds, rheumatism, skin beauty

Preparation: Tea (infusion) prepared from fruits is used in colds. Dried leaves (decoction) used for skin beauty and rheumatism (external use).

Location: Erenköy

Plant species: *Rubus canescens* DC. var. *glabratus* (Godr.) Davis & Meikle

Local name: Böğürtlen

Plant part used: Root, leaves, fruits

Traditional uses: Kidney sand and stone, oral health, tonsillitis

Preparation: Fruits used for making jam. Decoction with root for kidney sand and stone [oral administration], decoction with leaves (mouthwash) for oral health and tonsillitis.

Location: Altıparmak köyü

Plant species: *Sorbus aucuparia* L.

Local name: Çirkat

Plant part used: Fruits, leaves

Traditional uses: Diabetes

Preparation: The fruit used for making syrup and jam. Poisonous plant (if used overdose). Leaves used for making tea.

Location: Erenköy

Urticaceae

Plant species: *Urtica dioica* L. subsp. *dioica*

Local name: Cimcar

Plant part used: Leaves

Traditional uses: Milk enhancer, immune system booster

Preparation: The leaves are dried and boiled, oral administration. Used for making meal.

Location: Öğdem köyü

Local people in the Yusufeli region were recorded to use the leaves (17 of use reports), root and branch (5 of use reports), fruit and flower (4 of use-reports), whole plant and seed (2 of use reports). In addition to these, the using areal parts, resin, latex and bark have also been added to the used plant parts.

In this study, it was determined that the main disease groups were beneficial for skin diseases, digestive system diseases, urinary tract diseases and oral health treatment. It was found that the plants were mostly used to diabetes, antipyretic, stomach ache, wound healing, diuretic, abscess, blood stopper, constipation, rheumatism, skin beauty and sedative.

The main preparation methods of these plant species used for healing are the decoction method, followed by the infusion method. In addition, plants are consumed fresh, dust, mash, oil, plant parts also available in the form of heating. In order to achieve healing from plant species, the most commonly used route is oral administration preferred.

4. REFERENCES

Akbulut, S. and Bayramoglu, M. M. (2013). The trade and use of some medical and aromatic herbs in Turkey. Studies on Ethno-Medicine, 7(2), 67-77.

Akbulut, S. and Bayramoglu, M. M. (2014). Reflections of socio-economic and demographic structure of urban and rural on the use of medicinal and aromatic plants: The sample of Trabzon Province. Studies on Ethno-Medicine, 8(1), 89-100.

Akbulut, S. and Özkan, Z. C. (2014). Traditional usage of some wild plants in Trabzon region (Turkey). Kastamonu University Journal of Forestry Faculty, 14(1), 135-145.

Akbulut, S. (2015). Differences in the traditional use of wild plants between rural and urban areas: the sample of Adana. Studies on Ethno-Medicine, 9(2), 141-150.

Akbulut, S. and Karaköse, M. (2016). Some Wild Plants Commonly Used in Folk Medicine in Turkey. Book: Recent Advances in Health Sciences [Editors: A. Adil Çamlı, Bilal Ak, Ramiz Arabacı, Recep Efe]; Chapter 51; 547-559, ISBN 978-954-07-4136-9, St. Kliment Ohridski University Press Sofia.

Arslan, M., Şahne, B. S. and Sevgi, Ş. A. R. (2016). Dünya'daki geleneksel tedavi sistemlerinden örnekler: genel bir bakış. Mersin Üniversitesi Tıp Fakültesi Lokman Hekim Tıp Tarihi ve Folklorik Tıp Dergisi, 6(3), 100-105.

Başer, K.H.C. (2001). Sustainable Wild Harvesting of Medicinal and Aromatic Plants: An Educational Aproach. Harvesting on Non-Wood Forest Products, Seminar Proceedings, 2-8 October, pp. 349-355, Menemen/ İzmir, Turkey.

Cakilcioglu, U., Sengun, M. T. and Turkoglu, I. (2010). An ethnobotanical survey of medicinal plants of Yazikonak and Yurtbasi districts of Elazig province, Turkey. Journal of Medicinal Plants Research, 4(7), 567-572.

Davis, P.H. (1965-1985). Flora of Turkey and the East Aegean Islands. Edinburgh at the University Press, Vol. I-IX, Edinburgh.

Davis, P., H. (1988). Flora of Turkey and the East Aegean Islands, Vol. X, Supplement, University Press, Edinburgh.

Güner, A., Özhatay, N., Ekim, T. and Başer, K.H.C. (2000). Flora of Turkey and the East Aegean Islands and Suppl. Vol. XI, Edinburgh Univ. Press.

Güner, A., Aslan, S., Ekim, T., Vural, M. and Babaç, M.T. (eds.). (2012). Türkiye Bitkileri Listesi (Damarlı Bitkiler), NGBB ve Flora Araştırmaları Derneği Yayını, İstanbul.

Hayta, S., Polat, R. and Selvi, S. (2014). Traditional uses of medicinal plants in Elazığ (Turkey). Journal of Ethnopharmacology, 154(3), 613-623.

Kalankan, G., Özkan, Z. C. and Akbulut, S. (2015). Medicinal and aromatic wild plants and traditional usage of them in Mount Ida (Balıkesir/Turkey). Journal of Applied Biological Sciences, 9(3), 25-33.

Koyuncu, M. (1990). Türkiye Florasının Tıbbi Bitkiler Yönünden Önemi, Tarım Orman ve Köyişleri Bakanlığı Dergisi, 53.

Mükemre, M., Behçet, L. and Çakılcıoğlu, U. (2015). Ethnobotanical study on medicinal plants in villages of Çatak (Van-Turkey). Journal of ethnopharmacology, 166, 361-374.

Polat, R., Cakilcioglu, U., Kaltalioğlu, K., Ulusan, M. D. and Türkmen, Z. (2015). An ethnobotanical study on medicinal plants in Espiye and its surrounding (Giresun-Turkey). Journal of ethnopharmacology, 163, 1-11.

Özgen, U. and Kaya, Y. (2004). Ethnobotancal studies in the villages of the district of Ilica (Province Erzurum), Turkey. Economic Botany, 58(4), 691-696.

Özkan, Z.C. and Akbulut, S. (2012). Trabzon İlinin Etnobotanik Özellikleri. KTÜ BAP Projesi, Proje No: 1098, 128 s., Trabzon.

Saraç, D. U., Özkan, Z. C. and Akbulut, S. (2013). Ethnobotanic features of Rize/Turkey province. Biological Diversity and Conservation, 6(3), 57-66.

Şar, S. (1982). İç Anadolu Bölgesi Halk İlaçlarının Eczacılık Tarihi ve Farmakognozi Açısından İncelenmesi. Ankara Üniversitesi Eczacılık Fakültesi, Eczacılık Tarihi ve Deontoloji Bilim Dalı [Doktora tezi], Ankara.

Şar, S. (2008). Anadolu'da Rastlanan Halk Hekimliği Uygulamalarına Genel Bir Bakış, 38. ICANAS Uluslararası Asya ve Kuzey Afrika Çalışmaları Kongresi, 10-15 Eylül 2008, Bildiriler Kitabı, s. 1163-1178, Ankara.

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Chapter 5

SENSORS THAT CAN BE USED TO IMPROVE WHEAT YIELD AND QUALITY

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1. INTRODUCTION

Wheat is the most cultivated crop both in the world and in our country. Wheat cultivation and yield values may vary depending on climate, cultivation methods, and market conditions. Wheat belongs to the genus of wheat of the family Gramineae (Triticum). Wheat, which is rich in species and subspecies concentrate, are grouped into three classes: diploid, tetraploid, and hexaploid groups, considering its genome structure and chromosome number. The genomic structures and chromosome numbers of these groups and the Latin and Turkish names of some groups: 1-diploid, (AA 2n = 14) 2-tetraploid**,** (AABB 2n = 28) 3-hexaploid, and (AABBDD) 2n = 42).

2. WHEAT CULTIVATION

2.1. Usage Areas of Wheat

The grain and stem parts of the wheat plant, which were first cultivated and used for human consumption for thousands of years, can be used in many ways. According to data in Turkey in 2017, an average of 2806 kg/ha of wheat produced in our country plays a crucial role in the daily diet. The most common of the wheat classes produced is bread. (Anonymous, 2019).

Durum wheat is widely used in the pasta, bulgur, and semolina industries. Still, bread wheat is used in the flour industry, bakery, biscuits, shortbread, other bakery products, starch, dextrin, and glucose. Durum wheat is generally harder, vitreous, amber in color, larger than different types, and has higher protein content.

Grain protein ratio, grain color, and hardness are essential features in the use of wheat for various purposes. The protein ratio in wheat can vary between 8-17% depending on genetic traits, environmental conditions, and breeding techniques. Wheat with at least 12% protein content is used in the pasta, semolina, and bulgur industries, while wheat with a 10-12% protein content is used to manufacture bread with less than 10% protein content. They were used in the manufacture of biscuits and other bakery wares or as feed.

Durum and dark wheat usually contain more protein. However, durum wheat requires a longer grinding time and more grinding energy, and a large amount of damaged starch is formed during grinding. Gluten, which gives the dough elasticity and swelling, makes up about 78-85% of the total protein, and wheat is evaluated for these properties in bread or pasta production (Pena, 2002). Even if durum wheat gluten is grown under the same conditions, it is not as strong as bread wheat. In addition, durum wheat dough has lower properties than quality bread wheat, and the ash content in the endosperm is higher (Özkay and Özkaya, 1993).

Wheat grain is widely used in industry and human and animal nutrition, but its straw is used to feed livestock and bedding. In addition, the handles are used in the paper and construction industries and the manufacture of handicrafts and decorations.

2.2. Adaptation of Wheat

2.2.1 Climate Demands

Climatic conditions play a crucial role in adapting the variety to the area. Wheat is generally grown successfully in temperate and cold regions. Its cultivation areas are problematic are very humid and hot tropical areas parallel between 20 ° north and 27 ° south on both sides of the equator. In these areas, fungal diseases caused by high temperature and humidity make wheat cultivation impossible.

For wheat seeds to germinate, they must take at least 35-45% of their weight in water. Germination can occur between 4 ℃ and 37 ℃. The optimum germination temperature of wheat is 12-25 ℃. Cooling (vernalization) and daily light variation (light cycle) are the main factors adapting wheat to different regions.

Vernalization is the desire of some plant genotypes to remain at a specific low temperature for a certain period to move from the vegetative period to the generative period. Although the cooling process in wheat usually takes place between 0 and 12 ° C, it can vary between 5 and 15 days at 7 to 18 ° C for summer genotypes and between 30 and 60 days at 0 to 7 ° C winter. genotypes (Acevedo et al., 2002).

2.2.2 Soil Demands

Wheat can be grown on different soil types due to its many species and species richness. However, the demand for wheat soil is considered to be higher than for some cereals. Heavy mil clay soils are good wheat soils, provided they are free of lime. The presence of clay, clay, and organic matter in the soil is necessary to maintain the capacity of the soil in water. In successful wheat cultivation, soil clay and humus are essential in places where drought is increasing. In heavy clay soils, lime is more critical than humus. Blomeyer noted that calcareous, silty, clayey, and humus soils are first-class wheat soils (Gökgöl, 1969).

Two issues need to be considered when looking at the demand for wheat soil. The first is the nutrient state of the soil plants, and the second is the moisture state. In addition, the reaction of the soil (soil pH), which directly or indirectly affects soil fertility, such as the availability of plant nutrients in the soil, soil water uptake, and soil organisms, is also vital in wheat cultivation.

Wheat does not like the acidity of the soil too much. Because soil pH affects the solubility of ions, some ions (such as aluminum, manganese) may dissolve and cause toxic effects. In contrast, some ions (such as phosphate) may dissolve less and cause deficiency symptoms. Soils with a pH of 5.5 to 7.5 are generally suitable for growing wheat.

Depending on the variety, soil structure, and growing conditions in the area, the wheat yield will fall if the pH drops below 6. Therefore, when the pH drops below 5.5, it is recommended to apply lime (limestone or calcium carbonate, magnesium carbonate, etc.) homogeneously to the soil and mix 10- To a depth of 15 cm.

One of the soil properties that affect plant growth and development is salinity. The electrical conductivity value (EC) of typical soils is less than 4.0 dS / m. The wheat plant, which is moderately resistant to salinity, is much more sensitive to salinity between germination and young seedlings than in other periods. During these times, if the salinity is at least 4.5 dS / m in the upper parts of the soil, the number of plants per unit area decreases when young wheat plants are damaged. When the salinity increased to 8.8 dS / m, it was found that the presence of plants was reduced by 50%. Salinity adversely affects vegetative development in addition to wheat harvest but can increase protein. Durum wheat is generally more sensitive to salinity than bread, and the cut-off values for which yields are reduced are 5.9 dS / m for durum wheat and 8.6 dS / m for bread (Francois et al., 1986).

2.3. The Culture of Wheat

2.3.1 Crop Rotation

One of the methods widely used in wheat cultivation in many countries is wheat oilseed rape. When wheat is planted on the same field for several years, root rot and cervical diseases, as well as pests such as thrips (Zabrus tenebroides), wheat flies (Mayetiola destructor), bees (Cephus pygmaeus L.), and harvesting moth (Oria musculosa), increase significantly.

In addition, by planting different types and varieties of cereals on the same field in succession, the product will increase the mixture if field cleaning is not taken care of. Because oilseeds, such as sunflower and canola, remove large amounts of nutrients from the soil, the need for wheat fertilizer also increases after these crops. In addition, alfalfa (20-27 kg N / da), vetch (10-13 kg N / da), beans and peanuts (5-10 kg N / da), soybeans (6-12 kg N / da), which are legumes and peas (5-8 kg N / da) bind a significant amount of nitrogen (N) to the soil to be planted (Akçin, 1988; Gökgöl, 1969) when calculating the amount of nitrogen.

2.3.2 Tillage

Soil cultivation can occur at three different times than the autumn, spring, and summer periods in dry agricultural areas where the set-aside system is used. The field surface should be covered with plant residues as much as possible, especially in sloping and erosive regions, to protect it from the risk of erosion and preserve rainwater. In studies on this topic, if autumn tillage with a plow is unnecessary, but if a hard layer called "floor stone" or "plow floor" has formed underground, the hard layer should break, and the soil surface should be removed by pulling the bottom excavator in the fall. In the spring, when weeds begin to develop, and the soil is in a temperate state, the weeds are destroyed with tools such as crowbars that work without disturbing the soil, depending on the condition of the soil. To save water in the soil, summer treatment must be continued with a crowbar and similar tools according to the grazing of the field or the formation of a layer of cream in the following times of the soil (Pehlivantürk et al., 1977).

2.3.3 Planting

No matter how high quality the variety is genetic, low yields and poor quality products are obtained if it is not grown in a proper ecology and the necessary conditions are not met.

For plant development to be desired, wheat germination and germination must be completed before the soil temperature at planting depth drops to 5-8 ° C.

As the completion of plant development in late sowing shifts to a hotter and drier period, the protein and moisture content of the grain increases while the flour yield decreases (Alessi et al., 1979), but the grain yield decreases. A study of durum wheat under Konya conditions found that although the cereal protein percentage increased by 12% in summer planting than winter crops, the yield loss was 78% (Yıldız and Topal, 2002).

Several seeds to be used: Seed values, varietal characteristics, sowing time, growing conditions, and ecological factors effectively determine the number of seeds to be planted per unit area. It is noted that although the maximum yield is obtained from a small amount of seed under limited environmental conditions, high plant density is more appropriate when factors such as humidity, temperature, and nutrients are appropriate. Still, higher seed use requires better cultivation techniques (Roth et al., 1984).

Sowing depth: The most critical factor in determining the planting depth of wheat is soil moisture. If there is enough moisture in the soil to germinate and germinate the seeds, a depth of 2-4 cm is sufficient (outdoor sowing), while under normal conditions, the optimal sowing depth is 4-6

cm. Planting deeper than 8 cm negatively affects plant emergence. (Torres and Paulsen, 1982).

Sowing method: In a study in dry conditions in Konya, a yield of 289 kg/da was obtained when seeds and fertilizers were applied to the same belt, while fertilizer and seeds were used to separate belts in a yield of 303 kg/da. (Sade et al., 1995). Especially in dry and semi-dry areas, it has been found that it is more appropriate to use pressure drills that can sow deep in an arc shape, and because the seeds are in good contact with the soil, pressure drills offer 25% more efficiency than other seed drills (Kün, 1988).

When applied to the soil, ammonium nitrate (AN), one of the nitrogen fertilizers, can melt even at very low humidity and immediately become suitable for plants because AN fertilizer has more solubility than urea and ammonium sulfate. Because of this property, the nitrogen needs of plants can be met with this fertilizer even in years when there is little rainfall in dry areas, and in cases where there is a lot of rain, it is washed quickly from the soil. Under unfavorable conditions, the N losses of urea can be greater than the losses of AS. Therefore, urea should be applied to a depth of 10–14 cm from the soil or mixed into the soil immediately after surface application (Topbaş, 1987).

For plants to benefit more from the nitrogen used, we need to give importance to alternation to increase the efficiency of wheat nitrogen use. Studies on this topic have revealed that wheat nitrogen utilization efficiency in legumes and wheat alternation is much higher than wheat-set-aside or wheat-wheat alternation. Applications such as the choice of fertilizers suitable for climatic and soil conditions, the use of slow-release NH4 fertilizers, the breeding of high nitrogen-efficient varieties, the application period, and the use of leaf nitrogen, including fodder crops for irrigation and cultivation Johnson increase wheat nitrogen efficiency 85%, 1999).

Phosphorus (P) Application: Phosphorus is one of the elements that a wheat plant grows as desired. Phosphorus deficiency leads to growth retardation, root weakening, stem thinning, and delayed leaf maturation. An important symptom of phosphorus deficiency is the reddish or purple color of the leaf coat in some varieties (Akkaya, 1994).

Potassium (K) application: Potassium is one of the most important factors for yield and quality and the normal development of wheat plants. The plant's need for potassium is lower than nitrogen and phosphorus. In the absence of potassium, plants cannot benefit adequately from water and other substances, plant tolerance decreases, resistance to diseases, and pests decrease. Potassium deficiency is also reminiscent of drought symptoms (Anderson and Garlinge, 2000).

Other nutrients: As a result of low organic matter content, unconscious fertilization, and lack of water in highly reactive soils in addition to high lime and clay, trace element deficiencies are found to be very common in crops in our soil, especially in Central Anatolia. In addition, as there may be significant problems with the excess and deficiency of these elements, soil analysis results must be considered when fertilizing with micronutrients.

3. QUALITY PARAMETERS OF WHEAT

3.1. Earing Period

It was found that the variation between varieties in the number of peak days was quite considerable (145–160 days), and this variation was statistically significant. It has been reported that genotypes with an early number of spike days have a long grain filling time and an increase in the number of nutrients going into the grain (Bilgin and Korkut 2005).

3.2. Plant Height, Lean Rate, Ear Length

As with many plant species, lying is an undesirable property in wheat. Especially in areas where there is heavy rainfall, sleeping can cause significant crop losses. The rate of crop loss varies depending on the variety. It should not be forgotten that the lying situation is primarily due to the relationship between ear weight and stem thickness and plant height characteristics (Kün, 1983).

