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ORIGINAL ARTICLE

A brief review on water resources and climate change

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ABSTRACT

Human-caused climate change poses a growing threat to water resources that are valuable today and for the future. In addition, climate change is thought to have negative impacts on food, economy, natural resources and sustainability worldwide. In this article, the relationship between water resources and climate change is discussed and the importance of water is emphasized. In addition, recommendations are made for the sustainable use of water resources.

Keywords: Global climate change, water, ecology, sustainability

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1. INTRODUCTION

Among the indispensable natural resources that emerged with the formation of the water world, there is water, which is the second most important resource after air and is critical for human life. I is a building block of people whose dependence on it continues until the end of their lives. In addition, the amount of water in the human body varies from 60 to 70%. People need 2.5 liters of water every day to meet their biological needs. In addition, the average daily urban water demand for needs such as drinking, cooking, cleaning and laundry, which are necessary for a healthy life, is 150 liters per person. Water not only ensures the existence of the human body, but also a healthy life, ecosystem and food (Yarenoğlu, 2017). It is indispensable for life and has a great influence on living and inanimate beings. The natural balance, the environment and the life cycle depend on water. The important role of water in soil formation, flower diversity and survival, as well as in natural phenomena is indisputable. People need water (Özsoy, 2009).

Another focus factor is the contribution of water to the social and economic development of humanity. To be specific, people settled down thanks to watering. So they were able to produce and store grain and other agricultural products. As a result, they established civilizations along and around water sources. Water is definitely the only natural resource in the world that should always be used sparingly. Nevertheless, little attention was paid to the vital role of water after the Industrial Revolution and was considered an insignificant resource. There is no other source to replace water as a building block for humans and other living organisms. Water goes through various processes to make it usable. However, it should not be forgotten that water is not an infinite resource, even if people think the opposite (Yarenoğlu, 2017).

In this review, the importance of water resources for life is discussed by taking advantage of the results of previous research. To elaborate, it discusses how water resources, threatened more severely than ever before by rising temperatures globally, can be used sustainably and managed responsibly and reasonably for future generations.

2. WATER SUSTAINABILITY

Sustainability is intended to be passed on to future generations without causing harmful complications in the established mechanisms of all ecosystemic elements. A decisive implementation of sustainability requires limited use of available resources. Efforts to ensure that human needs are met in the future place various constraints on the current exploitation of natural resources. Although preserving the ecosystem as an intact heritage seems to be the most natural method, the inadequacy of today's resources to meet the increasing needs causes some plan changes (Meriç, 2003).

Every individual has the right to have water that is safe and affordable to use in sufficient quantities to lead a clean, healthy, and productive life (Mejia et al., 2012). Unless the imbalance between overdemand and limited supply is eliminated, the world is reportedly facing an exponentially worsening global water shortage. Water sustainability is the basis of development. Water resources, because of the variety of services they provide, pave the way for poverty reduction, economic growth and environmental sustainability (Connor, 2015).

Water makes significant contributions to improvements in social well-being and growth, from energy security to food security, the environment and individual health. Water sustainability can be achieved through settlements that are compatible with the natural water cycle and the ecosystems that support it, and through measures to reduce ecological fragility and increase resilience to water-related disasters.

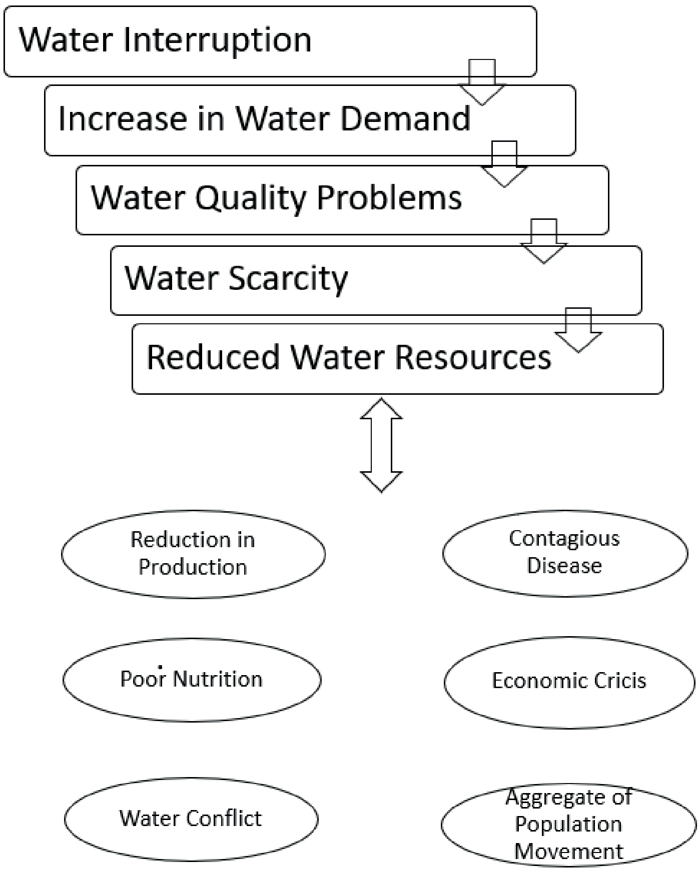
How to manage water resources is a challenge. An ever-increasing global population, rapid urbanization, settlement problems and uncontrolled economic development are reducing the quality of water resources and reducing their availability. All this must be taken into account for effective water management (Aküzüm et al. , 2010).