3.4. Hectoliter Weight, Thousand Grain Weight, Humidity Rate

Varieties weighing more than 82 kg per hectolitre are very good (Dipenbrock et al., 2005).

The weight of a thousand grains is one of the most important characteristics that affect the grain yield.

Properties such as harvesting time, growth, and storage conditions affect the moisture content of wheat grains (Elgün et al., 1998). The moisture content of wheat grains is essential for storage and grinding. Excess moisture in the wheat reduces the dry matter content, increases the activity of bacteria and fungi, and makes storage more complex as it promotes germination

3.5. Gluten Amount, Gluten Index Value

The amount of gluten is the most critical parameter used to determine the quality of the flour. During kneading of the dough, the gluten proteins that form the network ensure that the carbon dioxide created by the yeast is retained and the dough rises. It has been found that this proportion is more than 35% in wheat with a high gluten value, between 28-35% in wheat with good characteristics, between 20-27% in wheat of average quality, and less

than 20% in wheat with poor quality. quality. (Ünal, 2007). 2003). The gluten index value should be between 60-90 bread flours. Bread cannot be made from flour with a gluten index below 40 (Ünal, 2003).

4. SENSORS THAT CAN BE USED FOR IMPROVEMENT OF QUALITY

4.1. Chlorophyllometer Minolta SPAD meter 502

The chlorophyll meter is a lightweight hand-held device powered by two batteries (Figure 4.1). It is operated from the unlock button on the device, the first display is in "CAL" format, the latches are pressed for 2-3 seconds when empty, and the device calibrates itself and waits for the "0" position to read.

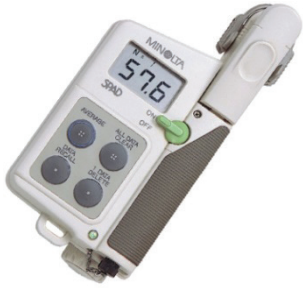

Figure 4.1 Minolta chlorophyll meter 502

4.1.1 Nitrogen fertilizer recommendation method with chlorophyll meter in wheat

The method described below; was obtained due to the TÜBİTAK-supported project "Study on the effect of seasonal nitrogen fertilizer management systems on bread wheat yield and quality under Eskişehir conditions."

Creating a rich ribbon; Fertilizer containing only nitrogen at a rate of 12 kg N / da in dry conditions and 17 kg N / da in irrigated conditions, excluding basic fertilizer, in the middle of the field and a longitudinal area 5-10 m wide before planting on the field in which the wheat is planted; Ammonium nitrate (AN), ammonium sulfate (AS), urea, etc. It is applied with a fertilizer machine. The purpose of this application; When nitrogen fertilizer is recommended in early spring, it must create an area with no nitrogen deficiency. This area is called the Rich Band, and the site is marked with stakes. The rake is pulled parallel to the rich belt across the field, and the rich belt fertilizer is mixed into the soil. The field barked and intended for planting (including a rich strip) is given with seed and the basic fertilizer with a drill.

Spring nitrogen fertilization; In the spring, we go to the field just before the wheat rooting period (Figure 4.2). In 20-50 plants, randomly selected according to the size of the application area and the areas believed to represent best the field, the last leaf at the end of its maturation (this is usually the second leaf from the top) Three leaf readings are made, namely the tip, middle and lower part. The device memory is limited to 30 readings, and every 30 readings should be centered and taken into account. Sick or damaged leaves or plants should not be selected as samples for reading; the leaves should not be wet.

Figure 4.2 Beginning of stem extension period in wheat.

NSPAD (normalized SPAD); It is the ratio of the SPAD readings of the farmer's application to the SPAD readings of the plants read from the affluent area in the same field (NSPAD = SPAD (ÇU) / SPAD (ZB)). The program calculates the NSPAD value automatically. These programs run between 0.86 and 0.95 NSPAD values. According to NSPAD values, the recommended nitrogen amounts are computed by selecting the appropriate Excel file for irrigated or non-irrigated conditions.

The Rich Band SPAD value, the Farmer Application SPAD value, and the nitrogen percentage of the fertilizer to be applied read from the data form created in Excel, as explained above, are entered in the relevant sections. Once the relevant information has been entered, the system automatically provides the amount of nitrogen fertilizer to the field in the spring.

4.1.2 Late nitrogen fertilizer application with chlorophyll meter in wheat

The method described below; was obtained due to the TÜBİTAK-supported project "Study on the effect of seasonal nitrogen fertilizer management systems on bread wheat yield and quality under Eskişehir conditions." The aim is to determine the critical thresholds at which cereal protein ratios can be increased with nitrogen fertilizer by increasing the nitrogen nutritional status of the plant by chlorophyll-meter measurements during head conditions in Central Anatolia. In other words, when using the

method described below, it is determined whether it is necessary to add nitrogen fertilizers at a later stage to improve the quality and protein of the wheat. The method for forming the rich zone, the recommended spring nitrogen fertilizer, and the measurement method with a chlorophyll meter are the same. The measurements are made this time during the grain-filling period.

Determining the need for nitrogen fertilizer with a chlorophyll meter; For late nitrogen, go to the field at the beginning of the primary cycle and read the flag sheets with the chlorophylometer in the rich lane at the sowing time write them down (SPAD Rich tape). Again, with a chlorophyll meter, the readings are taken from the farmer application, and the SPAD values are recorded (SPAD Farmer Application). Based on these readings, NSPAD (Normalized SPAD); The SPAD readings of the farmer application are calculated as the reading of the SPAD readings of the crop read from the rich band in the same field, i.e., NSPAD = SPAD (ÇU) / SPAD (ZB). It is understood that this critical threshold can be used under both conditions because in experiments with two varieties under dry conditions, an average crucial threshold of 0.95 was found in 0.95 experiments with one variety under wet conditions. If the calculated NSPAD value is less than the critical threshold of 0.95, increase the cereal protein ratio; Under dry conditions, nitrogen is applied as a 4% urea solution by spraying. For example; To prepare a 4% urea solution with a sprayer with a water volume of 300 liters, dissolve 300 liters of water x 0.04 = 12 kg of urea by calculating 4 kg of urea in 100 liters of water. 300 liters. It should be applied as a urea solution at the beginning of the peak season using a fertilizer tank installed in the irrigation system in wet conditions.

4.2. Optical Sensor (GreenSeeker)

Its portable weight is 5.5 kilograms. (Fig. 4.3). Its weight with accessories is 17 kg. Its dimensions are 355 x 355 x 1295 mm.

Figure 4.3 GreenSeeker

4.3. Spring Nitrogen Fertilizer Recommendation Method with Optical Sensor in Wheat

The method described below; was obtained due to the TÜBİTAK-supported project "Study on the effect of seasonal nitrogen fertilizer management systems on bread wheat yield and quality under Eskişehir conditions." Fertilizer recommendation with the optical sensor; forming the rich zone is the same as the chlorophyll meter. When it is ready to read, a rich strip is reached, and the optical eye of the device is kept at a 90-degree angle to the ground parallel to the ground and held at the height of 80 cm from the vegetation. To avoid the edge effect, stop reading by walking at a constant speed of 2 to 3 meters inside and in the center of the tape, holding down the green button on the hand panel and releasing the green button when the end of reading is reached. In this way, the NDVI Rich band value is obtained. The exact process is repeated on both sides in the Farmer App to obtain NDVI Farmer Practice values. Because the device has its light source, it is not affected by sunlight, it can be read at any time of the day, but the magazines should not be wet while reading. A small computer works with a rechargeable battery; when it is connected to the device, it changes continuously, so it is not a question of running out of charge. The date of October is recorded, and the days when the average daily temperature is above + 4˚C from this date are obtained from the weather data, and the total number of these days is called the growth rate days (BDG).

Spring nitrogen fertilization; In the spring, we visit the field and determine the development period of the wheat. Development time; If the plants have four siblings, Zadoks 2.4 and Zadoks 3.0, at the beginning of the onset period (Zadoks et al., 1974). The vegetation index (NDVI) is measured and recorded (NDVI Rich line) in the rich zone with the sowing time marked on the spring fertilizer as described below with an optical sensor; readings are taken from the farmer's application fields to the right and left of the optical sensor and NDVI values rich band. (NDVI Farmer App). The appropriate Excel file is selected according to the irrigation of the field or the period of irrigation and plant development. The NDVI values for the stored Rich Band and Farmer Application are entered. Enter the number of growth rate days from October to the reading day. The target protein percentage is entered. Enter the percentage of pure nitrogen in the fertilizer used.

Once the relevant data has been entered, the system automatically gives the amount of nitrogen fertilizer applied to the field in the spring.

5. CONCLUSION

The aim is to explore ways to minimize the economic losses caused by nitrogen losses, a big problem in our country and the world. The application of a quarter of nitrogen to 40 cm early in the spring during the set-aside period was positive because it produced similar yields and higher nitrogen utilization efficiencies than in a typical farmer application. A 4% urea solution at the beginning of the grain-filling period increased the grain protein and other quality characteristics. Nitrogen application during leaf grain filling can be easily applied under irrigated conditions. In dry conditions, there may be a mechanization problem. Still, this solution can be used without incurring additional mechanization costs during the method in recent years to combat sun pests and yellow rust. Applying premiums based on analyzes and quality products in our country has made these methods even more critical in recent years. It facilitates their introduction and dissemination among manufacturers.

REFERENCES

Acevedo, E., Silva, P., and Silva, H. (2002). *Wheat Growth and Wheat Physiology, Development*. Faculty of Agronomy and Forestry Sciences, University of Chile. Casilla 1004. Santiago, Chile.

Akçin, A. (1988). *Yemeklik Tane Baklagiller*. Ders Kitabı. Selçuk Üniversitesi Yayınları No: 43, Ziraat Fakültesi Yayın No: 8, Konya.

Akkaya, A. (1994). *Erzurum Koşullarında Azotlu Gübre Çesidi ve Uygulama Zamanının Kışlık Buğdayda Verim, Bazı Verim Unsurları ve Protein İçeriğine Etkisi*. DOĞA T. Tarım ve Ormancılık Dergisi, 18, 313-322.

Anderson, W. K., and Garlinge, J.R., (2000). *The Wheat Book, Principles and Practice*. Grain Research and Development Corporation. Agriculture Western Australia.

Anonim. (2019). Web Sitesi: http://www.fao.org/, Erişim Tarihi: 22.07.2019.

Bilgin, O. ve Korkut, K.Z. (2005). *Bazı Ekmeklik Buğday (Triticum aestivum L.) Çeşit ve Hatlarının Dane Verimi ve Bazı Fenolojik Özelliklerinin Belirlenmesi*, Trakya Üniversitesi, Tekirdağ Ziraat Fakültesi Dergisi, 2(1).

Diepenbrock, W., Ellmer, F., and Léon, J. (2005). *Ackerbau, Pflanzenbau und Pflanzenzüchtung*, UTB 2629, Verlag Eugen Ulmer, Stuttgart.

Elgün, A., Ertugay, Z., Certel, M., Kotancılar, H.G., (1998). *Tahıl ve Ürünlerinde Analitik Kalite Kontrolü ve Laboratuar Uygulama Kılavuzu* (2 Baskı). Atatürk Üniversitesi Yayınları No:867, Ziraat Fak. Yayın No:335, Ders Kitapları Serisi No:82, s 245, Erzurum, Turkey

Francois, L. E., Maas, E.V., Donovan, T.J., and Youngs, VL. (1986). *Effect of Salinity on Grain Yield and Quality, Vegetative Growth and Germination of Semi-Dwarf and Durum Wheat*. Agronomy J., Vol:78, Number:6, PP. 1053-1058.

Gökgöl, M. (1969). *Serin İklim Hububatı Ziraatı ve Islahı*. Tarım Bakanlığı Ziraat işleri Genel Müdürlüğü, Özaydın Matbaası İstanbul.

Kün, E. (1983). *Serin İklim Tahılları.* Ankara Üniversitesi, Ziraat Fakültesi Yayınları: 875. Ders Kitabı: 240, Ankara.

Kün, E. (1988). *Serin İklim Tahılları*. Ankara Üniversitesi, Ziraat Fakültesi Yayınları: 1032. Ders Kitabı: 299, Ankara.

Pehlivantürk, A., İzgin, C. N., Güler, M., Ünver, İ. ve Pala, M. (1977). *Nadas Toprak Hazırlığı ve Buğday Yetiştirme Tekniği Araştırmaları*. Gıda-Tarım ve Hayvancılık Bakanlığı, Tanmsal Araştırma Genel Müdürlüğü, Orta Anadolu Bölge Zirai Araştırma Enst. Müd. Yayın No.77- 2. Rapor No: 1, Ankara.

Özkay, H. ve Özkaya, B. (1993). *Makama Kalitesinde Buğday Bileşiminin Önemi*. Makarnalık Buğday Ve Mamulleri Sempozyumu. Tarımsal Araştırmalar Gen. Müdürlüğü Tarla Bitkileri Merkez Arş. Enst., sayfa: 289. Ankara.

Pena, R.J. (2002). *Wheat For Bread and Other Foods*. Bread Wheat improvement and Production, Pages, 483-494. CIMMYT scientist. Food and Agriculture Organization of the United Nations, Rome.

Raun, W.R., and Johnson, G.V. (1999). *Improving Nitrogen Use Efficiency for Cereal Production*. Agronomy Journal, vol: 91(3): 357-363.

Roth. G.W., Marshall. H.G, Hatley, O.E., Hill, R.R. (1984). *Effect of Management Practices on Grain Yield*. Test Weight and Lodging of Soft Red Winter Wheat. Agronomy Journal. 76. 379-383.

Sade, B., Topal. A., Yılmaz. A., Soylu, S., Kan, Y. ve Öztürk, Ö. (1995). *Konya Kıraç Koşullarında Farklı Gübre Formları ve Uygulama Metotlarının Ekmeklik Buğdayda Verim ve Verim Unsurları Üzerine Etkisi*. S.Ü. Ziraat Fakültesi Dergisi. 6(8): 88-102. Konya.

Topbaş, M.T. (1987). *Azotlu Gübreler*. Selçuk Üniversitesi Yayınlan No:7, Konya.

Torres, J.L., G.M. Paulsen. (1982). *Increasing seed protein content enhances seedling emergence and vigor in whea*t. Journal of Plant Nutrition, 5:9, 1133-1140,

Ünal, S.S. (2003). *Buğday Un ve Kalitesinin Belirlenmesinde Uygulanan Yöntemler, Nevşehir Ekonomisinin sorunları ve Çözüm Önerileri: Un Sanayi Örneği, Erciyes Üniversitesi*. Nevşehir İktisadi ve İdari Bilimler Fakültesi, 27-28 Haziran 2003, Nevşehir (Nevşehir Ekonomisi Sempozyumu Bildirileri I, Sayfa 15-29).

Yıldız, C. ve Topal, A. (2002). *Selçuklu-97 Makarnalık Buğday Çeşidinde Kışlık ve Yazlık Ekimde Farklı Azot Dozları ve Sulama Seviyelerinin Verim, Bazı Verim Unsurları ve Kalite Faktörlerine Etkisi*. S Ü Ziraat Fakültesi Dergisi. 16;30. 5-13.

Zadoks J.C., and Chang, T.T., Konzak, C.F. (1974). *A Decimal Code for the Growth Stages of Cereals*. Weed Research 14:415:421.

Chapter 6

A LITERATURE REVIEW ON THE WOOD FIBER MORPHOLOGY OF FRUIT TREES

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INTRODUCTION

Over the past few years, the valorization of lignocellulosic wastes due to important consideration of worldwide economical and environmental pollution issues has received significant attention. Lignocellulosic waste is renewable, cheap, and abundant, and provides an incomparable natural source for cost-effective and large-scale high value-added products (Anwar et al. 2014).

Fruit orchards in the World covered 65 293 377 ha in 2019 (FAO, 2021). Pruning is a significant biennial operation by farmers to remove old branches and thus renew the tree (García Martín et al. 2020). The pruning process results in the production of large quantities of lignocellulosic residues (Romero-García et al. 2016). These residues are usually considered wastes, not resources (Spinelli and Picchi, 2010). In general, pruning residues are ground and ploughed into the soil. In addition, they are burned in the orchards. These operations not only mineralize the soil but also increase the risks of pest outbreaks and fire accidents (García Martín et al. 2020). Also, the open burning of pruning residues contributes to atmospheric pollution (Proto et al. 2021).

The annual global paper production in 2020 was 402 million metric tons (FAO, 2021). Paper is commonly produced using natural lignocellulosic fibrous materials through mechanical or chemical processes or a combination of both (Jahan et al. 2020). Only 8% of global paper production is carried out with lignocellulosic residues. 92% of world production depends on wood (softwood or hardwood). Many countries without forests have to use lignocellulosic residues as raw materials for paper production. However, there is a tendency in forest-rich countries to use lignocellulosic residues, if available, to reduce deforestation. The percentage of use of lignocellulosic residues for paper production is expected to increase gradually (Fahmy et al. 2017).

Nearly all fibrous materials are appropriate to produce most paper grades (Ciolacu, 2013). However, wood fibers are generally preferred. The main wood groups used in papermaking can be classified into hardwoods and softwoods (Johansson, 2011). The term fiber refers to any type of wood cell retaining in the pulp. Most of these cells are tracheids in softwoods. The cells in hardwoods are libriform fibers, fiber tracheids, tracheids, and vessel elements. The type of fiber to be used in paper production depends on the specific requirements of the final product to be made from pulp. Hardwood fibers are shorter and thinner than softwood fibers, while softwood fibers are long and strong. Softwood fibers are preferred in the production of strong kraft paper, and hardwood fibers are preferred in the production of high-quality writing paper. (Panshin and De Zeeuw, 1980). Many grades of

paper are produced by blending both softwood fibers and hardwood fibers to meet demands on both print surface and strength (Johansson, 2011). Therefore, it is essential to know the papermaking properties of fibrous raw materials in order to determine the optimum blending ratio of pulps (Ciolacu, 2013).

Fiber morphology includes fiber length (L), fiber width (D), lumen width (d), cell wall thickness (w). In addition, morphological factors such as slenderness ratio (L/D), flexibility ratio ((d/D) x 100), and Runkel ratio (2w/d) are derived from fiber dimensions. These morphological factors are important in predicting the pulp quality of the fiber (Dinwoodie, 1965). Fiber dimensions significantly vary between wood species, within annual growth rings, in vertical and horizontal positions within the stem. They are also affected by the growth condition (Paavilainen 2002).

Fiber morphology has a dominant effect on pulp quality (Annergren, 1999). Fiber morphology affects the consolidation and formation of the paper structure in the course of the papermaking process and is liable to the features of the final product (Ciolacu, 2013). The fiber morphology affects paper machine performance, the optical and strength properties of the paper, water retention and swelling of fibers, and response to beating (Casey, 1960).

Fiber length is one of the important fiber properties related to the strength properties of paper. The bonding sites depend on the fiber length. Therefore, the paper strength of hardwood fibers is lower than that of softwoods with longer fibers due to their shorter fibers (Dinwoodie, 1965). Fiber flexibility depends on cell wall thickness and lumen width of fibers. They affect thickness affect the stiffness and strength properties of the paper (Panshin and De Zeeuw, 1980). Fibers having a large lumen and thin walls are inclined to flatten to ribbons in the course of papermaking with increased inter-fiber bonding. Thus, paper with good strength properties is obtained (Dinwoodie, 1965). Thick-walled fibers negatively correlated with the folding endurance, tensile and burst index of paper, and positively correlated with the tear index. In addition, the paper formed from thick-walled fibers has high bulk, a rough surface, and a large amount of void volume. On the contrary, thin-walled fibers create a uniform, smoother, and denser paper structure (Gülsoy and Şimşir, 2018).

The strength properties of the papers are positively correlated with the slenderness ratio of fibers (Ates et al. 2008). A slenderness ratio greater than 33 means that fibrous material is suitable for papermaking (Xu et al., 2006). It is desirable that the slenderness ratio is between 40-60 in hardwoods and 70-90 in softwoods. Flexibility ratio (lumen to fiber width) of fibers classified as very rigid fibers (<30), elastic fibers (50-70), rigid

fibers (30-50), and highly elastic fibers (>75) (Akgül and Tozluoğlu, 2009). A Runkel ratio greater than 1 means that lignocellulosic raw material forms stiffer, less flexible, and bulkier paper with the lower bonded area (Ashori and Nourbakhsh, 2009).

Many researchers have been studied the suitability of papermaking as alternative raw material. The utilization of orange (González et al., 2011, 2013; Moral et al. 2016; Aguado et al. 2016), olive (Jiménez et al. 2000; López et al. 2001; Requejo et al., 2012a,b), pomegranate (Gülsoy et al., 2015), kiwi (Gençer, 2015), white mulberry (Gençer et al., 2013), hazelnut (Gençer and Özgül, 2016), cherry (Gençer and Gül Türkmen, 2016; Song et al. 2017), lemon (Khider et al. 2021), mulberry (Walia and Gupta, 2015; Ji et al. 2018), and avocado (Vargas et al. 2006; Altunışık Bülbül and Gençer, 2021) in the paper production was previously evaluated.

Many studies have been reported on the fiber morphology of stem wood and pruning residues of fruit trees. This chapter reviews the literature on the fiber morphology of stem or pruning residues from 26 fruit trees.

FIBER MORPHOLOGY OF SOME FRUIT TREES

The fiber morphology of fruit trees is given in the tables below (Table 2-27). As can be seen in the tables, the fiber morphology of fruit trees resembles other hardwoods such as beech, hornbeam, maple, poplar, and oak (Table 1). Although the fiber morphology of olive, fig, and cherry has been extensively studied, the fiber morphology of other species has received less attention.

Table 1: Fiber morphology of some hardwood species.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Fagus orientalis (sapwood)	1.16	0.60	20.20	5.70	7.70	57.43	28.22	2.70	Gülsoy et al. (2021)
Quercus robur	1.17	0.49	20.50	-	5.50	-	-	-	Gülsoy et al. (2005)
Acer campastre	0.58	0.32	25.00	16.30	4.40	-	-	-	Eroğlu and Gülsoy (2008)
Carpinus betulus	1.24	0.71	22.10	11.00	5.10	-	-	-	Eroğlu and Gülsoy (2008)
Populous tremula	1.10	-	23.90	11.40	6.30	46.0	47.7	1.10	Gulsoy and Tufek (2013)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 2: Fiber morphology of olive wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Olea europaea	0.69	0.35	13.77	6.19	3.69	-	-	-	Merev (1998)
Olea europaea (pruning)	0.71	-	13.61	6.11	3.75	-	-	-	Requejo et al. (2012a)
Olea europaea (pruning)	0.85	-	15.10	6.20	4.50	56.20	41.00	1.40	Ververis et al. (2004)
Olea europaea	1.11	0.40	25.12	14.36	5.38	44.76	57.07	0.78	Topaloğlu et al. (2019)
Olea europaea var. *oleaster* L.	0.62	-	14.06	5.16	4.54	-	-	-	Kaya (1991)
Olea europaea var. *sativa* Lehr.	0.87	-	13.41	3.97	4.74	-	-	-	Kaya (1991)
Olea europaea (Aydın)	0.83	-	15.79	11.51	2.16	-	-	-	Kılıç Penezoğlu (2019)
Olea europaea (Kahramanmaraş)	0.78	-	12.29	8.17	2.06	-	-	-	Kılıç Penezoğlu (2019)
Olea europaea (wild)	0.90	-	-	-	-	-	-	-	Giagli (2010)
Olea europaea (cultivated)	0.64	-	-	-	-	-	-	-	Giagli (2010)
Olea europaea	0.81	-	15.60	10.94	2.33	-	-	-	Ali and Ali (2014)
Olea europaea	0.92	0.37							Baas and Xingying (1986)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 3: Fiber morphology of apple wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Apple prunings	0.91	0.40	-	-	-	-	-	-	Passialis and Grigoriou (1999)
Malus baccata (Qian Hong)	0.79	0.45	-	-	-	-	-	-	Zhang and Baas (1992)
Pyrus malus	0.98	0.51	-	-	-	-	-	-	Bailey (1920)
Pyrus malus	1.00	-	15.86	10.72	2.57				Nasir (2010)
Malus halliana	0.91	0.54	-	-	-	-	-	-	Zhang and Baas (1992)

Malus honanensis	0.85	0.42	-	-	-	-	-	-	Zhang and Baas (1992)
Malus hupehensis (Huang)	0.78	0.42	-	-	-	-	-	-	Zhang and Baas (1992)
Malus melliana (CAFw 15682)	1.08	0.65	-	-	-	-	-	-	Zhang and Baas (1992)
Malus mandshurica	0.87	0.41	-	-	-	-	-	-	Zhang and Baas (1992)
Malus pumila (CAFw 13818)	0.97	0.44	-	-	-	-	-	-	Zhang and Baas (1992)
Malus rockii	1.05	0.50	-	-	-	-	-	-	Zhang and Baas (1992)
Malus spectabilis	1.01	0.50	-	-	-	-	-	-	Zhang and Baas (1992)
Malus toringoides	0.95	0.43	-	-	-	-	-	-	Zhang and Baas (1992)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 4: Fiber morphology of peach wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Peach prunings	0.69	0.32	-	-	-	-	-	-	Passialis and Grigoriou (1999)
Amygdalus davidiana	0.77	0.27	-	-	-	-	-	-	Zhang and Baas (1992)
Amygdalus kansuensis	1.14	0.32	-	-	-	-	-	-	Zhang and Baas (1992)
Amygdalus mira	1.04	0.31	-	-	-	-	-	-	Zhang and Baas (1992)
Amygdalus persica (HEFw 3803)	0.82	0.27	-	-	-	-	-	-	Zhang and Baas (1992)
Amygdalus triloba	0.62	-	12.70	-	1.63	48.00	87.00	1.11	Ma et al. (2011)
Amygdalus triloba (CAFw 13721)	0.71	0.33	-	-	-	-	-	-	Zhang and Baas (1992)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 5: Fiber morphology of pear wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Pear prunings	0.62	0.35	-	-	-	-	-	-	Passialis and Grigoriou (1999)
Pyrus betulifolia	0.92	0.48	-	-	-	-	-	-	Zhang and Baas (1992)
Pyrus calleryana (HEFw 3710)	0.94	0.53	-	-	-	-	-	-	Zhang and Baas (1992)
Pyrus communis	1.00	0.51	20.78	6.84	6.97	-	-	-	Tümen (1999)
Pyrus elaeagnifolia Pallas subsp. *elaeagnifolia*	0.85	0.48	18.32	8.50	4.88	-	-	-	Merev (1998)
Pyrus pashia	1.11	0.54	-	-	-	-	-	-	Zhang and Baas (1992)
Pyrus pyrifolia (Zhang)	0.78	0.46	-	-	-	-	-	-	Zhang and Baas (1992)
Pyrus pyrifolia var. *culta*	0.91	0.43	-	-	-	-	-	-	Zhang and Baas (1992)
Pyrus serrulata (HEFw 329)	1.06	0.59	-	-	-	-	-	-	Zhang and Baas (1992)
Pyrus ussuriensis (CAFw 5928)	0.94	0.56	-	-	-	-	-	-	Zhang and Baas (1992)
Pyrus xerophila	0.98	0.50	-	-	-	-	-	-	Zhang and Baas (1992)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 6: Fiber morphology of plum wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Prunus domestica (branch)	0.97	-	16.83	7.99	4.42	58.85	48.58	1.21	Kiaei et al. (2014)
Prunus domestica (stem)	0.98	-	13.77	5.60	4.08	73.38	41.38	1.56	Kiaei et al. (2014)
Prunus spinosa	0.90	0.27	14.18	6.99	3.66	-	-	-	Merev (1998)
Prunus ussuriensis	1.20	0.56	-	-	-	-	-	-	Zhang and Baas (1992)

Prunus salicina (HEFw 132)	0.73	0.33	-	-	-	-	-	-	Zhang and Baas (1992)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 7: Fiber morphology of cherry laurel wood.

Species	FL (mm)	VEL (mm)	FW (µm)	FLW (µm)	FCWT (µm)	SR	FR	RR	Reference
Laurocerasus officinalis	1.50	0.56	20.82	11.34	4.76	-	-	-	Merev (1998)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 8: Fiber morphology of apricot wood.

Species	FL (mm)	VEL (mm)	FW (µm)	FLW (µm)	FCWT (µm)	SR	FR	RR	Reference
Apricot prunings	0.61	0.25	-	-	-	-	-	-	Passialis and Grigoriou (1999)
Prunus armeniaca (branch)	1.03	-	15.86	8.23	3.81	66.92	52.09	0.97	Tajik et al. (2015)
Prunus armeniaca (stem)	1.18	-	14.75	6.11	4.30	84.89	42.35	1.54	Tajik et al. (2015)
Prunus armeniaca (heartwood)	0.72	-	13.75	6.05	3.85	46.22	50.00	1.00	Gençer et al. (2018)
Prunus armeniaca (sapwood)	0.69	-	12.08	5.69	3.19	55.09	50.37	0.97	Gençer et al. (2018)
Armeniaca holosericea	0.49	0.26	-	-	-	-	-	-	Zhang and Baas (1992)
Armeniaca mandshurica	0.76	0.29	-	-	-	-	-	-	Zhang and Baas (1992)
Armeniaca mume (Zhang)	0.75	0.23	-	-	-	-	-	-	Zhang and Baas (1992)
Armeniaca sibirica	0.78	0.29	-	-	-	-	-	-	Zhang and Baas (1992)
Armeniaca vulgaris (CAFw 13823)	0.77	0.28	-	-	-	-	-	-	Zhang and Baas (1992)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 9: Fiber morphology of avocado wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Persea americana var. *guatemalensis*	0.97	-	35.60	21.30	7.20	27.19	59.79	0.67	Silva Guzmán et al. (1999)
Persea americana	0.89	-	23.00	12.00	5.00	41.27	-	0.95	Ajuziogu et al. (2010)
Persea americana	1.06	-	25.78	16.18	4.80	41.00	63.00	0.59	Altunışık Bülbül and Gençer (2021)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 10: Fiber morphology of cherry wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Cherry prunings	0.67	0.30	-	-	-	-	-	-	Passialis and Grigoriou (1999)
Cerasus avium (sapwood)	1.11	0.42	20.35	10.50	4.93	54.56	51.60	0.94	Gençer and Gül Türkmen (2016)
Cerasus avium (heartwood)	1.10	0.43	19.05	10.35	4.35	57.72	54.33	0.84	Gençer and Gül Türkmen (2016)
Cerasus avium	0.96	0.40	19.35	11.26	4.04	49.69	57.98	0.74	Yaman (2002)
Cerasus avium var. *decumana*	1.00	0.39	-	-	-	-	-	-	Zhang and Baas (1992)
Cerasus campanulata (CAFw 13055)	1.00	0.39	-	-	-	-	-	-	Zhang and Baas (1992)
Cerasus cerasoides (FRIGw 1208)	1.07	0.37	-	-	-	-	-	-	Zhang and Baas (1992)
Cerasus mahaleb	0.96	0.31	17.50	11.08	3.23	-	-	-	Merev (1998)
Cerasus mahaleb	0.71	-	19.85	-	-	-	-	-	Sekhavati et al. (2012)
Cerasus maximowiczii	0.60	0.29	-	-	-	-	-	-	Zhang and Baas (1992)
Cerasus tomentosa	0.56	0.30	-	-	-	-	-	-	Zhang and Baas (1992)
Prunus maackii (CAFw 17308)	0.97	0.55	-	-	-	-	-	-	Zhang and Baas (1992)
Padus racemosa (CAFw 17309)	0.79	0.26	-	-	-	-	-	-	Zhang and Baas (1992)

Prunus sargentii	0.76	0.41	6.35	-	-	-	-	-	Hong et al. (2007)
Prunus serotina	0.99	0.45	-	-	-	-	-	-	Bailey (1920)
Prunus serotina	0.75	-	-	-	-	-	-	-	USDA Forest Products Laboratory (1953)
Prunus serrulata (soda-AQ pulp)	0.62	-	17.00	-	-	-	-	-	Song et al. (2017)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 11: Fiber morphology of almond wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Prunus dulcis (pruning)	0.77	-	13.10	4.30	4.40	58.70	32.80	2.00	Ververis et al. (2004)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 12: Fiber morphology of fig wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Ficus ampelas	1.43	-	34.68	30.21	2.23	41.32	87.00	0.15	Rulliaty (2014)
Ficus benjamina	1.71	0.39	24.96	19.22	2.87	-	-	-	Balfas (2016)
Ficus carica subsp. *carica* (branch)	0.80	0.25	19.60	12.40	3.60	-	-	-	Yaman (2014)
Ficus carica subsp. *carica* (stem)	0.95	0.26	21.40	12.50	4.50	-	-	-	Yaman (2014)
Ficus carica (Aydın)	0.83	-	22.05	16.05	5.44	-	-	-	Odabaş Serin and Kılıç Penezoğlu (2020)
Ficus carica (Kahramanmaraş)	0.88	-	20.44	16.58	3.86	-	-	-	Odabaş Serin and Kılıç Penezoğlu (2020)
Ficus carica	1.05	-	30.47	23.60	5.42	-	-	-	Tichi and Divkolae (2019)
Ficus fulva	1.62	-	37.94	32.90	2.52	42.50	87.00	0.15	Adi et al. (2014)
Ficus exasperata (middle height)	1.39	-	21.47	10.97	5.25	65.71	50.39	1.02	Ekhuemelo et al. (2018)

Ficus exasperata	1.24	-	21.25	14.85	2.94	58.76	65.00	0.42	Ogunkunle and Oladele (2008)
Ficus ingens	1.16	-	24.34	19.77	2.82	48.03	77.00	0.29	Ogunkunle and Oladele (2008)
Ficus lutea	1.10	-	26.62	16.64	4.99	43.75	63.00	0.68	Ogunkunle and Oladele (2008)
Ficus mucuso	1.28	-	19.97	15.39	2.29	71.99	76.00	0.32	Ogunkunle and Oladele (2008)
Ficus natalensis	1.10	-	23.38	17.15	3.20	47.95	73.00	0.38	Ogunkunle and Oladele (2008)
Ficus nervosa	1.42	-	40.60	35.70	2.50	34.96	88.00	0.14	Ogunkunle and Oladele (2008)
Ficus ottonifolia	1.22	-	23.81	18.56	2.62	51.94	78.00	0.30	Ogunkunle and Oladele (2008)
Ficus ovata	1.11	-	20.74	15.36	2.88	55.10	73.00	0.40	Ogunkunle and Oladele (2008)
Ficus polita	1.00	-	21.12	15.87	2.63	48.28	74.00	0.36	Ogunkunle and Oladele (2008)
Ficus populifolia	1.01	-	18.69	14.80	1.94	55.34	79.00	0.26	Ogunkunle and Oladele (2008)
Ficus rumphii (14.22 m height)	1.32	0.24	25.00	-	-	-	-	-	Ajmal and Iqbal (1992)
Ficus rumphii (1.08 m height)	1.80	0.25	29.00	-	-	-	-	-	Ajmal and Iqbal (1992)
Ficus sur	1.20	-	28.93	20.99	3.97	42.38	72.00	0.39	Ogunkunle and Oladele (2008)
Ficus sur	1.55	-	31.30	23.9	3.75	49.52	76.36	0.33	Essien et al. (2012)
Ficus sycomorus	1.27	-	24.00	15.69	4.28	54.80	64.00	0.61	Gamal et al. (2012)
Ficus thonningii	1.33	-	25.09	17.92	3.58	54.11	71.00	0.42	Ogunkunle and Oladele (2008)
Ficus umbellata	0.99	-	20.48	15.62	2.30	50.51	75.00	0.31	Ogunkunle and Oladele (2008)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 13: Fiber morphology of Artocarpus sp. (breadfruit, jackfruit, etc.) wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Artocarpus altilis	1.52	-	35.09	22.95	6.11	44.79	63.59	0.60	Areo and Omole (2020)
Artocarpus anisophyllus	1.37	0.43	15.50	-	1.45	-	-	-	Takeuchi et al. (2019)
Artocarpus chaplasha	1.39	0.35	-	-	3.80	-	-	-	Singh et al. (2017)
Artocarpus communis	1.65	-	42.48	37.28	2.60	39.61	87.70	0.14	Feryanto (2006)

Artocarpus dadah	1.21	0.34	15.70	-	1.46	-	-	-	Takeuchi et al. (2019)
Artocarpus elasticus	1.78	-	47.20	42.24	2.48	49.44	89.00	0.12	Adi et al. (2014)
Artocarpus elasticus	-	-	-	-	-	66.2	86.00	0.16	Istikowati et al. (2016)
Artocarpus elasticus	1.14	0.48	35.00	-	1.10	-	-	-	Takeuchi et al. (2019)
Artocarpus heterophyllus	1.19	0.32	-	-	3.2.	-	-	-	Singh et al. (2017)
Artocarpus lakoocha	1.43	0.35	-	-	4.5.	-	-	-	Singh et al. (2017)
Artocarpus nitidus	1.32	0.28	-	-	4.9.	-	-	-	Singh et al. (2017)
Artocarpus nitidus	1.28	0.36	16.20	-	1.49	-	-	-	Takeuchi et al. (2019)
Artocarpus odoratissimus (pith)	0.95	-	20.97	13.23	3.87	47.91	63.00	0.67	Andara (2014)
Artocarpus odoratissimus (heartwood)	1.29	-	35.00	16.21	9.40	37.74	61.00	0.70	Andara (2014)
Artocarpus odoratissimus (transition wood)	1.26	-	26.21	16.05	5.08	50.11	61.00	0.69	Andara (2014)
Artocarpus odoratissimus (sapwood)	1.29	-	28.47	17.10	5.69	47.01	60.00	0.78	Andara (2014)
Artocarpus odoratissimus	1.50	0.44	17.80	-	1.15	-	-	-	Takeuchi et al. (2019)
Artocarpus odoratissimus	1.71	-	26.72	19.81	3.46	-	-	-	Marbun et al. (2019)
Artocarpus tamaran	1.43	0.40	26.30	-	1.08	-	-	-	Takeuchi et al. (2019)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 14: Fiber morphology of water berry wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Syzygium guineense	2.00	-	31.86	18.18	6.84	60.00	57.00	0.75	Sadiku and Abdukareem (2019)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 15: Fiber morphology of cashew wood.