Water management consists of various sub-components such as efforts to increase water supply in relation to various economic sectors such as agriculture, industry, environment and transportation, management and planning of the demand for water under the stressful conditions of water resources, protection of water quality, production and implementation of managerial strategies, development of decision and support systems (Kırtorun and Karaer, 2018). Managing water resources effectively and sustainably is vital for sustainable development. The importance of water for flora and fauna, the preservation of ecological balance and socio-economic development. Given the growing scarcity, there is a growing need for optimal, economic and equitable use of resources, wastewater treatment and innovative holistic actions (Hoekstra et al., 2012).

3. INTERACTION BETWEEN WATER RESOURCES AND CLIMATE CHANGE

Observed and predicted changes in climate include depletion of water resources, increasing drought, ecological degradation, forest fires, erosion, a degraded agricultural system, diseases and deaths caused by extreme heat (Aydoğdu, 2020). Drought is no longer considered a natural phenomenon, especially due to human intervention in the hydrological cycle. Aggressive and harmful use of water resources to disrupt ecology, ineffective interventions in wetlands and streams, unconscious drainage of groundwater resources, overuse of water for agriculture and livestock, and global climate change have caused irreversible effects. Figure 1 shows climate change as the obvious factor driving pressure on the water cycle through pollution, population growth and reckless land use (Kang et al., 2009). In addition, global climate change causes negative effects such as the critical decrease in water resources and the decrease in competition for them and the decrease in water quality (Doğan and Tüzer, 2011). All these impacts pose serious threats to water resources, which are vital to rural development and food production, and underscore the urgency of measures to manage them. Water resources management includes the determination and planning of wa-

Figure 1. Projected Effects of Climate Change on Water Resources (Dikmen, 2021)



ter rights, rational operation, effective protection and comprehensive observation of these resources (Karaman and Gökalp, 2010). The management of water resources aims to minimise the risks arising from global climate change and is supported by reasonable demands. Therefore, a wide range of adaptation techniques must be produced and applied for the conservation and conservation of water resources. New methods should be encouraged for approaches such as changing institutional practices with supply-demand strategies (Kindler, 2000). The increase in global water demand due to population growth and high temperatures requires effective demand management and the implementation of working water policy (Bayraç and Doğan, 2016).

Wetlands, which are the source of many important species, are home to 40% of all species in the world and 12% of animal species (WWF-Türkiye 2008). It also offers benefits such as tourism, recreation and aquaculture, as well as many other benefits such as flood control, coastline protection, groundwater nutrition, food storage, climate change control and protection from storms. The current growth rate puts heavy pressure on water consumption routines. Worldwide, groundwater is the main source of water in large rural areas and in arid and semi-arid regions. Groundwater has been widely used for many years and plays a very important role in water potential. Changes in the temperature regime have adversely affected the amount of snow, rain, groundwater and surface water. Surface waters cover 1.6% of Türkiye's surface area and most rivers flow into the seas surrounding the country (Kurt, 2020). Therefore, water resources are extremely important for energy production and agricultural production. The most obvious limiting factors in the use of water resources for economic purposes are irregular rainfall and flow.