Species	FL (mm)	VEL (mm)	FW (µm)	FLW (µm)	FCWT (µm)	SR	FR	RR	Reference
Anacardium occidentale (branch)	0.63	-	-	-	-	-	-	-	Bhat et al. (1985)
Anacardium occidentale (stem)	0.75	-	-	-	-	-	-	-	Bhat et al. (1985)
Anacardium occidentale	1.15	-	24.00	9.00	6.00	50.07	-	1.35	Ajuziogu et al. (2010)
Anacardium occidentale (outer zone)	0.69	-	19.30	13.80	2.70	-	-	-	Bhat and Bhat (1983)
Anacardium occidentale (inner zone)	0.76	-	19.50	13.90	2.80	-	-	-	Bhat and Bhat (1983)
Anacardium occidentale	0.66	0.42	-	-	-	-	-	-	Bailey (1920)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 16: Fiber morphology of orange wood.

Species	FL (mm)	VEL (mm)	FW (µm)	FLW (µm)	FCWT (µm)	SR	FR	RR	Reference
Citrus sinensis (core-base)	0.55	-	10.60	7.40	1.62	-	-	0.47	Eromosele (2015)
Citrus sinensis (core-middle)	0.60	-	9.10	6.67	1.67	-	-	0.52	Eromosele (2015)
Citrus sinensis (core-top)	0.45	-	9.90	6.26	1.82	-	-	0.64	Eromosele (2015)
Citrus sinensis (intermediate-base)	0.44	-	9.85	6.46	1.70	-	-	0.60	Eromosele (2015)
Citrus sinensis (intermediate-middle)	0.54	-	9.85	6.77	1.54	-	-	0.50	Eromosele (2015)
Citrus sinensis (intermediate-top)	0.57	-	9.80	6.77	1.52	-	-	0.50	Eromosele (2015)
Citrus sinensis (outer-base)	0.54	-	10.40	7.17	1.62	-	-	0.50	Eromosele (2015)
Citrus sinensis (outer-middle)	0.69	-	10.15	7.22	1.46	-	-	0.42	Eromosele (2015)
Citrus sinensis (outer-top)	0.60	-	9.10	6.82	1.60	-	-	0.50	Eromosele (2015)

Citrus sinensis (average of 36 pulps)	0.47	-	21.09	-	-	-	-	-	Aguado et al. (2016)
Citrus sinensis	0.76	-	23.64	9.23	7.21	-	-	-	Tichi et al. (2020)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 17: Fiber morphology of kiwi wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Actinidia deliciosa (residues)	1.37	-	30.04	14.17	7.93	-	-	-	Vaysi and Yosefi (2008)
Actinidia deliciosa	1.58	-	35.97	22.30	6.84	44.03	61.99	0.61	Yaman and Gencer (2005)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 18: Fiber morphology of lemon wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Citrus lemon var. *lamas*	0.75		13.74	6.36	3.69	54.37	46.29	1.16	Tutuş et al. (2018)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 19: Fiber morphology of dogwood wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Cornus mas	1.22	0.90	19.68	7.48	6.10	-	-	-	Merev (1998)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 20: Fiber morphology of persimmon wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Diospyros amboinensis	1.34	0.66	12.00	-	-	-	-	-	Van der Graaff and Baas (1974)
Diospyros blancoi	1.19	0.16	42.20	32.00	-	-	-	-	Krisdianto and Abdurachman (2005)
Diospyros kaki	1.10	-	26.20	14.27	5.98	41.98	54.30	0.84	Tutuş et al. (2014)

Diospyros lotus	0.94	0.42	16.59	6.17	5.21	58.66	36.44	1.86	Topaloğlu et al. (2019)
Diospyros lotus	1.13	-	12.05	4.89	3.58	93.75	40.59	1.47	Kiaei and Bakhshi (2014)
Diospyros lotus	0.91	0.32	21.34	14.44	3.45	-	-	-	Merev (1998)
Diospyros mespiliformis	0.92	-	18.00	9.00	5.00	50.62	47.10	1.21	Ajuziogu et al. (2014)
Diospyros mespiliformis	0.98	-	18.80	9.08	4.86	50.20	48.00	1.21	Gamal et al. (2012)
Diospyros virginiana	1.27	0.38	19.00	-	-	-	-	-	Van der Graaff and Baas (1974)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 21: Fiber morphology of mulberry wood.

Species	FL (mm)	VEL (mm)	FW (µm)	FLW (µm)	FCWT (µm)	SR	FR	RR	Reference
Morus alba	1.02	-	11.00	-	-	-	-	-	Guha and Madan (1962)
Morus alba	1.02	-	-	-	-	-	-	-	Pourtahmasi and Golpayegani (2009)
Morus alba	1.10	0.25							Karami et al. (2010)
Morus alba	0.97	-	14.02	8.62	2.70	-	-	-	Nasir (2010)
Morus alba	0.91	-	12.50	-	-	71.80	-	-	Ji et al. (2018)
Morus alba	1.51	-	27.25	18.74	4.25	-	-	-	Tichi and Divkolae (2020)
Morus alba	0.50	-	15.00	-	-	-	-	-	Sharma (2020)
Morus mocroura	1.62	-	31.93	16.99	-	-	-	-	Fakhruzy (2019)
Morus nigra	1.30	-							Karami et al. (2010)
Morus nigra	1.28	-	23.00	14.20	3.60	55.65	-	0.51	Walia (2013)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 22: Fiber morphology of mango wood.

Species	FL (mm)	VEL (mm)	FW (µm)	FLW (µm)	FCWT (µm)	SR	FR	RR	Reference
Mangifera altissima	1.40	-	18.00	14.00	2.00	77.80	78.00	-	Moriya (1967)
Mangifera altissima	1.00	-	-	-	2.70	-	-	0.37	Koeppen (1978)
Mangifera foetida	-	0.68	-	-	-	-	-	-	Terrezas Salgado (1994)

Mangifera griffithii	1.26	-	-	-	-	-	-	-	Terrezas Salgado (1994)
Mangifera indica	0.94	-	26.00	10.00	4.00	47.29	-	0.82	Ajuziogu et al. (2010)
Mangifera longipes	0.50	0.35	-	-	-	-	-	-	Terrezas Salgado (1994)
Mangifera monandra	0.92	0.52	-	-	-	-	-	-	Bailey (1920)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 23: Fiber morphology of jackalberry wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Diospyros mespiliformis	-	-	17.41	6.59	5.41	-	-	1.64	Adeniyi et al. (2013)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 24: Fiber morphology of pomegranate wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Punica granatum	0.58	0.30	14.93	8.52	3.14	-	-	-	Merev (1998)
Punica granatum (branch)	0.70	0.54	19.20	11.50	3.85	36.60	59.90	1.34	Gülsoy et al. (2015)
Punica granatum (stem)	0.75	0.59	20.95	11.65	4.65	35.58	55.61	1.60	Gülsoy et al. (2015)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 25: Fiber morphology of hawthorn wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Crataegus azarolus (stem, 1800 m)	0.84	-	20.93	-	5.76	-	-	-	Dong et al. (2021)
Crataegus azarolus (branch, 1800 m)	0.79	-	21.74	-	5.85	-	-	-	Dong et al. (2021)
Crataegus azarolus (below 1800 m, slope 30-45%)	0.93	-	18.91	-	5.89	-	-	-	Nazari et al. (2021)
Crataegus microphylla	0.83	0.48	17.31	9.10	4.17	-	-	-	Merev (1998)

Crataegus pseudoheterophylla	0.88	0.46	17.12	6.15	5.43	-	-	-	Merev (1998)
Crataegus tanacetifolia	0.77	0.39	16.01	6.88	4.57	-	-	-	Merev (1998)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 26: Fiber morphology of hazelnut wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Corylus avellana (prunings)	-	0.63	-	-	-	46.93	61.53	0.63	Özgül (2014)
Corylus avellana (prunings)	1.04	-	22.20	13.66	4.30	-	-	-	Gençer and Özgül (2016)
Corylus avellana	1.06	-	23.8	14.08	4.8	-	-	-	Merev (1998)
Corylus colurna (average of 9 samples)	1.23	-	27.21	16.39	4.93	-	-	-	Sarıbaş (1998)
Corylus cornuta	0.67	-	14.00	-	-	-	-	-	Chase and Young (1978)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

Table 27: Fiber morphology of loquat wood.

Species	FL (mm)	VEL (mm)	FW (μm)	FLW (μm)	FCWT (μm)	SR	FR	RR	Reference
Eriobotrya deflexa	0.98	0.77	-	-	-	-	-	-	Zhang and Baas (1992)
Eriobotrya japonica (Guangxi)	1.02	0.64	-	-	-	-	-	-	Zhang and Baas (1992)
Eriobotrya japonica	1.16	0.60	17.00	6.74	5.12	69.17	39.51	1.58	Topaloğlu et al. (2019)

FL: Fiber length, VEL: Vessel element length, FW: Fiber width, FLW: Lumen Width, FCWT: Cell wall thickness, SR: Slenderness ratio, FR: Flexibility ratio, RR: Runkel ratio

CONCLUSIONS

Pruning residues are one of the main sources of potential unused lignocellulosic raw materials. Many of these residues are underutilized or incinerated in situ, causing significant air pollution. Therefore, a circular economy, as a way to achieve sustainable development, should convert these lignocellulosic residues into high value-added products (Eugenio et al.

2021). In this sense, pruning residues can be turned into a high value-added product such as paper. When pruning residues are used as an alternative source in pulp and paper production, pruning residues converting into fibers due to pulping process can be recycled and reused many times over. This situation helps to reduce deforestation and environmental pollution.

REFERENCES

Adeniyi, I. M., Adebagbo, C. A., Oladapo, F. M., Ayetan, G. (2013). Utilization of Some Selected Wood Species in Relation to Their Anatomical Features. *Global Journal of Science Frontier Research Agriculture and Veterinary*, *13*, 20-27.

Adi, D. S., Risanto, L., Damayanti, R., Rullyati, S., Dewi, L. M., Susanti, R., Dwianto, W., Hermiati, E., Watanabe, T. (2014). Exploration of unutilized Fast Growing Wood Species from Secondary Forest in Central Kalimantan: Study on the Fiber Characteristic and Wood Density. *Procedia Environmental Sciences*, *20*, 321-327.

Aguado, R., Moral, A., López, P., Mutjé, P., Tijero, A. (2016). Morphological Analysis of Pulps from Orange Tree Trimmings and its Relation to Mechanical Properties. *Measurement*, *93*, 319-326.

Ajmal, S., Iqbal, M. (1992). Structure of the Vascular Cambium of Varying Age and its Derivative Tissues in the Stem of *Ficus rumphii* Blume. *Botanical journal of the Linnean Society*, *109*, 211-222.

Ajuziogu, G. C., Nwosu, M. O., Nzekwe, U., Onyeke, C. C., Odo, G. E., Nwosu Ejikeme, P. M., Onyeonagu, C. C. (2014). Biomechanics, an Aspect of the Relationships between Wood Anatomical Parameters and Mechanical Strength in Ten Nigerian Timber Species. *International Journal of Scientific and Engineering Research*, *5*, 629-645.

Ajuziogu, G. C., Nzekwe, U., Chukwuma, H. I. (2010). Assessment of Suitability of Wood Fibres of Four Nigerian Fruit Trees for Paper–making. *Bio-Research*, *8*, 679-681.

Akgül, M., Tozluoğlu, A. (2009). Some Chemical and Morphological Properties of Juvenile Woods from Beech (*Fagus orientalis* L.) and Pine (*Pinus nigra* A.) plantations. *Trends in Applied Sciences Research*, *4*, 116-125.

Ali, H. H., Abd Ali, B. A. (2017). Consequences of Soil Crude Oil Pollution on Some Wood Properties of Olive Trees. *Ibn AL-Haitham Journal For Pure and Applied Science*, *27*, 1-6.

Altunışık Bülbül, G., Gençer, A. (2021). Determination of Some Chemical and Morphological Properties of Avocado Wood and Researching Its Suitability for Pulp Production. *Journal of Bartin Faculty of Forestry*, *23*, 95-103.

Andara, M. (2014). Kajian Struktur Anatomi Dan Sifat Fisis Kayu Terap (*Artocarpus odoratissimus*), a Lesser Known Species Asal Kalimantan Selatan. Bachelor Thesis, Departemen Teknologi Hasil Hutan Fakultas Kehutanan Institut Pertanian Bogor, Bogor Agricultural University, Bogor.

Annergren, G. (1999). Fundamentals of Pulp Fiber Quality and Paper Properties. In *TAPPI Pulping Conference* (No. 1, pp. 29-40).

Areo, O., Omole, D. (2020). Cell Morphological Studies of *Artocarpus altilis* (Parkinson ex. Zorn) Forsberg Wood. *Pro Ligno*, *16*, 36-45.

Ashori, A., Nourbakhsh, A. (2009). Studies on Iranian Cultivated Paulownia–A Potential Source of Fibrous Raw Material for Paper Industry. *European Journal of Wood and Wood Products*, *67*, 323-327.

Ates, S., Ni, Y., Akgul, M., Tozluoglu, A. (2008). Characterization and Evaluation of *Paulownia elongota* as a Raw Material for Paper Production. *African journal of Biotechnology*, *7*, 4153-4158.

Baas, P., Xinying, Z. (1986). Wood Anatomy of Trees and Shrubs from China. I. Oleaceae. *IAWA Journal*, *7*, 195-220.

Bailey, I. W. (1920). The Cambium and its Derivative Tissues. II. Size Variations of Cambial Initials in Gymnosperms and Angiosperms. *American Journal of Botany*, *7*, 355-367.

Balfas, J. (2016). Struktur Anatomi Dan Kualitas Serat Kayu Dan Akar Gantung Beringin (*Ficus benjamina* Linn.). *Jurnal Ilmu Pertanian Indonesia*, *21*, 13-19.

Bhat, K. V., Bhat, K. M. 1983. Anatomical Changes Associated with Interlocked Grain in *Anacardium occidentale* L. *IAWA Journal*, *4*, 179–182.

Bhat, K. M., Bhat, K. V., Dhamodaran, T. K. (1985). Wood and Bark Properties of Branches of Selected Tree Species Growing in Kerala. KFRI Research Report 29, 34 pp.

Casey, J. P. (1960). *Pulp and Paper. Chemistry and Chemical Technology*. Interscience Publishers, New York.

Chase, A. I., Young, H. E. (1978). Pulping, Biomass, and Nutrient Studies of Woody Shrubs and Shrub Size Tree Species. The University of Maine. Maine Agricultural and Forest Experiment Station Bulletins (USA). No. B749.

Ciolacu, F. (2013). Cellulose Fibers in the Papermaking Process, Chapter 7. Popa, E. I. (Ed.). In: *Pulp Production and Processing: From Papermaking to High-Tech Products*, Smithers Rapra, Shawbury, United Kingdom.

Dinwoodie, J. M. (1965). The Relationship between Fiber Morphology and Paper Properties: A Review Of Literature. *Tappi Journal*, *48*, 440-447.

Dong, H., Bahmani, M., Humar, M., Rahimi, S. (2021). Fiber Morphology and Physical Properties of Branch and Stem Wood of Hawthorn (*Crataegus azarolus* L.) Grown In Zagros Forests. *Wood Research*, 66, 391-402.

Ekhuemelo, D. O., Aidoko, V. O. Tembe, E. T. (2018). Evaluation of Pulp and Paper Making Potentials of *Ficus exasperata* Vahl in Makurdi, Nigeria. *South Asian Journal of Biological Research*, *1*, 61-78.

Eroğlu, H., Gülsoy, S. K. (2008). A Comparative Study of Some Tumorous and Normal Hardwood Kraft Pulp Properties. *Wood Research*, *53*, 77-84.

Eromosele, O.J. 2015. Fibre Characteristics of the Trunk of *Citrus sinensis* (L.) Osbeck. *IOSR Journal of Pharmacy and Biological Sciences (IOSR-JPBS)*, *10*, 76-81.

Essien, C., Ofori, J., Sekyere, D., Owusu, F. W., Tekpetey, S. L. (2012). Assessing the Suitability of *Ficus sur* and *Cola gigantea* as Raw Material for Pulp and Paper Production in Ghana. *Annals of Biological Research*, *3*, 4650-4656.

Eugenio, M. E., Martín-Sampedro, R., Santos, J. I., Wicklein, B., Ibarra, D. (2021). Chemical, Thermal and Antioxidant Properties of Lignins Solubilized during Soda/AQ Pulping of Orange and Olive Tree Pruning Residues. *Molecules*, *26*, 3819.

Fakhruzy, M. N. (2019). Struktur Anatomi Kayu Andalas (*Morus mocroura* Miq) Asal Sumatera Barat. *Menara Ilmu*, *13*, 22-27.

FAO. (2021). Food and Agriculture Organization of the United Nations, FAOSTAT data. http://www.fao.org/faostat/en/#data/QC.

Fengel, D., Grosser, D. (1975). Chemische Zusammensetzung von Nadel-und Laubhölzern. *Holz als Roh und Werskstoff*, *33*, 32-34.

Feryanto, H. (2006). Variasi Aksial Dan Radial Sifatsifat Kayu Sukun (*Artocarpus communis* Forst) Dari Bantul Yogyakarta. PhD Thesis, Sekolah Pasca Sarjana Universita Gadjah Mada. Yogyakarta.

Gamal, H. M. S., yassin Abdelgadir, A. A., & Bues, C. T. (2012). Variation in Wood Fiber Characteristics among Thirty Two Hardwood Species Grown in Low-Rainfall Wood land Savannah (Sudan). In *The 5th Conference on Hardwood Research and Utilisation*, 104-114 pp.

García Martín, J. F., Cuevas, M., Feng, C. H., Álvarez Mateos, P., Torres Garcia, M., Sánchez, S. (2020). Energetic Valorisation of Olive Biomass: Olive-tree Pruning, Olive Stones and Pomaces. *Processes*, *8*, 511.

Gençer, A., (2015). The Utilization of Kiwi (*Actinidia deliciosa*) Pruning Waste for Kraft Paper Production and the Effect of the Bark on Paper Properties. *Drewno*, *58*, 103-113.

Gençer, A., Gül Türkmen, H. (2016). Determination of Paper Production Conditions of Wild Cherry Heartwood and Sapwood. *Journal of Bartın Faculty of Forestry*, *18,* 23-31.

Gençer, A., Özgül, U. (2016). Utilization of Common Hazelnut (*Corylus avellana* L.) Prunings for Pulp Production. *Drvna Industrija*, *67*, 157-162.

Gençer, A., Şirin, G., Gül, H., Özgül, U. (2013). Determination of the Product Conditions of Pulp and Paper from White Mulberry (*Morus alba* L.) by Kraft Method. *Journal of Bartın Faculty of Forestry*, *15*, 63-68.

Gençer, A., Özgül, U., Onat, S. M., Gündüz, G., Yaman, B., Yazıcı, H. (2018). Chemical and Morphological Properties of Apricot Wood (*Prunus*

armeniaca L.) and Fruit Endocarp. *Journal of Bartin Faculty of Forestry*, *20*, 205-209.

Giagli, K. F. (2010). Structural Characteristics and Technical Properties of Olive Wood (*Olea europaea* L.) in Relation to its Utilization (No. GRI-2010-5723). Aristotle University of Thessaloniki.

González, Z., Rosal, A., Requejo, A., Rodríguez, A. (2011). Production of Pulp and Energy Using Orange Tree Pruning. *Bioresource Technology*, *102*, 9330-9334.

González, Z., Rodríguez, A., Vargas, F., Jiménez, L. (2013). Refining of Soda-AQ, Kraft-AQ, and Ethanol Pulps from Orange Tree Wood. *Bioresources*, *8*, 5622–5634.

Guha, S., Madan, R. N. (1962). Chemical Pulps for Writing and Printing Papers from *Morus alba*. *Indian Forester*, *88*, 64-66.

Gulsoy, S. K., Tufek, S. (2013). Effect of Chip Mixing Ratio of *Pinus pinaster* and *Populus tremula* on Kraft Pulp and Paper Properties. *Industrial & Engineering Chemistry Research*, *52*, 2304-2308.

Gülsoy, S. K., Şimşir, S. (2018). Chemical Composition, Fiber Morphology, and Kraft Pulping of Bracken Stalks (*Pteridium aquilinum* (L.) Kuhn). *Drvna Industrija*, *69*, 23-33.

Gülsoy, S. K., Eroğlu, H., Merev, N. (2005). Chemical and Wood Anatomical Properties of Tumorous Wood in a Turkish White Oak (*Quercus robur* subsp. *robur*). *IAWA Journal*, *26*, 469-476.

Gülsoy, S. K., Kılıç Pekgözlü, A., Aktaş, A. C. (2015). Utilization of the Pomegranate Tree (*Punica granatum* L.) in the Paper Industry. *Turkish Journal of Agriculture and Forestry*, *39*, 295-299.

Gülsoy, S. K., Aksoy, H., Gül Türkmen, H., Çanakcı, G. (2021). Fiber Morphology and Chemical Composition of Heartwood and Sapwood of Red Gum, Black Willow, and Oriental Beech. *Journal of Bartin Faculty of Forestry*, *23*, 119-124.

Hong, S. D., Ahmed, S. A., Chun, S. K. (2007). Flow Behavior of Safranine Solution in *Prunus sargentii* Rehder. *Journal of the Korea Furniture Society*, *18*, 282-286.

Istikowati, W. T., Aiso, H., Sunardi., Sutiya, B., Ishiguri, F., Ohshima, J., Iizuka, K., Yokota, S. (2016). Wood, Chemical, and Pulp Properties of Woods from Less-Utilized Fast-Growing Tree Species Found in Naturally Regenerated Secondary Forest in South Kalimantan, Indonesia. *Journal of Wood Chemistry and Technology*, *36*, 250-258.

Ji, L., Fan, Y., Zhao, T. (2018). Research on High Yield Cultivation of *Morus alba* and its Pulping and Papermaking. *Journal of Agricultural Science and Technology (Beijing)*, *20*, 105-111.

Jiménez, L., Pérez, I., De la Torre, M. J., García, J. C. (2000). Influence of Process Variables on the Properties of Pulp and Paper Sheets Obtained by Sulphite Pulping of Olive Tree Wood. *Wood Science and Technology*, *34*, 135-149.

Johansson, A. (2011). Correlations Between Fibre Properties and Paper Properties. Master Thesis, KTH, School of Chemical Science and Engineering.

Karami, E., Pourtahmasi, K., Shahverdi, M. (2010). Wood Anatomical Structure of *Morus alba* L. and *Morus nigra* L., Native to Iran. *Notulae Scientia Biologicae*, *2*, 129-132.

Kaya, Z. 1991. Delice (*Olea europea* var. *oleaster* L.) ile Zeytin (*Olea europea* var. *sativa*) Arasında Anatomik ve Palinolojik Ayrıcalıklar. *İstanbul Orman Fakültesi Dergisi, A Serisi*, *41*, 132-148.

Khider, T., Safaa, O., Elzaki, O., Mohieldin, S., Shomeina, S. (2021). Application of Alkaline Pulping to Pruned Branches of *Citrus limon* from Sudan. *Walailak Journal of Science and Technology (WJST)*, *18*, 9409.

Kiaei, M., Bakhshi, R. (2014). Radial Variations of Wood Different Properties in *Diospyros lotus*. *Forest Systems*, *23*, 171-177.

Kiaei, M., Tajik, M., Vaysi, R. (2014). Chemical and Biometrical Properties of Plum Wood and its Application in Pulp and Paper Production. *Maderas. Ciencia y tecnología*, *16*, 313-322.

Kılıç Penezoğlu, M. (2019). Determination of Morphological, Chemical and Physical Properties of Some Fruit Tree Woods. Master Thesis, Kahramanmaraş Sütçü İmam University, Kahramanmaraş, Turkey.

Koeppen, R. C. (1978). Some Anatomical Characteristics of Tropical Woods. In *Papers for Conference on Improved Utilization of Tropical Forests*, May 21-26, 1978, Madison, Wisconsin (p. 23-37).

Krisdianto, K., Abdurachman, A. (2005). Anatomical and Physical Propertiesof Bisbul Wood (*Diospyros blancoi* A. dc.). *Indonesian Journal of Forestry Research*, *2*, 57-67.

López, F., Ariza, J., Eugenio, M. E., Díaz, J., Pérez, I., Jiménez, L. (2001). Pulping and Bleaching of Pulp from Olive Tree Residues. *Process Biochemistry*, *37*, 1-7.

Ma, J. F., Yang, G. H., Mao, J. Z., Xu, F. (2011). Characterization of Anatomy, Ultrastructure and Lignin Microdistribution in *Forsythia suspensa*. *Industrial Crops and Products*, *33*, 358–363.

Marbun, S. D., Wahyudi, I., Suryana, J., Nawawi, D. S. (2019). Anatomical Structures and Fiber Quality of Four Lesser-Used Wood Species Grown in Indonesia. *Journal of the Korean Wood Science and Technology*, *47*, 617-632.

Martínez-Patiño, J. C., Romero-García, J. M., Ruiz, E., Oliva, J. M., Álvarez, C., Romero, I., Negro, M. J., Castro, E. (2015). High Solids Loading Pretreatment of Olive Tree Pruning with Dilute Phosphoric Acid for

Bioethanol Production by *Escherichia coli*. *Energy & Fuels*, *29*, 1735-1742.

Merev, N., (1998). *Odun Anatomisi Cilt 1. Doğu Karadeniz Bölgesindeki Doğal Angiospermae Taksonlarının Odun Anatomisi*, General Publication No. 189, Faculty Publication No. 27, Karadeniz Technical University Press, Trabzon.

Moral, A., Aguado, R., Mutjé, P., Tijero, A. (2016). Papermaking Potential of *Citrus sinensis* Trimmings using Organosolv Pulping, Chlorine-free Bleaching and Refining. *Journal of Cleaner Production*, *112*, 980-986.

Moriya, M. (1967). Characteristics of Papers and the Morphological Properties of Woods. Japan *TAPPI Journal*, *21*, 141-150.

Nasir, G. M. (2010). Wood Anatomy and Technological Properties of Some Tree Species Grown in Balochistan. *Pakistan Journal of Forestry*, *60*, 39-45.

Nazari, N., Bahmani, M., Kahyani, S., Humar, M. (2021). Effect of Site Conditions on the Properties of Hawthorn (*Crataegus azarolus* L.) Wood. *Journal of Forest Science*, *67*, 113-124.

Odabaş Serin, Z., Kılıç Penezoğlu, M. (2020). Chemical, Physical and Morphological Properties of Fig (*Ficus carica*) Wood. *European Journal of Science and Technology*, *19*, 843-849.

Ogunkunle, A. T. J., Oladele, F. A. (2008). Structural Dimensions and Paper Making Potentials of Wood in Some Nigerian Species of *Ficus* L. (Moraceae). Adva*nces in Natural and Applied Sciences*, *2*, 103-111.

Özgül, U. 2014. Feasibility of Using Common Hazelnut (*Corylus avellana* L.) Wood for Pulp Production. Master Thesis, Bartin University, Bartin, Turkey.

Paavilainen, L. (2002). Fiber Structure, Chapter 13. (Eds. Mark, R.E., Habeger Jr., C. C., Borch, J., Lyne, M. B.), 2nd Ed., In: *Handbook of Physical Testing of Paper*, Marcel Dekker, New York, USA.

Pacheco, C. M., Bustos, C., Reyes, G., Aguayo, M.G., Rojas, O. J. (2018). Characterization of Residues from Chilean Blueberry Bushes: A Potential Source of Cellulose. *Bioresources*, *13*, 7345-7359.

Panshin A. J., De Zeeuw C. (1980). *Textbook of Wood Technology*. McGraw-Hill Book Company, New York.

Passialis, C. N., Grigoriou, A. H. (1999). Technical Properties of Branch-Wood of Apple, Peach, Pear, Apricot and Cherry Fruit Trees. *Holz als Roh-und Werkstoff*, *57*, 41-44.

Pourtahmasi, K., Golpayegani, A. (2009). Introducing Mulberry's Wood (Morus alba L.) Used in Bowl Shaped Musical Instruments of Iran. *Le Bois: Instrument du Patrimoine Musical*, *29*, 78-87.

Requejo, A., Rodríguez, A., Colodette, J. L., Gomide, J. L., Jiménez, L. (2012a). Comparative Study of *Olea europea* and *Eucalyptus urograndis* Kraft Pulps. *Cellulose Chemistry and Technology*, *46*, 517-524.

Requejo, A.; Rodríguez, A.; González, Z.; Vargas, F.; Jiménez, L. (2012b). Ethanol Pulping as a Stage in the Bio-Refinery of Olive Tree Prunings. *Bioresources*, *7*, 3142-3159.

Romero-García, J. M., Sanchez, A., Rendón-Acosta, G., Martínez-Patiño, J. C., Ruiz, E., Magaña, G., Castro, E. (2016). An Olive Tree Pruning Biorefinery for Co-Producing High Value-Added Bioproducts and Biofuels: Economic and Energy Efficiency Analysis. *BioEnergy Research*, *9*, 1070-1086.

Rulliaty, S. 2014. Identifikasi Dan Kualitas Serat Lima Jenis Kayu Andalan Setempat Asal Jawa Barat Dan Banten. *Jurnal Penelitian Hasil Hutan*, *32*, 297-312.

Sadiku, N. A., Abdukareem, K. A. (2019). Fibre Morphological Variations of Some Nigerian Guinea Savannah Timber Species. *Maderas. Ciencia y Tecnología*, *21*, 239-248.

Salgado, T. T. (1994). Wood Anatomy of the Anacardiaceae: Ecological and Phylogenetic Interpretation. PhD Thesis, The University of North Carolina at Chapel Hill.

Sekhavati, N., Akbarinia, M., Zanganeh, H. (2012). Investigation of Selected Physical, Biometrical and Mechanical Properties of *Cerasus mahaleb* (L.) Mill in the Middle Zagros Forest Site. *Iranian Journal of Wood and Paper Science Research*, *27*, 267-274.

Sharma, V. (2020). Evaluation of *Morus alba* L. Clones for Morphometric and Wood Characteristics. Master Thesis, Dr. Yashwant Singh Parmar University.

Silva Guzmán, J. A., Fuentes Talavera, F. J., Richter, H. G., Angeles Alvarez, G., Sanjuan Dueñas, R. (1999). Estructura de la Madera de *Persea americana* var. *guatemalensis* Mill (Hass). *Madera y Bosques*, *5*, 53-59.

Singh, M. K., Sharma, C. L., Sharma, M. (2017). Comparative Wood Anatomy of Four Artocarpus Species of North East India with Reference to Their Identification. Pandey K., Ramakantha V., Chauhan S., Arun Kumar A. (Eds), In: *Wood is Good*, Springer, Singapore.

Song, W-Y., Park, J-T., Kang, S-H., Han, S-H., Shin, S-J. (2017). Properties and Chemical Characteristics of Soda-Anthraquinone Pulp from *Prunus serrulata* Wood Chips. *Journal of Korea TAPPI*, *49*, 49-54.

Spinelli, R., Picchi, G. (2010). Industrial Harvesting of Olive Tree Pruning Residue for Energy Biomass. *Bioresource Technology*, *101*, 730-735.

Tajik, M., Kiaei, M., Torshizi, H. J. (2015). Apricot Wood – A Potential Source of Fibrous Raw Material for Paper Industry. *Comptes Rendus de l'Académie Bulgare des Sciences*, *68*, 329-336.

Takeuchi, R., Wahyudi, I., Aiso, H., Ishiguri, F., Istikowati, W. T., Ohkubo, T., Ohshima, J., Iizuka, K., Yokota, S. (2019). Anatomical Characteristics and Wood Properties of Unutilized Artocarpus Species Found in Secondary Forests Regenerated After Shifting Cultivation in Central Kalimantan, Indonesia. *Agroforestry Systems*, *93*, 745-753.

Tichi, A. H., Divkolae, M. R. (2019). Anatomical, Physical and Biometric Properties of *Ficus carica* Wood in Longitudinal and Transverse Direction of Tree Stem. *Iranian Journal of Wood and Paper Science Research*, *34*, 228-241.

Tichi, A. H., Divkolae, M. R. (2020). Changes of Biometric, Physical and Anatomical Properties of juvenile wood and mature wood of *Morus alba* tree in Longitudinal and Transverse Directions. *Iranian Journal of Wood and Paper Industries*, *11*, 305-316.

Tichi, A. H., Khademieslam, H., Divkolae, M. R. (2020). Evaluation of Physical, Anatomical, and Biometric Characteristics of *Citrus sinensis* Trees in Longitudinal and Transverse Axes of Stem. *Bioresources*, *15*, 5696-5709.

Topaloğlu, E., Öztürk, M., Ustaömer, D., Serdar, B. (2019). Doğu Karadeniz Bölgesinde Yetişen Meyve Ağaçları Gövde Odunlarının Anatomik, Morfolojik Özellikleri ve Kağıt Üretimi Açısından Değerlendirilmesi. *Ormancılık Araştırma Dergisi*, *6*, 142-151.

Tümen, İ. (1999). Anatomical Physical and Chemical Properties of Wild Pear, *Pyrus communis* L. Master Thesis, Zonguldak Karaelmas University, Zonguldak, Turkey.

Tutuş, A., Çiçekler, M., Özdemir, F., Yılmaz, U. (2014). Evaluation of *Diospyros kaki* Grown in Kahramanmaraş in Pulp and Paper Production. *II. National Mediterranean Forest and Environment Symposium*, Isparta, Turkey.

Tutuş, A., Çiçekler, M., Bektaş, İ., Odabaş-Serin, Z., Özdemir, F. (2018). Investigation of the Chemical and Morphological Properties of Lamas Lemon Tree Wood Growing in the Erdemli. In *Proceedings Book of International Erdemli Symposium*, pp. 894-899.

USDA Forest Products Laboratory. (1953). Density, Fiber Length, and Yields of Pulp for Various Species of Wood. USDA For. Serv. For. Prod. Lab. Tech. Note 191.

Van der Graaff, N.A. Baas, P. (1974). Wood Anatomical Variation in Relation to Latitude and Altitude. *Blumea*, *22*, 101–121.

Vargas, R., Sanjuán, J. R., Silva, J. A., Rivera, J., Fuentes, F. J., Richter, H. G. (2006). Properties of Bleached Pulp Sheets of Avocado Wood (*Persea americana* Mill.) Pulped by Kraft and Soda Processes. *Madera y Bosques*, *12*, 29-36.

Vaysi, R.; Yosefi, F. 2008. An Investigation on the Production Possibility of NSSC Pulp and Fluting Papers from Kiwi Residues. *Journal of Sciences and Techniques in Natural Resources*, *3*, 51-64.

Ververis, C., Georghiou, K., Christodoulakis, N., Santas, P., Santas, R. (2004). Fiber Dimensions, Lignin and Cellulose Content of Various Plant Materials and Their Suitability for Paper Production. *Industrial Crops and Products 19*, 245–254.

Walia, Y. K. (2013). Chemical and Physical Analysis of *Morus nigra* (Black mulberry) for its Pulpability. *Asian Journal of Advanced Basic Sciences*, *1*, 40-44.

Walia, Y. K., Gupta, D. K. (2015). Sulphate Chemical Pulping (Anthraquinone) of *Morus nigra*. *Journal of Biological and Chemical Chronicles*, *1*, 41-45.

Xu, F., Zhong, X. C., Sun, R. C., Lu, Q. (2006). Anatomical Ultrastructure and Lignin Distribution in Cell Wall of *Caragana korshinskii*. *Industrial Crops and Products*, *24*, 186-193.

Yaman, B. (2002). The Morphological, Anatomical and Palynological Characteristics of Wild Cherry (*Cerasus avium* (L.) Moench) Growing Naturally in the Euro-Siberian (Euxine) Area of Turkey. PhD Thesis, Zonguldak Karaelmas University, Zonguldak, Turkey.

Yaman, B. (2014). Anatomical Differences between Stem and Branch Wood of *Ficus carica* L. subsp. *carica*. *Modern Phytomorphology*, 6, 79-83.

Yaman, B., Gencer, A. (2005). Fiber Morphology of Kiwi (*Actinidia deliciosa* (A. Chev.) CF Liang & AR Ferguson) Grown in Trabzon. *Turkish Journal of Forestry*, *6*, 149-155.

Zhang, S.-Y., Baas, P. (1992). Wood Anatomy of Trees and Shrubs from China. III. Rosaceae. *IAWA Journal*, *13*, 21-91.