The effects of climate change on water resources are due to a change in the rainfall regime. Precipitation is the primary source of the change in water balance, spatially and temporarily. Climate-induced changes in precipitation lead to critical hydrological consequences. Hydrological deterioration in a particular watershed is influenced by changes in daily, seasonal, annual and decadal cycles. Decreasing rainfall caused by increasing temperatures can be the cause of undesirable events such as decreasing flow rate, a mixture of salt water and fresh water, and an increased storm incidence (Doğan and Tüzer 2011). Türkiye is located in an arid and semi-arid region. The country's current environmental problems, such as drought, desertification and salinity, are worsening as a result of global warming. In rainy regions, the salt that occurs naturally in the soil is transported by rainwater to groundwater and streams. It is then introduced into the seas and lakes. Therefore, salinity is lower in rainy regions. The purposeful use and high performance of irrigation tools is only possible with the drought eliminated and the expected amount of rainfall (Kadıoğlu, 2012). In order to combat agricultural and hydrological drought, the annual reasonable amount of gross water required for irrigation in Türkiye constitutes 48% of the 234 billionm3 of water determined by the General Directorate of State Hydraulic Works of Türkiye, which corresponds to 112 billion m 3 (Öztürk, 2016).

The decrease in the amount of precipitation that feeds groundwater due to climate change and the careless and uncontrolled drilling of wells lead to the drying up of aquifers and lakes. It has been observed that the water levels accumulated in many dam reservoirs are decreasing. Above-average seasonal temperatures due to climate change caused by global warming and therefore rapidly melting snows increase the flow rate of streams discharged into dams. This causes floods and related disasters (Sandalcı et al., 2007; Sandalcı et al., 2011). Rising sea temperature endangers many species in the seas and oceans, endangering the activities of fishermen. Increased temperature accelerates evaporation, which reduces the volume of irrigation water (Bayraç et al., 2016). In addition, it is reported that the levels and qualities of lakes as important water resources are adversely affected (Sandalcı et al., 2011). The increase in water temperature threatens the chemical process in a particular lake due to the production of in-lake alkali (Psenner and Schmidt, 1992). The surface area and water potentials of some lakes are known to have decreased significantly in quantity and quality. In addition, acid rain is listed among the main causes of degraded water quality. Acid rain is sulfur and nitrogen compounds linked to human activity. These compounds are effective in the transfer of chemical charges in rivers. Furthermore, acid rain plays a decisive role in the mineralization of organic nitrogen in soil (Bates et al., 2008; Delpla et al., 2009). It is estimated that shallow lakes will be most severely affected by a 2 O C increase in water temperature caused by climate change by 2070 (George et al., 2007; Malmaeus et al., 2006).

4.CONCLUSION AND RECOMMENDATIONS

This review discusses climate change and the importance of water resources and the potential impacts of climate change on water resources. The data obtained show that adaptive processes should be implemented against climate change and urgent efforts should be made to minimize the risks involved. In order to ensure the sustainability of water resources at their natural potential, the quantity and quality of groundwater and surface water should be evaluated. Annual water consumption records of countries should be produced by determining the water demands of societies. We propose that in order to protect water resources from overexploitation and pollution, to secure their supply in terms of quality and quantity, it is necessary to help educate and make communities more aware, and to adopt a long-term strategy on the rational use of these resources.

REFERENCES

AKÜZÜM, T., ÇAKMAK, B., & GÖKALP, Z. (2010). Evaluation of water resources management in Türkiye. *TABAD, Tarım Bilimleri Araştırma Dergisi*, *3*(1), 67-74.

AYDOGDU, G. (2020). Interaction of climate change and agricultural practices. *Ondokuz Mayıs University Journal of Human Sciences*, 1(1), 43-61.

BATES BC, KUNDZEWICZ ZW, WU S, PALUTIKOF JP (eds) (2008) *Climate change and water*. Technical document of the intergovernmental panel on climate change. IPCC Secretariat, Geneva, 210 pp.

BAYRAC H. N. & DOĞAN E., (2016). The Effects of Climate Change on the Agricultural Sector in Türkiye, Eskişehir Osmangazi University *Journal of FEAS*, April 2016, 11(1), 23- 48.

CONNOR R. (2015) United Nations World Water Development Report 2015: water for a sustainable world, puplishing UNESCO.

DELPLA I, JUNG AV, BAURES E, CLEMENT M, THOMAS O (2009) Effects of climate change on surface water quality related to drinking water production. *Environment Int* 35(8):1225–1233

DIKMEN, D., (2021), *Water and Sustainable Living, Sustainable Living GuideBook*, New People Publishing House, Ecology Series, Editor Yaman, Ö. and Akson, E., 65pp

DOĞAN S., & TÜZER M., (2011), Global climate change and its potential impacts, C.U. *Journal of Economics and Administrative Sciences*, 12(1), 21-34

GEORGE G, HURLEY M. & HEWITT D (2007) The impact of climate change on the physical characteristics of larger lakes in the English Lake District. *Freshw Biol* 52:1647–1666

HOEKSTRA Y., MEKONNEN M.M., CHAPAGAIN A. K., MATHEWS R. E. & RICHTER B. D. (2012). *Global monthly water scarcity: Blue water footprints versus blue water availability*. PLOS One 7, e32688.