Chapter 7

ANTIMICROBIAL ACTIVITIES OF JUNIPER BERRIES (*JUNIPERUS COMMUNIS*), BOTTLE BRUST (*EQUISETUM ARVENSE*), STAR ANISE (*ILLICIUM VERUM*) AND UVEZ (*CORMUS DOMESTICA*)

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1. Introduction

People have used plants for food supply and treatment of diseases since ancient times. The ongoing connection between humans and plants has caused the ethnobotanical field to emerge (1). Through the accumulation of knowledge for years, ethnobotany has contributed plants to be investigated scientifically and used in medical and various fields (2). World Health Organization describes Herbal Medicines as prepared and labeled products that contain herbal drugs or mixtures as an effective part, as is or herbal mixtures, in order to prevent or treat the diseases. The importance and amount of use of Medicinal and Aromatic Plants, which have been used in many fields such as food, spice, condiment, and treatment for centuries, are increasing day by day. World Health Organization (WHO) data report that approximately 21,000 plant species are used for medical purposes in the world. Today, the medicinal plant market is estimated to be around $ 100 billion per annum. Germany (Hamburg), USA (New York), and Hong Kong are the main commercial centers for herbal drugs in the world. Although substantial progress has been made in the modern medicine, pharmaceutical, and chemical industry, alternative treatment methods and treatment with medicinal plants have continued to be relevant, and have even attracted intensive attention in developed countries in recent years. On the other hand, a population of approximately 2.5 billion in underdeveloped and developing countries cannot make benefit of known modern drugs (2). The World Health Organization (WHO) finds the use of medicinal plants in these countries important to consider as an alternative to these medicines only for economic reasons, but to develop a health technology compatible with its own culture and natural resources, and to avoid being dependent on developed countries (3). Available studies show that primary and secondary metabolites, which are natural products produced by plants, are, directly and indirectly, one of the most basic products of the industry. Plants convert the water, minerals, and some components obtained from the soil into compounds in their own metabolism in a way that the human body can use. For example, some primary metabolites such as carbohydrates, proteins, fats, vitamins, and secondary metabolites are among these compounds. These are active ingredients that can be used for medical purposes. These active substances can enhance the body's defensive power and have a positive effect on the functions of certain tissues and organs in the organism (1). The active substances should be isolated in order to make use of plants for medical purposes. The active ingredient extracts of plants are of vital importance (3).

This study aims to determine the antimicrobial activities of methanolic extracts of juniper berries (*Juniperus communis*), bottle brust (*Equisetum arvense*), star anise (*Illicium verum*) and uvez (*Cormus domestica*).

1.1. Definition of Medicinal and Aromatic Plants

Today, the term medicinal and aromatic plants are usually used in conjunction. Medicinal and aromatic plants are those used as medicine to prevent diseases, maintain health or cure diseases. Medicinal plants are used in areas such as nutrition, cosmetics, body care, incense, or religious rituals while aromatic plants are used for their smell, fragrance, and taste characters (4). Aromatic plants have a wide range of usages in food, cosmetics, and perfumery sector (5). The original material of herbal medicines is usually included in the group of medicinal plants. Herbal medicine is plant-derived materials or preparations that have therapeutic properties and contain either raw or processed ingredients from one or more plants, or that are useful for other people's health (6). However, this definition does not apply to the cases in which a drug product is isolated or synthesized as a chemical component and the active substance is defined (7). When it comes to medicinal and aromatic plants, they cover a very large area in terms of both plants and active substances and consumption areas. Use Areas of Medicinal Plants are as follow:

1. Increasing the quality of life by reducing the side effects of medical treatment that has been administered.
2. Wanting people to take a more active role in protecting their health
3. Preferring traditional treatment methods and products due to cultural impact.

On the other hand, the World Health Organization (WHO) deems this tendency significant not only for the use of medicinal plants as an alternative to medicines for economic reasons in underdeveloped and developing countries but also for the countries to develop a health technology compatible with their own culture and natural resources and to avoid being dependent on developed countries (8).

1.2.Production and use of Medicinal and Aromatic Plants from past to present

Considering the developments in the production and use of medicinal and aromatic plants in the 20th century, innovations, social and political changes about which technology have brought at the beginning of the century have caused a rapid decrease in the use of plants as medicines. The synthesis of sulfa drugs in the 1930s and of the organic chemicals in the 1940s encouraged the production of synthetic drugs in addition to medicinal plants. Economic and social changes following the World War and new definitions about plants and treatments have led to a decrease in the use of plants and their extracts until the end of the 1970s in the modernized western countries through industrial advances as a result of the

production of synthetic chemical drugs (9). While more than 40% of the drugs (mostly those which are not refined) listed in the early 20th century are of herbal origin, this has fallen to below 5% by the mid-1970s (10). In the 1980s and 1990s, having consumers more information about the health, increased interest in herbal medicines, especially in developed countries, and the tendency towards organic and natural foods had brought medicinal and aromatic plants up. This has pushed the laws and regulations related to herbal medicines in developed countries to rehandle seriously (11). Concerns about the trade globalization of and conservation of genetic diversity in the late 1990s and early 2000s affected the cultivation of medicinal plants. The quality standards of plant materials have increased with the processing of the product and the buyers' demands for clean, continuous, and certified products. Researches on medicinal and aromatic plants in the 1980s and 1990s pioneered the developments in the production of plants, the extraction of bioactive components and the verification of medical applications (10). In the same years, many new medicinal plants were cultivated, produced, and put on the market. They formulated products containing extracts of a large number of herbs, such as *Aloe barbadensis*, *Celastrus paniculatus*, *Cyperus scariosus*, *Ginkgo biloba*, *Myrtus caryophyllus*, and *Withania somnifera*, to revitalize and protect the skin in cosmetics (12). In parallel with the fact that income growth in Asia raises the people's standard of living, the demand for medicinal and aromatic plants will increase as a result of the aging, weight gain, and increase in the population with other medical problems frequently occurring in very rich societies (13). This increase in demands will likely pose a permanent threat to natural species in some regions. Due to the demand for natural plant material or the lack of cultivated plant material, the price differences between natural and cultivated plants encourage unsustainable excessive collection practices in some regions, especially those that suffer from resource deficits to protect the vegetative material and in economically underdeveloped regions (14). It is expected that continued habitat loss in the future due to the deforestation and development will continue to threaten many medicinal and aromatic plants in both developing and industrialized countries (15). The interest in and demand for organically produced plants and drugs are increasing day by day. There has still been a trend towards organic products that match the demand for organic foods in the medicinal and aromatic plant markets. This reveals that the current basis of consumers of medicinal and aromatic herbal products is the same as those who purchase organic foods (16). Medicinal and aromatic plant combinations and sales of herbal beverages have increased their market gains in the past five years by offering the vitality and strength of youth, and the hope, simplicity, and sustainability of youth that are expected to remain a key market concept in the sale of medicinal and aromatic products in the near future. Sales

of non-food organic products, including medicinal and aromatic plants or plant extracts, had increased by 1/3 in 2005 (17).

Publications of nutrition report that sales of dietary supplements containing many medicinal plants reached to $ 21.3 billion in 2005 with an increase of 4.5%. The use of aromatic plants and plant extracts has become widespread in the flower arrangements and perfumery industry. The market in candles and home fragrances containing aromatic plants and/or plant extracts that contribute to aromatherapy and scented candles has reached to an estimated $ 8.4 billion in 2004 by a growth of 14.1% as from 2003. Global market estimates for medicines derived from plants are $ 18 billion in 2005. In view of the fact that the market demands will exceed 50% in the USA and Canada, this value is expected to reach 26 billion dollars in 2011 (18). In recent years, a great increase in the use of medicinal and aromatic plants and products derived from them has been striking in Turkey. In order to meet the ever-growing demand and produce a higher quality standard product in the future years, it is expected that the production of medicinal and aromatic plants, the plant extracts derived from them and the branches of industry processing these products will expand and grow.

1.3. Distribution of Medicinal and Aromatic Plants in Turkey

Turkey is one of the leading countries that trade in the medicinal and aromatic plants in terms of geographical features, climate diversity, plant variations, agricultural capacity, and wide agricultural areas. The importance of Turkey is due to the presence of plants in the eight natural areas of our country that constitute the input of the industries such as herbal medicine, plant chemicals, food additives, cosmetics and perfumery in the developed countries and that provide the raw materials for herbal products. These plants are mostly wild-collected and put on the market. Medicinal and aromatic plants are collected mainly from the Aegean, Marmara, and Mediterranean regions (18). The countries that import and export medicinal and aromatic plants in the world include the USA, England, Germany, France, Netherlands, China and India. Turkey ranks 18th among 110 countries that export medicinal plants while it ranks 5th in the export and 8th in the import among the East and the southeast European countries (19). A study on the medical and aromatic plants, which are traded in Turkey, showed that the number of plant species including sub-species is 347, of which 139 are exported. Some of the important medicinal, pharmaceutical and spice plants exported by Turkey are thyme, bay leaf, cumin, anise, fennel seeds, juniper bark, mahaleb, fenugreek, rosemary, licorice, mint, sumac, sage and lime flower (20). In order to increase the production amounts of medicinal and aromatic plants and to obtain products with high-quality standards, the product should be done upon cultivation. Although

wild-collection of some species is very economical, it is very difficult to obtain quality and standard products from wild-collected plants. In this way, it is very difficult to make a sustainable collection without damage to nature. Unnecessary wild-collection of medicinal and aromatic plants in an unconscious manner may also lead to decreases in plant populations (19). Incentivizing the producer with various supports and establishing facilities that will provide post-harvest packaging, packaging, and storage in accordance with ordinary standards will be able to increase production. Export may also be boosted by taking medicinal and aromatic plants within the scope of incentive. In order to adequately assess the sustainable production and market potential of medicinal and aromatic plants, these products should be in the requested quantity and quality (21).

1.4. Use of Medicinal Plants in Phytotherapy

The use of medicinal plants before chemical drugs in the treatment of diseases is an old order that took place with the transition to humankind's settled life. Herbal medicines constitute an important part of the traditions of the rural populations in developing countries.

In addition, the active ingredients of many synthetically produced drugs are structural analogs of chemicals that are for the first time isolated from plants. Demand for plants from which the drug is obtained increases at a high level in both developed and developing countries since they are moderate-cost, have low side effects compared to synthetic medicines and very rare toxic effects and are organically produced (22). Medicinal plants are the natural source of compositions that may utilize to cure many diseases today (23). Many herbs contain a wide variety of chemicals and active substances that have important effects on humans. Chemicals such as flavonoids, alkaloids, terpenoids, tannins, berberine and quinine, all of which are synthesized by plants, are widely used to improve health and treat most diseases. Due to the increase of microorganisms with multiple antibiotic resistance in recent years, the treatment of the infection caused by these microbes has become increasingly complicated. Thus, it is recommended to use medicinal plants as an alternative to medicines, and some traditional herbs are also used as antimicrobials. Some studies indicate that the therapeutic properties of plants are caused by a single active ingredient and the interplay of a large number of compositions, and that herbal compositions provide a more effective healing process by overcoming the resistance of microorganisms that are difficult to kill with a single synthetic drug (24).

This pushes researchers to investigate the inhibitory compositions of the active ingredients obtained from plant extracts. A study by American scientists in Saudi Arabia revealed that black tea significantly reduced

the risk of heart disease. The research results showed that an antioxidant substance called flavonoid, which is copious amounts in black and green tea, heals the heart and vascular diseases. They reported that the antioxidant substance present in black tea significantly prevents the risk of heart disease although some of the subjects participating in the research of American scientists have a habit of smoking and an unhealthy diet. They also reported that 20% of adults aged 30 to 70 participating in the research conducted in Saudi Arabia, where drinking tea is a social lifestyle, consume more than 6 cups of tea a day. Experts stated that the flavonoid substance present in tea also prevents vessel stiffness (arteriosclerosis) and reduces bad cholesterol (25). Studies showed that antioxidant-containing compounds would be beneficial to apply locally in order to heal wounds and protect tissues from damage to destruction reactions. While some plants are usedin the treatment of newly formed wounds, others are used in the treatment of chronic, prolonged wounds (26).

While the primary and secondary metabolites, which are naturally produced by plants, are used, directly and indirectly, plants convert the water, minerals and various substances up which they take from the soil into compositions able to be absorbed by the human body in their own metabolism. Carbohydrates, proteins, fats, vitamins, and minerals from essential nutrients are an example to these. These are the active ingredients commonly used in plant metabolism. On the other hand, essential oils, tannins, alkaloids and bitter substances are an example to these (27). Side effects of herbs and drug interactions that may occur when used with drugs have not yet been known. While plants and herbal products are used in the treatment and in the prevention of the occurrence of any disease, attention should be paid that when used with medicines, potential drug interactions and side effects may occur. It has been reported that the active substances in spices consumed daily with antibiotics may interact with each other and cause undesirable side effects and decreased effectiveness.

The use of herbal medicines in pregnant women and breastfeeding mothers can be inconvenient. Caution should also be exercised in the use of herbal medicines in infants and children. Because children's physiology is quite different from adults' body physiology, their metabolic enzyme systems are not as developed as those of adults. In addition, it is possible to reach toxic doses easily since it is difficult to adjust the dose according to body weights (28).

1.5. Classification of Medicinal Plants

1.5.1. Alphabetical Classification: Medicinal plants are classified according to their names in Latin or any language, and this classification is often used in the encyclopedia and introductory books.

1.5.2. Morphological Classification: It is a form of classification based on the used parts of medicinal plants (leaves, flowers, fruits, seeds, etc.), which is widely used in the trade of medicinal plants. It is also an important classification in terms of cultivation. According to the morphological classification;

Herba (herb): plants used in the classification of aboveground parts. Chicory, sage, milk thistle.

Folia: (leaf): plants whose leaves are used. Peppermint, sage, melissa, balm.

Flores (flower): plants whose flowers are used. Marshmallow, chamomile, lavender.

Fructus (fruit): Rosehip, cumin, anise, coriander

Semen (seed): linum, fenugreek

Radix (root): Licorice, centranthus, couch-grass

Rhizome (rhizome): Licorice, couch-grass

Tuber (Tuber): Sahlep

Bulb (onion): Garlic

1.5. 3. Botanical (taxonomic) Classification: It is a classification based on the order, family, genus, and species of the plants and is an important form of classification in terms of the recognition of plants. This classification is used in pharmaceutical botany. Compositae, Alliaceae, Amaryllidaceae, Papaveraceae, Solanaceae, Umbelliferae, Labiatae and Iridaceae, Liliaceae.

1.5.4. Chemical Classification: It is the classification method based on the structure of the active substances included in the plants, which is mostly used in pharmacognosy. A. Essential oil-containing plants- Anise, parsley, mint

B. Bitter substance-containing plants- Vermouth, gentian

C. Glycoside-containing plants- Digitalis, Sicilla

D. Saponin-containing plants- Chalk plant, Saponaria, Hedera helix

E. Alkaloid-containing plants- Datura, atropa, poppy, Nicotiana

F. Flavonoid-containing plants- Silybum, Verbascum

G. Tannin- containing plants- Hamamelis, Quercus

1.5. 5. Pharmacological classification: It is the classification method of the substances included in the plants according to their mechanism of action. Accordingly;

1. Nervina - Effective on nervous system - morphine, nicotine, egotamine 2. Effective on blood circulation - digitalin 3. Diuretica-diuretics - coffein, theobromin 4. Effective on digestion function (laxatives)

1.5.6. Pharmachemical classification: In this classification that is a combination of two classification forms, drugs are divided into the main group according to their pharmacological effects and into the subgroups according to their chemical effects.

1.5.7. Classification According to Their Consumption and Use:

1. Soft drinks, herbal teas and stimulating plants (tea, coffee, tobacco)

2. Spice plants (pepper, mustard, thyme)

3. Pharmaceutical plants (digitalis, Atropa)

4. Perfume plants (Lavender, rose)

5. Gum and mucilage plants (Acacia, Astragalus, Plantago)

6. Resin plants (Sığala tree, Ferula)

7. Tannin plants (Sumac, oak)

8. Dye plants (Rubia tinctorum, Bixa, Alkana tinctorium)

9. Insecticide plants (Phyretrum, anabasis, neem tree)

10. Wax plants (jojoba, myrica)

1.6. Juniper berries (*Juniperus communis*)

1.6.1. Botanical characteristics: The plant is coniferous and belongs to the family Cupressaceae. There are many species of juniper known by the genus Juniperus. Its seedling grows very slowly, takes years to reach a human height, and lasts tens of years to become a tree. Pointed, stiff and blue color needles can even withstand the most severe drought without damage. The needles of the juniper tree owe their stiffness not only to thick outer cells but also to the rich silicic acid they contain. When you burn such a needle, a white skeleton made up of silicic acid remains, which bears all the detail of the needle in its initial form.

The berries of this coniferous tree, which can remain evergreen, are actually not real fruit, but fleshy fruit leaves. These are called pseudo-fruit, in fact, they are cones completely covered with pericarp. Thus, juniper tree is included in the group of trees with cones, such as black pine, calabrian pine, and other pine trees. While young needles and shoots of juniper trees are collected from April to June, the fruits are collected by shaking their branches from September to November in the fall. The collected harvest is cleaned and the underripe product is winnowed out. It should not be

forgotten that there are many varieties of juniper, which are partially poisonous. Dwarf juniper (*Juniperus nana*), whose berries are extremely curative, is distributed in mountainous areas over 3.500 m. Juniper berry is considered an ancient herbal therapy for the digestive system. It supports metabolism and removes uric acid from the body (29). It helps digest dock (*Rumex*) and like foods that lead to fart. Berries and leaves of juniper are used for wound healing as a diuretic, stimulant and antiseptic. J. excelsa widespread in the Anatolian mountains was used by locals against tuberculosis and hepatitis (30). Juniper berries had also been considered a traditional remedy for diabetes in the past. The extract obtained by decoction from *Juniperus communis* was found to decrease the glycemic level in normoglycemic rats at a dose of 250mg / kg. With the effect of the mountain-wind, its branches look as if they are leaning on the ground. Juniper (*Juniperus oxycedrus*) with red fruit is found in Mediterranean countries. The chestnut berries of this juniper are likewise used as a medicinal herb. Juniper we used medically should not be confused with black juniper (*Juniperus sabina*), which has the same growth pattern but foul-smelling and scaly leaves. The fruits and leaves of this juniper species are poisonous. Similarly, thuja or tree of life (*Thuja occidentalis*) with fleshy scaly leaves resembling a multipartite fern form is also poisonous. There are woody brown cones on its branches. The healing aspect of juniper berries had been known in ancient times as juniper berries, antiseptic and water-attracting drugs. New researches reveal that fruits contain essential oils consisting of turpentine and juniperin, tannin, resin, oil, pentosan, glucose, antic acid (acid formic), acid acetic, calcium, potassium and manganese as the main active ingredients.Fresh needles of juniper tree are rich in vitamin C. *Juniper* berries are invigorative, warm the blood of the human, relaxes the internal cramps, clear the stomach, intestines, lungs and blood, are diuretics, removes excess water, are disinfector, strengthens the stomach and stimulates metabolism (31). When juniper berry is taken orally, essential oils are degraded by the kidney. Thus, the kidney wall is stimulated and urine flow increases.

1.6.2. Use of juniper berries: When the juice obtained from the crushed fruit is consumed as tea, it helps to strengthen the stomach and intestines, increase body resistance, reinforce the metabolism, remove uric acid and salt from the body in rheumatism and gout disease and urinate plentifully in the hydropysis (overhydration), edema, swelling and weakening cures. Juniper essence can be used in rheumatism, eczema, herpes, and skin rash. When taken overdose, juniper berries can irritate the kidneys. Therefore, the recommended allowance should be taken (30). **1.7.Chinese star anise (*Illicium verum*)** Although it is indigenous to southern China, it is cultivated in Japan, East Indian islands, China and

Vietnam. It is used internally as an antiflatulent, gastric and galactagogue substance in a decoction form (0.5%). While it is used in indigestion, bloating, intestinal spasm, dysentery, facial paralysis, partial paralysis, and rheumatoid arthritis in Indian medicine, it is used in nausea, abdominal pain, and insomnia, and externally, in skin inflammations and rheumatic pain in Chinese medicine (32).

1.7.1. Botanical characteristics: They are trees with a straight round stem and green, hairless branches that can reach 8-15 meters in length. Its bark is white or bright gray. Its leaves are 3-6 bunches in clusters in nodes and petiole is 0.8-2 cm. The fruit is clustered in a star shape and in boat form. The seeds are bright brown or reddish and contain high levels of oil. Fruits are collected and dried before ripening. Flowering occurs in March-May and August-October. This species is cultivated in various states of China and Vietnam to be used in perfumery, medicine, and food industry (as a spice) (33).

1.7.2. Use of Chinese star anise: In terms of chemical composition, star anise contains containing oil, lignan, sesquiterpene, phenylpropanoid and flavonoid compounds. The main compounds of containing oil from its fruits are trans-anethole, estragole, d-limonene, l-limonene, d-fenkon, d-pinene, dl-limonene and anisaldehyde. Most of the sesquiterpene compounds it contains are seco-pyrazine sesquiterpene derivatives. The main flavonoids present in the drug are chemferol, routinozide, quercetin, isocercitrin, isoramnetin 3-O-rutinozide and tamariksetin 3-O-neohesperidoside. In addition to these, other compounds isolated from drog are fatty acids (hexadecanoic, heptadecanoic, octadecanoic, linoleic and oleic acid), farnesol, safrol, foenukulin and shikimic acid. Effects and Usage: Essential oil and flavonoids it contains are effective on mucous membranes in respiratory system diseases and on smooth muscles in gastrointestinal diseases. It is also used in diminishing appetite and cough (34,35). Antimicrobial Effect: A study investigating the in vitro antibacterial effect of methanolic extract and decoction of Ilicium verum fruits showed that it was effective against anaerobic and aerobic peridontal bacteria (Porphyromonas gingivalis, Prevotella spp., Fusobacterium nucleatum, capnocytophaga gingivalis, veilonella parvula, eikenella corrodens, peptostreptococcus micros and actinomyces adontolyticus). E. corrodens of these bacteria are only sensitive to both methanolic extract and decoction (with MIC values of 256 and 512 mg / mL, respectively) (36). The supercritical CO2 and ethanolic extract of the *I. verum* showed a significant antibacterial effect against a total of 67 resistant bacterial strains, including 27 acinetobacter baumannii, 20 pseudomonas aeruginosa and 20 methicillin-resistant staphylococcus aeruginosa. The diethyl-ether fraction obtained from ethanolic and supercritical CO2 extracts showed a

strong antibacterial effect with MIC values of 0.15, 0.17 and 0.11 mg / mL (37). In the glyoxylate cycle, isocitrate is broken down into succinate and glyoxylate via the enzyme isocitrate lyase. This metabolic pathway occurs in the majority of pathogens and is also of the utmost importance for Mycobacterium tuberculosis bacteria, which is the cause of tuberculosis disease. An in vitro study found that extract of I. verum inhibited the isocitrate lyase enzyme with an IC50 value of 47.7 +/- 16.9 µg / mL, thus disrupting the glyoxylate cycle (38). Antifungal effect: In a study conducted to use natural products to control plant diseases, the essential oil of star anise fruits was examined due to its antifungal effect against pathogenic fungi in plants. The essential oil in the fruit was obtained by hydrodistillation and the chemical components it includes were analyzed by GC and GC-MS. Among the compounds obtained, the main compound with an antifungal effect was determined to be trans-anethole. Inhibitory effect of both the essential oil and trans-anethole against the fungi Alternaria solani, bipolaris maydis, botryodiplodia theobromae, Fusarium graminearum, fusarium oxysporum f. Sp. cucumerium, pythium aphanidermatum, rhizoctonia cerealis, rhizoctonia solani was tested using carbendazim standards. IC50 values of essential oil were found to be 0.09, 0.07, 0.11, 0.08, 0.16, 0.14, 0.25, 0.22, 0.09, 0.10, 0.08 mg / mL, respectively (39, 40).

Other Studies: The inhibitory effect of 70% ethanolic extract of *Illicium verum* fruits and butanol, ethyl acetate, chloroform fractions and anetol obtained from this extract on the acetylcholinesterase and butyrylcholinesterase was investigated colorimetrically in another study. IC50 values for acetylcholine esterase werre 58.67 +/- 0.16, 44.94 +/- 2.49, 83.75 +/- 0.11, 103.03 +/- 1.76,36.00 +/- 0.44 µg / mL, respectively, while I50 values for butyrylcholinesterase were 91.84 +/- 1.29, 80.67 +/- 0.33, 136.03 +/- 2.19, 171.44 +/- 0.55, 70.65 +/- 0.96 µg / mL, respectively. The effect of chimic acid obtained from *Ilicium verum* on proliferation of HepG2 Hepatocellular Carcinoma Cell Line and nuclear factor-kB (NF-KB) p65 was examined. The morphology of liver tumor cells varied under the microscope depending on different concentrations of shikimic acid and apoptotic cells were detected in cells exposed to different concentrations of shikimic acid for 48 hours. As a result, shikimic acid inhibited the proliferation of liver carcinoma cells and downregulated the NF-KB (p65) protein level (41).

1.7. Bottle-Brust (Equisetum arvense)

1.7.1. Botanical characteristics

It is spread over the temperate regions of the northern hemisphere. It grows naturally throughout America, Europe and North Africa and a part of the Asian continent. It grows naturally in the south of Turkey and Iran,

in the Himalayas and in the middle and north of China and Japan in the Asian continent. It is spread over streamsides and uncultivated land in the North and Eastern Anatolia in Turkey (42). It is a perennial, herbaceous and flowerless plant that grows up to 100 cm high, reproduces by spores and bears rhizome. Its leaves are quite small and scaly. Its stem is cylindrical, branched or unbranched, green or brown-green, hard and hollow. It is spread over streamsides and uncultivated lands up to 1700 m above sea level (43, 44).

1.7.2. Use of Bottle-Brust (Equisetum arvense): It was used by people in tuberculosis, kidney and bladder inflammations and as hemostatic in nose, lung and gastric bleeding, as well as against hand and nail breaks and hair loss and in the treatment of difficult-to-heal wounds and ulcers. It has been reported to be used in the supportive treatment of chronic leg swelling, difficult-to-heal sprain and fractures, dermatological disorders, rheumatic joint inflammation, jaundice and sore throat. The plant is used as a pain reliever, blood pressure reduction, blood cleanser, diuretic, and edema remover. Teas prepared from this herb in Iran are consumed against diabetes and kidney diseases (45).

Chemical Composition: Aboveground parts of *Equisetum arvense* should contain total flavonoids calculated on at least 0.3% isoquercetin. There are two chemotypes according to flavonoids. Asian and North American varieties contain high amounts of quercetin-3-O-beta-glucopyranoside and its manonyl esters, as well as apigenin of flavor derivatives, 5-O-glucosides of luteolin and malonyl esters. The composition of chemotype in Europe mainly contains quercetin-3-O-soforoside, genkwanin and chemferol derivatives, as well as protogenkwanin 4-O-beta-glucopyranoside, genkwanin-5-O-glucoside, chemferol 3,7-di-O- glucoside, chemferol-3-O-7-O-glucoside and luteolin glycosides and onitine and onitin-9-O-glucoside of phenolic petrosins (46). There are 1% of caffeic acid esters in the composition of *E. arvense*. Although di-E-cafeol-meso-tartaric acid of these compounds is found in small amounts (0.008%) in *E. arvense*, it is not found in other *Equisetum* species. So, it is a marker compound in both chemotypes. *E. arvense* also contains mono-Ocafeol-meso-tartrate, methyl esters of caffeic acids and 5-cafeoylchimic acid. Polyenic acids, rare dicarboxylic acids and other organic acids (aconitic acid, arabinoic acid, citric, fumaric gallic, gluconic, glyceric, malic, malonic, protocathic, threonic, p-coumaric, 4-hydroxybenzoic, vanicic acid and kinic acid) have been reported to be found. It has also been reported that Equisetum arvense contains traces of alkaloids (nicotine, spermidine bases, palustrine and palustrinine). The plant also contains carotenoids and rhodoxantine. The plant has also been reported to contain potassium (1.8%), calcium (1.3%), aluminum, magnesium, and manganese. Hexahydropharynyl acetone

(18.34%), cis-geranyl acetone (13.74%), thymol (12.09%) and trans-phytol (10.06%) were detected as major compounds in the chemical composition of essential oil obtained from the stem of *Equisetum arvense* (47). Antimicrobial Effect: It was determined that the extract prepared with 90-95% ethanolic from the aboveground parts of Equisetum arvense exhibited weak activity against Bacillus subtilis and Streptococcus faecalis strains at 500 μg / disc concentration. The essential oil obtained from the fruitless stem of the plant was evaluated using the disk diffusion method in terms of the antimicrobial activity against Staphylococcus aureus, Escherichia coli, Klebsialla pneumoniae, Pseudomonas aeruginosa, Salmonella enteritidis, Aspergillus niger and Candida albicans strains. The solution of essential oil diluted in 1:10 was found to be active against all the strains tested and showed a broad-spectrum antimicrobial effect. It was observed that the dry extract prepared from the fresh above-ground part of the plant was active against the Aspergillus flavus strain. Extract prepared with 50% ethanol from the stem of Equisetum arvense was examined by using macrodilution method for antimicrobial effect against Escherichia coli, staphylococcus aureus and bacillus cereus strains. The strongest effect was found to be against S. aureus strain, with a MIC (minimum inhibitory concentration) values of 11.14 mg / mL and a MBC (minimum bactericidal concentration) values of 22.28 mg / mL (48). The weakest effect was detected against B. cereus strain with a MIC value of 89.10 mg / mL. Antimicrobial effect of the aqueous ethanolic extract of the plant was investigated against Pseudomonas aeruginosa, Escherichia coli, Salmonella enteritidis, Klebsiella pneumoniae, Staphylococcus aureus, Candida albicans and Aspregillus niger strains. When inhibition zones were measured, it was found to be effective against all strains tested (inhibition zones: 11.3-14.1 mm) (49).

Other Studies: The aqueous extract (30 μL) obtained from the dried aboveground parts of *Equisetum arvense* exhibited a radical scavenging effect on cultured microsomes. The aqueous extract prepared from the dried above-ground part of *Equisetum ravens* was examined for its antioxidant capacities on various radicals. The aqueous extract was found to be a high activity of superoxide anion radical scavenging (>80%) (50). The antioxidant activities of the extract prepared from the above-ground parts with phosphate buffer (pH = 7) were investigated using four different methods. The radical scavenging effect of the extract was found to be 51.4 +/- 3.3% in DPPH (2,2-diphenyl-1-picrylhydrazyl) method, 73.5% in ESR (electron spin resonance) method and 9.13 +/- 0.98% in NO (Nitric Oxide) radical inhibition assay. Its total reductive effect was detected to 2.85 +/- 0.45 FRAP unit in the FRAP test. 70% ethanolic extract among extracts prepared from the plant using solvents with different polarities such as

water, ethanol, 70% ethanol, methanol, 70% methanol, and chloroform was found to be effective in terms of antioxidant activity, with an IC50 value of 168.1 µg / mL. Superoxide scavenging effects of onitine and luteolin, isolated from the methanolic extract of the plant were IC50 = 35.3 and 5.9 µM, respectively while free radical scavenging effects of 1, diphenyl-2-picrylhydrazyl and 2.2-di (4-ter-octyl-phenyl) -1-picrylhydrazyl were IC50 = 35.8 +/- and 22.7 +/- 2.8 µM, respectively (51).

1.8.Uvez (*Cormus domestica*)

1.8.1. Botanical characteristics: *Cormus domestica*, which has fruits resembling a miniature apple or pear, grows naturally or is cultivated in a small number of regions. Although it has been recorded that the plant has been widely cultivated since the time of the ancient Roman empire, it is not known exactly what the natural distribution area of this species is. It is spread in Western, Central and southeastern Europe, especially in the Balkan peninsula, and rarely in some parts of North Africa and West Asia. This plant also has a record as a species of the forest ecosystem of Central and Southern Europe. However, the regions in which it is widespread are not exactly known. In Turkey, it grows wild in the Western Part of Northern Anatolia (Kastamonu, Zonguldak), Marmara and Thrace region (Sakarya, Bolu), Central Anatolia (Ankara), Central Black Sea Region (Sinop, Tokat), and South Anatolia (Hatay) (52).

1.8.2.Traditional Use: Cormus domestica has been known as a valuable tree since the Roman empire. Its leaves are used against diabetes in the form of 5% infusions among the people. Its fruits are known to have important therapeutic effects in intestinal diseases, anemia, and extreme weakness in folk medicine. It is registered that its fruits are used as a diuretic, anti-inflammatory, anti-diarrhea, vasorelaxant and vitamin source. Its fruits are also reported to be effective in situations such as dysentery, strengthening memory, and improving thinking. It has been noted that its fruits are traditionally used in the treatment of long-term diabetes-related disorders. It is emphasized that over-ripening fruits are used only in Traditional Medicine. It is also stated that boiling its fruits in water and drinking are good for cough. It is stated that jam and marmalade prepared from fruits are also an internally antitussive around İstanbul. It has been reported that fruit decoction is used for gallbladder diseases in Sakarya and that after the fruits are kept in sugar and saltwater around Balikesir, they are internally used in diabetes. The fruit peel is brown and the fleshy part is yellowish-brown, and it is recommended to be consumed when it is ripen (53, 54).

Chemical Composition: Its fruits contain vitamins A, B2, C, and other minerals. The sexangularetin glycoside and the isorhamnetin conjugates,

both of which have the flavonoid structure, were detected in a wide variety of parts of C domestica, such as leaves, fruits, and flowers. Its fruits are also rich in procyanidins, cinnamic acids, and quercetin. It has been reported that the plant is rich in phenolic compounds. These studies were conducted in various ripening periods of the plant for qualitative and quantitative purposes and all fruits were found to be rich in benzoic acid. In addition, cinnamoylquinic acid from phenylpropanoids, quercetin glycosides from flavonoids, hydroxycinnamic acid and its derivatives, cercetole and chemferol derivatives have been identified. In addition to these, a cercetole dimer was also found. In another study, caffeoylquinic acid and chlorogenic acid were isolated from its fruits (55, 56).

Other studies: The aqueous extracts of Cornos domestica fruits exhibited higher antioxidant activity (68.29%) than synthetic antioxidants (BHA, BHT and propyl gallate). Hydrogen peroxide scavenging capacity (12.89% and 3.62%) of Cormus domestica was found to be quite low. Cormus domestica showed a lower effect in experiments performed to determine the antioxidant capacity equivalent to trolox. The antioxidant capacity of the methanolic extracts of the fruits of Cormus domestica collected during 5 different ripening periods were also investigated. DPPH radical scavenging effect was found to be EC50 = 0.341-39.5 mg dry extract / mg. The butanol fraction of the fleshy portion and unripe fruit showed the best effect, followed by ether and ethyl acetate fractions. Water extract exhibited the weakest effect. The best antioxidant capacity was detected in all methanolic extracts and fleshy parts during different ripening periods (EC50=2.55+/-0.11; 10.6+/-0.34; 1.89+/-0.06; 20.0+/-0.12; 1.45+/-0.02). It has been determined that when the fruits were over-ripening, their antioxidant capacity is lower (57, 58).

2. MATERIAL and METHOD

2.1.Plant Material: Juniper berries(Juniperus communis), Bottle brust (Equisetum arvense) plant, star anise (Illicium verum) and üvez (Cormus domestica) leaves were used in this study. Plant materials were obtained from a herbalist in Mısır Çarşısı as ready-packed (Harem Palace). A dried sample (10 g) was chopped into small pieces using a blender. Extraction was followed by filtration through Whatman No 1 filter paper and evaporation of the filtrate to dryness at 30^{O}C in the Büchi V-700 rotary vacuum evaporator. The dry residue was mixed with 150 ml of metanol in a screwcapped Erlenmeyer flask and placed on a Nüve SL 350 shaker (Nüve, Ankara, Turkey) to obtain an metanol extract. Extraction was repeared until the solvent became colourless; 200 ml of metanol was used in total. 59**).**

2.2.Antimicrobial Activity: Disk diffusion susceptibility test was applied to determine the antimicrobial activity of plant extracts. Antibiotic disks were impregnated with 50 µL from these extracts under aseptic conditions using a micropipette with a diameter of 6 mm (Schleicher & Schül, Nr 2668, Germany). In our study, Mueller Hinton Agar (OXOID) was used to determine the antimicrobial activity of bacteria and yeast as medium. Plaques in which bacteria were inoculated were incubated for 24 hours at 35°C and plates inoculated with yeasts were incubated for 3 days at 30°C. When the time was over, the diameters of the inhibition zones formed around the disks were measured. The antimicrobial activity experiments against all the test microorganisms were repeated three times (60,61).

3. RESULTS

Test organisms were used to test the antimicrobial activity. Namely, *Staphylococcus aureus* (ATCC 25923), *Listeria monocytogenes* (ATCC 15313) ve *Saccharomyces cerevisiae* (ATCC 9763) are gram positive, *Escherichia coli* (ATCC 25922), *Salmonella typhimurium* (ATCC 14028) are gram negative.

Table 1. Result of antimicrobial activity

Microorganisms	Juniper berries (*Juniperus communis*) fruit MeOH Exract	Bottle brust (*Equisetum arvense*) plants MeOH Exract	Star anise (*İllicium verum)* fruit MeOH Exract	Uvez (*Cormus domestica*) leaves MeOH Exract
Staphylococcus aureus (ATCC 25923) (Gram-positive)	18 mm	9 mm	15 mm	12 mm
Escherichia coli (ATCC 25922) (Gram-negative)	8 mm	-	-	-
Listeria monocytogenes (ATCC 15313) (Gram-positive)	18 mm	-	19 mm	12 mm
Salmonella typhimurium (ATCC 14028) (Gram-negative)	-	10mm	11 mm	-
Saccharomyces cerevisiae (ATCC 9763) (Gram-negative)	-	-	18 mm	-
Ofloxocin (standard)	10 mm	10 mm	8 mm	10 mm

Inhibition zones of Juniper berries (*Juniperus communis*) methanol extract against *Staphylococcus aureus*, *Escherichia coli* and *Listeria monocytogenes* were measured and found to be 18 mm, 8 mm, and 18 mm, respectively, as displayed in Table 1. Inhibition zones of Bottle brust (*Equisetum arvense*) methanol extract against *Staphylococcus aureus* and *Salmonella typhimurium* were measured and found to be 9 mm and 10 mm, respectively, as seen in Table 1. Inhibition zones of star anise (*İllicium verum*) methanol extract against *Staphylococcus aureus*, *Listeria monocytogenes, Salmonella typhimurium,* and *Saccharomyces cerevisiae* were measured and found to be 15 mm, 19 mm, 11 mm, 18 mm and 18 mm, respectively, as shown in Table 1. Inhibition zones of Uvez leaves (*Cormus domestica*) methanol extract against *Staphylococcus aureus* and *Salmonella typhimurium* were measured and found to be 12 mm, and 12 mm, respectively, as shown in Table 1.