KADIOĞLU M., (2012), *Climate change risk management in Türkiye*, Publication of Türkiye's Project on the Preparation of the Second National Declaration on Climate Change, 172pp.

KANG, Y., KHAN, S., & MA, X. (2009). Climate change impacts on crop yield, crop water productivity and food security–A review. *Progress in natural Science*, *19*(12), 1665-1674.

KARAMAN, S., & GÖKALP, Z. (2010). The Effects of Global Warming and Climate Change on Water Resources. *International Journal of Agricultural and Natural Sciences*, 3(1), 59-66.

KINDLER, J. (2000). Integrated Water Resources Management: Meanderings: Ven Te Chow Memorial Speech: Xth World Water Congress Melbourne, Australia, 14 March 2000. *Water International*, 25 (2), 312-319.

KIRTORUN, E. & KARAER, F. (2018). Water management and sustainability of water, *Journal of Sustainable Engineering Practices and Technological Developments*, 1 (2), 151-159.

KURT, D. (2020). Evaluation of the effects of climate change on the water resources of the Çukurova region (Çukurova University, Master's thesis, Institute of Natural and Applied Sciences).

MALMAEUS JM, BLENCKNER T, MARKENSTEN H, & PERSSON I (2006) Lake phosphorus dynamics and climate warming: a mechanistic model approach. *Ecol Model* 190:1–14

MEJIA A., NUCETE HUBNER M., RON SANCHEZ E. & DORIA M. (2012). United Nations World Water Development Report, N 4, Water and Sustainability (Review of Objectives, Instruments and Regional Cases): UNESCO;

MERIÇ, B.T., (2003). Akarçay (Afyon) Basin water resources, management model Hacettepe University Institute of Science and Technology, Department of Geology (Hydrogeology) Engineering PhD Thesis (unpublished), Beytepe, Ankara.

ÖZSOY, S., (2009). Water and Life: The Social Importance of Water, T.C Ankara University Institute of Social Sciences, Department of Labor Economics and Industrial Relations Master's Thesis

PSENNER R, SCHMIDT R (1992) Climate-induced pH control of remote Alpine lakes and the effects of acid accumulation. *Nature* 356:781–783

SANDALCI, M. &YÜKSEL, İ., (2007). "The Effect of Water Resources Use on Climate Change", I.Türkiye Climate Change Congress – Tikdek 2007, Istanbul, 447-453.

SANDALCI, M. & YÜKSEL, İ., (2011). "The Impact of Climate Change on Lakes and Dams in Türkiye", *Yapı Dünyası Dergisi*, 181, 25 – 29.

WWF-Türkiye (2008). (Ed. Deniz Şilliler Tapan) Ramsar Sites Assessment Report in Türkiye. Ankara: WWF-Turkish World Wildlife Fund. (World Wide Fund for Nature)

YARENOGLU, T., (2017). The Impact of Climate Changes on Izmir Water Resources, Dokuz Eylül University Institute of Natural and Applied Sciences, Master's Thesis

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ORIGINAL ARTICLE

Gene silencing RNAi technology: Uses in plants

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ABSTRACT

Ensuring sustainable food production in national and global area depends on the determination of plant species and varieties that can survive under the influence of various stress factors that may occur due to global climate changes and other factors that adversely limit growth and development, and depends on the protection and development of existing ones. It is important to develop new plant varieties that are resistant to abiotic stress factors that have occurred as a result of global climate changes. At this point, modern biotechnological methods have been widely needed in plant breeding in recent years. One of these techniques is RNAi technology. The mechanism of RNA interference (RNAi) is defined as post-transcriptional gene silencing or regulation of gene expression, resulting in the degradation of mRNA chain, which is the complement of double-stranded RNA (dsRNA) entering the cell. RNA interference begins when double-stranded RNA is cut into small inhibitory RNAs (siRNA) by an RNase III enzyme called as Dicer. These siRNAs then bind to the RNA-inducing silencing complex (RISC) which is a multiprotein-RNA nuclease complex. RISC uses siRNAs to find complementary mRNA and cuts the target mRNA endonucleolytically. The resulting decrease in specific mRNA leads to a decrease in available protein(s). Post-transcriptional gene silencing, RNA interference and other forms of RNA silencing have been observed particularly in plants. In recent years, RNAi studies, which are among the leading topics in the global area, have shown that non-coding RNAs in plants play a role in the control of tissue differentiation and development, signal transmission, interaction with phytohormones, abiotic (drought, salinity, etc.) and environmental factors such as biotic stress. In this review paper, the basics of RNAi mechanism and the usage of RNAi in plants are explained.

Keywords: Gene silencing, RNAi, siRNA, climate, plants

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1. INTRODUCTION

RNAi technology, which emerged as a result of genetic transformations, is a mechanism used in the regulation of gene expression after transcription with double-stranded RNA. RNAi is also defined as the post-transcriptional gene silencing mechanism through the degradation of mRNA chain, which is the homolog of dsRNA entering into the cell. This technology is a heavily and newly researched field in gene function (functional genomics) research. RNAi was named as "molecule of the year" and "the most important scientific breakthrough of 2002" by Science in 2001 by Fire et al., (1998).

RNA interference technology has revolutionized the field of functional genomics and is an important tool that allows the function of many different plant genes to be elucidated. Thanks to RNA interference-mediated gene expression suppression studies, the amount of protein synthesized from the gene of interest is reduced and information about the function of the protein can be obtained (Bora, 2020). RNAi is an important breakthrough during genetic transformation studies. The gene silencing mechanism is a very important discovery made by the botanist Napoli et al. (1990) during their research in which they tried to over-express the chalcone synthase gene in petunia plant. These researchers wanted to increase the effects of enzymes that catalyze pigmentation in petunia by adding a gene (*CHS*). However, they declared that whiter petunias were formed instead of more purple petunias, sometimes with unexpected reverse results Napoli et al., (1990). Although, this mechanism was not elucidated at the time, but, it was later discovered by Jorgensen et al., (1990) they report that this is a result of degeneration of the dsRNA region within the chalcone synthase gene (*CHS*), and may be associated with a PTGS (post-transcriptional gene silencing). In recent years, effective gene silencing mechanism has yielded successful results in Petunia, Nicotiana and Arabidopsis plant species Van der Krol et al., (1988).

With the increase in studies in the field of plant genetics & breeding and the development of the methods used, a lot of research has been done on plants as in many other fields. To date, studies on crops of agricultural importance such as wheat, tomato, corn, and beans are carried out by using epigenetic mechanisms such as DNA methylation, histone modification, mRNAs, ncRNA, RNAi. The methods to be applied to take precautions against pests are also important. It is critical that new methods and practices to be used against insects for plant production are environmentally friendly and healthy for humans and animals. RNAi is one such method. Parallel to the developments in the field of biotechnology, RNAi technology, which is one of the latest developments in the field of plant genetics, has a lot of contributions to agricultural applications Ayaz et al., (2018).

2. RNAI MECHANISM AND TYPES OF RNA INVOLVED

During the RNAi mechanism, RNA complementary to the target mRNA binds to the significant sequence of the mRNA on the RISC (RNA Inducing Silencing Complex) factor, an RNA-multiprotein complex with nuclease activity. Gene silencing is controlled through this RISC factor. The mRNA interacting with the protein named as 'Argounate' in the RISC factor is recognized and cut by the 'Dicer' enzyme (Figure 1), which is a ribonuclease in the RNase III family and thus silencing occurs. The RNAi mechanism or gene silencing mechanism is carried out by two different types of molecules in eukaryotic organisms (Zamore et al., 2000). These molecules are consisted of 22 nucleotides with long miRNA (micro RNA) and 21-23 nucleotide long double-stranded small interfering RNA (Figure 2).

Figure 1. Schematic representation of the predicted consensual domain structure for the Dicer enzyme. Helicase: N-terminal and C-terminal helicase domains. PAZ: Pinwheel-Argonaute-Zwille domain. RNase III: bidentate ribonuclease III domains. dsRBD: Double stranded RNA-binding domain (Bernstein et al., 2001).