The highest and lowest antimicrobial activity were observed against *Listeria monocytogenes* (Star anise (*İllicium verum*) and *Escherichia coli* (Juniper berries(*Juniperus communis*) MeOH Extract), with 19 mm and 8 mm zone of inhibition, respectively. Methanol extracts were found to be more effective against gram positive bacteria. This may be since gram-negative bacteria has a multi-layered structure which consists of a lipopolysaccharide layer on the outhermost wall of the cell. This structure ensures gram-negative bacteria to be more resistant against microorganisms in the range of 8-19 mm in the antimicrobial activity of the plants. No antimicrobial activity was detected against *Salmonella typhimurium* and *Saccharomyces cerevisiae* (Juniper berries (*Juniperus communis*) MeOH Extract). No antimicrobial activity was detected against *Escherichia coli, Listeria monocytogenes* and *Saccharomyces cerevisiae* (Bottle Brust (*Equisetum arvense*) MeOH). No antimicrobial activity was detected against *Escherichia coli* (star anise (*İllicium verum)* MeOH). No antimicrobial activity was detected against *Escherichia coli, Salmonella typhimurium* and *Saccharomyces cerevisiae.* (Uvez leaves (*Cormus domestica*) MeOH).

4. DISCUSSION

Continuous exposure of people to substances with toxic activity, increase in diseases such as nutrition-related cardiovascular diseases and cancer, and failure to reach to sufficient and quality food are today increasing the significance of quality nutrition. Striving to produce foods with high nutritional value and long shelf life has also increased the importance of the quality of the produced foods and the ingredients used. Due to the devastating effects of synthetic antimicrobials on the body, the search for natural preservatives that can replace synthetic substances continues swiftly. Plant extracts with high antimicrobial activity should be determined

through these types of studies and continuity of the studies should be ensured for industrial application by examining their protective effects on food systems (62). The antimicrobial effects of the aqueous-ethanolic extract of juneper berries (*Equisetum arvense*) against *Escherichia coli, Salmonella enteritidis* and *Candida albicans* strains were investigated and inhibition zones were found between 11.3 and 14.1 mm (63). Aqueous and ethanolic extracts of *E. arvense* were investigated in terms of antibacterial activity by using the disc diffusion method against *Escherichia coli* strain, which is one of the pathogens of the urinary system. The inhibition zone was found to be 7-14 mm for different concentrations (64). Ethyl acetate extract was found to exhibit antimicrobial activity against *Staphylococcus aureus* by the disc diffusion method (11 mm) (65). The aqueous extract that examines effects on viability, virulence factor, and biofilm formation of *Escherichia coli* strain being the urinary tract pathogen was found to have antimicrobial activity ($p < 0.05$). The antimicrobial activities of various aqueous ethanolic extracts prepared from *E. arvense* leaves using different extraction parameters (temperature, mixing speed, ethanol ratio, extraction time, and solvent amount) were investigated against *C. albicans, Escherichia coli* and *Staphylococcus epidermides* strains by disc diffusion method. None of the 24 different extracts were found to have an inhibitory effect against C. albicans. Their results are consistent with our findings (66).

Methanolic extract of I. verum fruits was found to be an antibacterial effect against *P. gingivalis, F. nucleatum, C. gingivalis, V. parvula, E. corrodens, P. micros* and A. *adontolyticus* (67). Another study showed that the ethanolic extract of I. Verum had a significant antibacterial effect against Acinetobacter baumannii, Pseudomonas aeruginosa and Staphylococcus aeruginosa (68).The highest and lowest antimicrobial activity were observed against Listeria monocytogenes and *Escherichia coli* with 19 mm and 8 mm zone of inhibition, respectively. In general, methabolic extracts exerted moderate inhibitory effects against the tested bacteria. The most reasonable explanation for this is that methanol is active in separating flavonoids and phenolics. Still, the inhibitory effect has a direct relation with extract concentration. So, if the concentration were higher, then bigger zones could likely be observed (69). In addition, various different factors should also be taken into consideration. In fact, the antibacterial of plant extracts are strongly with to their chemical composition. This composition and their relative chemical concentrations may vary in plant extracts with respect to the geographical location of the plant, climatic and growth environments (temperature, soil, fertilizers, etc.), the part of the plant used, the season during which plants were collected and the stage of plant development, as well as processing and storage conditions (69).

Additionaly, culture conditions, e.g. the composition of the test medium, temperature and time of incubation, may also influence the result. In future studies, Juniper berries (*Juniperus communis*),bottle brust (*Equisetum arvense*) plants, star anise (*İllicium verum)* fruit, Uvez (*Cormus domestica*) leaves can be further analysed because of its biochemical composition that is specifically responsible for its antimicrobial activity. In addition, our results show that they are able to use as a food additive to prevent biological or microbial spoilage against deterioration.

In conclusion, consumers have an increased interest in natural antimicrobial agents due to the side effects of artificial preservatives on health. In recent years, research on the use of plants for medical purposes and preserving nutrients have increased, and therefore, the importance of plants' use as natural antimicrobials is increasing day by day. Antimicrobial resistance in bacteria is increasing rapidly. In contrast, bacteria do not develop resistance to plant and plant products that show antimicrobial properties. The reason for this is that synthetically produced medicines are made by isolating any active substance in plants. Bacteria can neutralize medicines by creating resistant breeds against synthetic drugs containing a single structure in time.

5. REFERENCES

1. Faydaoğlu E., Sürücüoğlu M.S. 2011. Geçmişten günümüze tıbbi ve aromatik bitkilerin kullanımı ve ekonomik önemi. Kastamonu Üniv. Journal of Forestry. 11(1), 52-67.
2. Koçyiğit M. 2005. Yalova ilinde etnobotanik araşitırma, Yüksek Lisans Tezi, İstanbul Üniversitesi Sağlık Bilimleri Enstitüsü.
3. John, R.L., Foster, S., Doğ T.L., Kiefer D. 2016. Şifalı Bitkiler Ansiklopedisi. İstanbul:Promat Basım.
4. Alpınar,K.,2010. Halk arasında kullanılan tıbbi bitkilerin derlenmesi. Bitkilerle Tedavi Sempozyumu 5-6 Haziran 2010.Zeytinburnu/İstanbul. Bildiri Kitabı,19-28.
5. Özdemir, Y., Doğan, Aslan, D., Özkan, M. 2014. Türkiye'de Tıbbi ve Aromatik Bitkiler Sektörünün Tüketici Güvenliği Açısından risk değerlendirilmesi. 11. Tıbbi ve Aromatik Bitkiler Sempozyumu, 23-25 Eylül 2014 Yalova, Bildiriler Kitabı,157.
6. Başer, H.C.1998. Tıbbi ve Aromatik Bitkilerin Endüstriyel Kullanımı TAB Bülteni13-14:19-43.
7. Brinckmann, J. 2004. The Medical Plant Supply Chain: Creating Social and Environmental Sustainability. Herbal Gram , 64: 56-60.
8. World Health Organization (WHO), 1998. Guidelines fort he Appropriate Use of Herbal Medicines. WHO, Manila. WHO Regional Publications, Western pasific Series no. 23. http://www.wpro.who.int/publications/pub_9290611243.htm
9. Kumar, S.A. 2009. Plants-based Medicines in India.http:/pib.nic.in/feature/feyr2000/fmay2000/f240520006.htlm.
10. Lange, D., 2006.International trade in medicinal and aromatic plants, Medicinal and Aromatic Plants, 155-170.
11. L'amar-Herbal Products, 2006. Skin care.www.mall. coimbatore.com/bnh/lamar/skincare.htm.
12. Craker, L.E., Gardner, Z., Etter, S.C. 2003.Herbs in American Fields: A Horticultural Perspective of Herb and Medical Plant Production in the United States, 1903-2003. Hortscience 38:977-983.
13. Craker, L.E., Gardner, Z.,2005. Sustaining the Harvest: Challenges in MAP production and Markets. Acta Hort.676:25-30
14. Craker, L.E.,2007. Medical and Aromatic Plants-Future Opportinities Reprinted from:Issues in New Crops and New Uses., J. Janick and A. Whipkey(eds.)ASHS Press. Alexandria, VA.
15. Anonim,2005. Medicinal and Aromatic Plants Working Goup-ECP/GR.
16. Anonim,2007. Tarım ve Köy İşleri Bakanlığı, Ankara

17. Başer, H.C. 1998. Tıbbi ve Aromatik Bitkilerin Endüstriyel Kullanımı. TAB bülteni.13-14:19-43

18. Brickmann,J.,2004. The Medical Plant Supply Chain:Creating Social and Environmental Sustainability. Herbal Gram. 4:56-60

19. Ekim, T., Koyuncu, M., Erik, S., İlarslan, R. 1992.Türkiye'nin tehlike altndaki nadir ve endemik bitki türleri, Türkiye Tabiatını Koruma Derneği Yayın no:18.227s

20. Elson J., 1999. With Aromatherapy gaining acceptance as an aspect of home fashion, sales of scented candles are lighting up supermarkets' cash registers. Supermarket News, Feb.8, 1999,findarticles.com/p/articles/mi_hb4331/is_199902/ai_n12098264

21. Özgüven, M., Sekin, S.,Gürbüz, B., Şekerlioğlu, B., Ayanoğlu,F., Ekren, S. 2005. Tütün, Tıbbi ve Aromatic Bitkiler üretimi ve ticareti. Türkiye Ziraat Mühedisleri VI. Teknik Kongresi. Ankara.

22. Özhatay, N., Koyuncu M.,1998. Türkiye'de doğal bitkilerin ticareti.XII. Bitkisel İlaç Hammaddeleri Toplantısı 20-22 Mayıs 1998. Özet Kitabı, 5.

23. Tarakçıoğlu, G.B., Koç, D. 2005. Organik Tarım Ürünlerinde Dış Pazar Araştırması.251s.

24. Binici, A., 2002. Baharat değerlendirme raporu, Orta Anadolu İhracatçı Birlikleri Genel Sekreterliği, 1-37.

25. Şener, B.,2010. Bitkisel İlaçlar ve Bitkisel İlaç Mevzuatı, Bitkilerle Tedavi Sempozyumu, 5-6 Haziran 2010, Zeytinburnu, İstanbul, 153-171.

26. Kendir, G., Güvenç, A.,2010. Etnobotanik ve Türkiye'de yapılmış etnobotanik çalışmalara genel bir bakış. Hacettepe Üniversitesi, Eczacılık Fak. Der., 8(2), 129-134.

27. Ertem, H.,1987. Boğazköy metinlerine göre Hititler Devri Anadolusu'nun Florası, Türk Tarih Kurumu yayınları VII. Dizi-S65a

28. Shanley, P., Luz, L., 2003. The impacts of forest degradation on Medicinal plant use and implications for health. BioScience. 53(6):573-584.

29. Kırtunç, E. Doğa Eczanesi Şifalı Bitkiler. 2002. 4 Renk Yayınları, Ankara.

30. Saraçoğlu, İ. A'dan Z'ye Şifalı Bitkiler Kitabı.http://www.ibrahimsaracoglu.org.

31. Emre, A. Şifalı Bitkiler ve Vitaminler. http://www.ayşeemre.org

32. Baytop, T. Türkiye'de bitkiler ile tedavi (Geçmişte ve Bugün), İlaveli 2. Baskı, Nobel Tıp Kitapevleri, İstanbul;1999.

33. PDR for Herbal Medicenes, 2nd ed., Thomson Medical Economics, Montvale, NJ(2000).

34. Chouksey,D., Sharma, P., Pawar, RS. 2010. Biological activities and chemical constituents of *Illıcium verum* Hook fruits.(Chinese star anise), Pharm. Sin., 1:1-10.

35. Xia, N., Saunders, R.M.K., Illiciaceae, in: Flora of China.Vol.7, pp.32-38, Beijing/St Louis: Science Press/Missouri Botanical Garden. 2008.

36. Song, W.Y. , Ma, Y.B., Bai, X., Zhang, X.M., Gu, Q. *et al*. 2007. Two new compounds and anti-HIV active constituents from *Illıcium verum,* Planta Med., 73,372-375.

37. Yang, J.F., Yang, C.H., Chang, H.W., et al., 2010. Chemical composition and antibacterial activities of *Illıcium verum* against antibiotic-resistant pathogens. J. Med. Food., 13, 1254-1262.

38. Zhu, K.M., Gu, S.J., Gu, X.W., Luo, CZ. 2014. Influence of shikimic acid on proliferation and expression of nuclear factor-XB in human hepatome HepG2 cells. Zhongguo Shiyan-fangjixue Zazhi.20:126-129.

39. Hitokoto, H., Morozumi, S., Wauke, T., et al., 1980. Inhibitory effects of spices on growth and toxin production of toxigenic fungi. Appl Environ Microbial. 39:818-822

40. Huang, Y., Zhou, L., 2010. Antifungal activity of the essential oil of *Illıcium verum* fruit and its main component trans-anethole, Molecules.15:7558-7569

41. Zhu, K.M., Gu, S.J., Gu, X.W., Luo, CZ. 2014. Influence of shikimic acid on proliferation and expression of nuclear factor-XB in human hepatome HepG2 cells. Zhongguo Shiyan-fangjixue Zazhi.20:126-129.

42. WHO Monographs on Medicinal Plants Commonly Used in the Newly Independent States (NIS), 2010. Geneva

43. Duke, J.A. Handbook of Medicinal Herbs, 2nd ed. CRC press, Boca Raton, FL2002.

44. Soleimani, S., Azarbaijani, F.F., et al. 2007. Effect of *Equisetum arvense* L.in microalbuminuria and creatinine excretion in streptozotozin-induced diabetes in male rats. Int J Pharmacol., 3, 155-159.

45. EP-European pharmacopoeia, European Directorate fort he Quality of Medicines, Strasbourg, 2010.

46. Oh, H., Kim, D.H., Cho, J.H., Kim, Y.C. 2004. Hepatoprotective and free radicl scavenging activities of phenolic petrosins and flavonoids isolated from *Equisetum arvense*. J Ethnopharmacol.95:421-424

47. Holzhueter, G.,Narayanan, K., Gerber, T. 2003. Structure of silica in *Equisetum arvense,* Anal Bioanal Chem.376;512-517

48. Radulovic, N., Stojanovic, G., Palic, R., 2006. Composition and antimicrobial activity of *Equisetum arvense* L. essential oil. Phytother Res. 20; 85-88.

49. Garcia, D., Garcia-Cela, e., Ramos, A.J., et al. 2011. Mould growth and mycotoxin production as effected by *Equisetum arvense* L. extracts. Food Control. 22;1378-1384

50. Myagmar, B.E. Aniya, Y. 2000. Free radical scavenging action of medicnal herbs from Mongolia. Phytomedicina. 7; 221-222

51. Jia, G., Jin, Y.S., Han, W., et al. 2006. Studies for component analysis, antioxidative activity and alfa-glucosidase inhibitory activity from *Equisetum arvense* L. Phytomedicina.49;77-81

52. Labuda, R., et al., 2005. Mycological survey of ripped servive tree fruits with an emphasis on toxicogenetic fungi. Int J Food Microbial. 99;215-223.

53. Tertmentzi, A. Zervou, M., Kokkalou, E. 2009. Isolation and structure elucidation of novel phenolic constituents from sorbus domestica fruits. Food Chem., 116;371-381

54. Tuzlucı, E., Tolon, E.,Turkish folk madical plants, Part III: Şile (İstanbul), Fitoterapia. 71;673-685

55. Olszewska, M. 2008. Separation of quercetin, sexangularetin, kaempferol and isorhamnetin for simultaneous HPLC determination of flavonoid aglyconed in inflorescences, leaves and fruits of three *Sorbus* species. J Pharm Biomed. Anal. 48;629-635

56. Forino, M., Tenore, GC., et al. 2015. Ciminiello, P. (1S,3R,4S,5R)5-O-cafeeoylquinic acid: Isolation, stereo-structure characterization and biological activity. Food Chem. 178, 306-310

57. Egea, I., Romojaro, F., Pretel, M.T. 2010. Six edible wild fruits as potential abntioxidant additives or nutritional supplements. Plant Foods Hum Nutr. 65; 121-129

58. Tertmentzi, A., Alexiou, P.,et al.,2006. Antioxidant activities of various extracts and fractions of Sorbus domestica fruits at different maturity stages. Food Chem. 98;599-608

59. Demir H, Bicim G. 2019. Determination Antioxidant and Phenolic Content of Edible Plants.J Tourism and Gastronomy Studies.Doi: 10.21325/jotags.2019.406

60. Gulluce, M., Sokmen, M., Sahin, F., Sokmen, A., Adıguzel, A., and Ozer, H. 2004. "Biological Activities of the Essential Oil and Methanolic Extract of *Micromeria fruticosa* (L) Druce ssp serpyllifolia (Bieb) pH Davis Plants from the Eastern Anatolia Region of Turkey." *J. Science of Food and Agriculture* 84: 735-41.

61. Johnson, A.G., Zieger, R.J., Lukasewycz, OA., Hawley L.B. 2000. Bakteriyoloji, Mustafa Öztürk, Mikrobiyoloji ve İmmunoloji, 2, İstanbul, Nobel Tıp Kitabevleri.

62. Özdemir, E.D. 2019. Bilberies(*Vaccinium myrtillus* L.) ' in antioksidan, fenolik içerik ve antioksidan aktivitesinin belirlenmesi. Yeditepe Üniversitesi Sağlık bilimleri Enstitüsü, Yüksek Lisans Tezi.

63. Nilovanovic, V., Radulovic, N., Todorovic, Z., Stankovic, M., Stojanovic, G. 2007. Antioxidant, antimicrobial, and genotoxicity screening of hydro-alcoholic extracts of five serbian *Equisetum arvense* species, Plant Foods Hum Nutr.62;113-119.

64. Geetha, R.V., Lakshmi, T., Roy A. 2011. *In vitro* evaluation of antibacterial activity of *Equisetum arvense.* Phytomedicine. 6;639-246

65. Fathi, Azad, F., Lotfipour, F. 2004. Study on the in vitro anti microbil activity of *Achillea millefolium* and *Equisetum arvense,* Pharmocology Sciences.1;37-46

66. Wojnicz, D., Kucharska, A.Z., et al.2012. Medicinal plants extracts affect virulence factors expression and biofilm formation by the uropathogenic E. coli. Urol Res.40; 683-697.

67. Song,W.Y., Ma, Y.B., Bai, X., Zhang, X.M., Gu, Q., et al. 2007. Two new compounds and anti-HIV active constituents from *I. Verum*.Planta Med. 73; 372-375.

68. Sung, Y.Y., Yang, W.K. et al. 2013. *I. Verum* extract suppresses IFN-gama induced ICAM-expression via blockade of JAL/STAT pathway in HaCaT human keratinocytes. J Ethnopharmacol.,149;626-632.

69. Zairi, A.,Nouir, S., et al.,2019.Chemical composition, fatty acids profile and biological properties of T. Capitatus Hoffmanns, ssential oil. Scientific Report. 9;20134