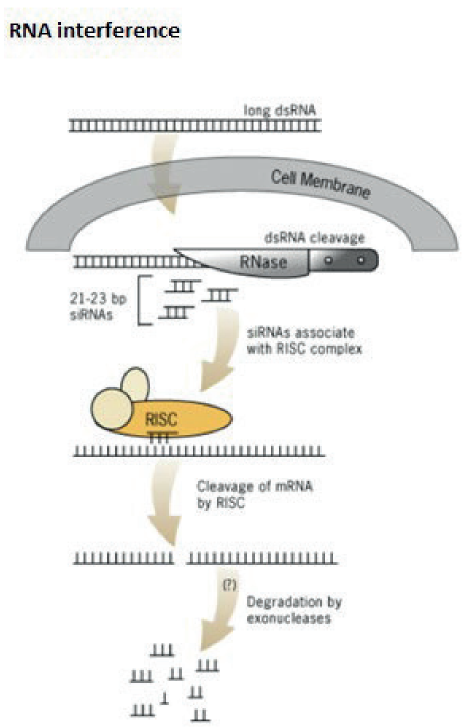

Figure 2. RNAi mechanism; dsRNA recognition and screening process, recognition and cleavage of double-stranded dsRNA in the presence of Dicer-RDE-1 (RNAi deficient-1), an RNase III family enzyme, production of siRNAs: Formation of RNAs with a length of 21-23 nucleotides, fusion of the siRNA-RISC complex pair with the specific complementary mRNA region, destruction of target mRNA by exonucleases in RISC and RISC complex returning for a new process (Ambion, 2007).

miRNAs and siRNAs are very similar to each other, but the differences between them are as follows:

a) The miRNA precursor is single stranded RNA (single strand: ssRNAs) in the hairpin structure, while the siRNA precursor is long dsRNAs.

b) Argounate proteins required for miRNA are AGO1, AGO10, and Argounate proteins required for siRNA are AGO1, AGO4, AGO6, AGO7.

c) miRNA is responsible for mRNA degradation, suppression of translation, while siRNA is responsible for DNA methylation, modification of histones, and mRNA degradation.

d) In plants, miRNA provides partial or full complementarity to the target sequence, while siRNA provides full complementarity.

e) miRNA is involved in cell development and differentiation, developmental processes, and response to biotic and abiotic stresses, while siRNA is involved in protection against transposons and viruses, and in stress adaptation (Zilberman et al., 2003; Bartel, 2004; Kim, 2005; Sunkar & Zhu, 2007; Watanabe et al., 2007; Carthew & Sontheimer, 2009; Pratt & MacRae, 2009).

The miRNA pathway begins with the conversion of pri-miRNAs in the nucleus into pre-miRNAs, which are approximately 70 nucleotides in length and hairpin structure, via the "Drosha enzyme". The pre-miRNAs are transferred to the cytoplasm and translated into miRNA duplexes by another RNase, Dicer. After the Dicer enzyme functions, one of the short dsRNA duplexes interacts with the RISC factor to bind to the target mRNA via base pairing. These miRNAs have the capacity to mediate translation suppression or degradation of mRNAs. With these features, they have taken their place among the interesting subjects of modern molecular biology. The capacity of translation suppression or direct degradation of mRNAs in plants varies according to the region where miRNAs bind on target mRNA. If it binds to the untranslated region (UTR) of mRNA, there is incomplete complementarity and translation is suppressed. Binding to the translated ORF (open reading frame) region shows complete complementarity and mRNA is degraded by Aragunate2 (AGO2). siRNAs are the precursor of dsRNAs, and dsRNAs are cut by the Dicer enzyme in such a way that the 3′ end remains protruding to form 20-25 bp siRNAs. Double-stranded siRNAs combine with RISC factors to become single-stranded and function as gene silencing by mRNA degradation Khvorova et al., (2003).

3. USAGE OF RNA INTERFERENCE TECHNOLOGY IN PLANTS

The basis of RNA interference studies in plants was laid by Napoli et al., (1990) when they investigated the overexpression of the *CHS* gene in Petunia plant by the vector *Agrobacterium tumefaciens*. In the research, it was tried to obtain darker petunias by increasing the pigmentation, but colorless, light-colored or variegated plants were obtained.

Further research by the same team showed that the expression of the gene responsible for pigment production and homologous genes were suppressed by the 35S promoter of the virus. It has been determined that gene silencing occurs with the degeneration of the dsRNA region in *CHS*. The miRNA mechanism was first described by Park et al., (2002) discovered by their research on *Arabidopsis* plant. It was thought that the micRNA metabolisms of the *CAF-1* (Carpel Factory) gene and *HEN1-1* genes, which have similar tasks in the study, would also be similar. In order to determine the functions of these genes, miRNA has been isolated from *HEN1-1* and *CAF-1* mutant *Arabidopsis* plants and from *Arabidopsis* plant that did not contain any mutations. In addition, isolation was done from tobacco, rice and maize crop plants thought to carry potential homologous genes. As a result of the research, it was determined that miRNA formation is controlled by growth and its density decreased in *HEN1-1* and *CAF-1* mutant plants. Many details regarding the biogenesis of miRNAs were also determined by this model plant. miRNA has been identified to date in a wide variety of plants such as *Chrysanthemum*, *Gossypium*, *Arabidopsis*, *Sorghum*, *Brassica* and *Vitis* (Adai et al., 2005; Bedell et al., 2005; Billoud et al., 2005; Dezulian et al., 2005; Li & Zhang, 2005; Lu et al., 2005; Sunkar et al., 2005; Qiu et al., 2007; Velasco et al., 2007).

Fruits are important as they are a source of additional nutrients. The nutritional value of the fruit, such as flavor and shelf life, are the factors that determine the quality. For this reason, reducing product loss by increasing fruit shelf life by illuminating the metabolic process in fruit ripening is of great interest for commercial reasons. The 1-Aminocyclopropane-1-carboxylate (*ACC*) oxidase gene, which catalyzes the oxidation of ethylene, a plant growth regulator (PGR), was used in an RNAi study to delay ripening in tomato, one of the most consumed fruits in the world. Successful conversion of double-stranded RNA (dsRNA) of tomato ACC oxidase into tomato variety Hezuo 906 by *A. tumefaciens* using the cauliflower mosaic virus (CMV) 35S promoter produced a transgenic tomato with a shelf life of more than 120 days (Xiong et al., 2005).

Certain studies have been conducted in which plant color changes in transgenic plants as a result of inhibiting the accumulation of anthocyanins by suppressing some structural genes involved in anthocyanin biosynthesis with RNAi. In another study, the 3’UTR region of chalcone synthase (*CHS*) mRNA, is an important enzyme in anthocyanin and flavonoid biosynthesis, was targeted and suppressed with RNAi to obtain plants with a lighter color than normal color in *Torenia hybrida* plant (Fukusaki et al., 2004).

In a study conducted on rice seed, the phytochelatin synthase (*OsPCS1*) gene, which has an important role in heavy metal accumulation and resistance, was suppressed by RNAi to reduce cadmium (Cd) accumulation. For this, the hairpin structure of the PCS gene fragment was designed in pRNAi-OsPCS1 under the control of *ZMM1*, a maize seed-specific promoter, and transferred to rice by *A. tumefaciens* (Li et al., 2007).

As stated by researchers working on the RNAi technology in potatoes, β-carotene content was increased by silencing the β-carotene hydroxylase gene (*BCH*) transcript, which converts β-carotene to zeaxanthin using RNAi technology (Van Eck et al., 2007).

According to the results of a study conducted on the subject in which the two E-class *MADS* box genes, *MaMADS1* and *MaMADS2*, which are homologous to the *RIN MADS* ripening genes in tomato, were functionally characterized, ripening was delayed in transgenic bananas in which these two genes were silenced with RNAi, and the banana ripening process was characterized by at least two *SEPALLATA-MADS* box genes in bananas (Elitzur et al., 2016).

Terpenoid gossypol toxin found in cotton seed and oil, which is an important industrial plant, and the RNAi and cadinene synthase gene in the gossypol biosynthesis pathway were suppressed only in the seed using a seed-specific promoter, and the leaves continued to produce terpenoids at normal levels in order not to affect the defence against insects Sunilkumar et al., (2006).

Plants may encounter a wide variety of stress factors such as biotic factors, infection by microorganisms and stress factors caused by the attacks of harmful animals, and abiotic factors (temperature, water, radiation, chemicals, magnetic and electrical fields) during their life (Levitt, 1980). Plants can respond through a wide variety of stress-related proteins, transcription factors, metabolites, or through epigenetic regulation. Epigenetic changes; encompasses RNA-directed DNA methylation, histone or DNA modifications, which play an important role in gene expression changes, particularly when the plant is exposed to an abiotic stress. It has been predicted that non-coding RNAs in plants may be formed by different mechanisms, such as insertion of a protein-coding gene after duplication or originating from transposons that make up more than 80% of the plant genome, but it has been stated that it is very difficult to determine a precise origin due to mutations accumulated in plants (Cushman and Bohnert 2000). Although there is no definite opinion about its origin. RNAi in plants is a technology that has the potential to be used in many areas such as genomics, determining the functions of genes, controlling tissue differentiation and development, signal transmission, interaction with phytohormones, and determining the response to environmental factors. It is possible to give a wide variety of examples for the application of RNA interference technology in plants (Priyapongsa and Jordan 2008).

According to the obtained results of a study, tobacco plants were manipulated with the tobacco mosaic virus (TMV) coat protein gene (*CP*). While all the features of the infection were observed in the initially transformed plants. It was noted that the plants recovered in the following weeks. As a result of the molecular analyzes performed in the healed tissues, it was understood that the transcription of the TMV sequences continued, but the functions of the mRNAs did not continue. At the end of the study, researchers were agreed with the opinion that gene silencing or co-repression is localized in cytoplasm and occurs at the post-transcriptional stage (Lindbo et al., 1993).

In a recent study on drought stress resistant *Physcomitrella patensis*, 16 miRNAs (DsAmR) associated with drought stress were identified and miR902a-5p and miR414 were reported to be important in inducing drought stress resistance (Wan et al., 2011).

The useage of RNAi technology in increasing resistance to sugarcane mosaic virus (SCMV) in maize (*Zea mays*) was investigated by researchers. As a result of the study, it was seen that the hairpin RNAs formed by the transcription of the sheath protein (*SHP*) gene prevent SCMV infection and it has been stated that the RNA interference-post transcriptional gene silencing approach may be important. It has been emphasized in other studies that the virus resistant plants can be obtained by inhibiting gene expression (Gan et al., 2014).

By silencing the GTPase *MtROP9* gene in *Medicago truncatula*, it was observed that ROS-related enzymes were suppressed and ROS products were reduced in transgenic roots (MtROP9i) infected with pathogenic (*Aphanomyces euteiches*) and symbiotic microorganisms i.e., *Sinorhizobium meliloti* and *Glomus intraradices*. In this study, time-dependent proteome responses were investigated in plants under the same conditions (22°C temperature, 65% humidity and 16hs photoperiod at 220 μE m−2 s−1 in plant growth chamber). When the induced proteins were analyzed as a result of the study, it was determined that the ROS production and clearance mechanism was controlled by the roots, while *MtROP9i* had alternative protection mechanisms Kiirika et al., (2012).

According to the obtained results of a study, it has been found that the MYB transcription factors play a role in plant development, metabolism and stress response. In the study, the function of *OsMYB103L* gene encoding the R2R3-MYB transcription factor in rice crop was investigated. The *OsMYB103L* gene is located in the nucleus and has processing capacity. As a result of the study, it was observed that ovarian expression of this gene caused the curly leaf phenotype in rice. The study further determined that the expression of cellulose synthesis genes (*CESA*) increased by silencing of *OsMYB103L* gene with RNAi technology.

It was observed that the expression of *CESAs* gene decreased the cellulose content in plant and the curl in the leaf decreased (Yang et al., 2014).

RNA interference technology has been successfully used in plant breeding and genetics. Homozygous parental lines can be obtained from heterozygous plants by stopping the recombination of meiosis. Recombination in meiosis can be achieved by RNAi (RNA interference) assisted gene editing. With this method, double haploid lines can be obtained and by crossing these lines, heterozygous lines can be obtained again. Recombination in meiosis can be prevented using different methods, including RNAi technology. For example, *DMC1* and *SPOL1* genes are involved in the recombination processes of meiosis. By silencing these genes with RNAi technology, homozygous parental lines are obtained from a heterozygous line (Schaart et al., 2016; Savadi et al., 2018).

4. CONCLUSION

Molecular technologies such as RNAi technology offer important opportunities to increase agricultural production in order to ensure adequate and balanced nutrition for the rapidly increasing world population. In addition to the application of sustainable agricultural techniques, the development of high yielding and high-quality plant varieties that are resistant to biotic and abiotic stress conditions is an important priority. In the development of these plants, it will be more accurate to focus mainly on molecular plant breeding techniques, not only transgenic plants obtained by transformation, in the short and medium term. It will help developing countries such as Türkiye, which have rich genetic resources, to determine their priority areas and to establish sufficient infrastructure for plant genetics and breeding studies.

It depends on the determination of plant species and varieties that can survive under the influence of various stress factors that may occur due to global climate changes and other factors that adversely limit growth and development, and it depends on the protection and development of existing ones. At this point, new and modern biotechnological approaches are important. In this sense, RNAi technology, which is an innovative approach in plant breeding, has become the preferred biotechnological approach in the international area. RNAi technology is the biggest advance in studying the function of genes in recent years. This mechanism is one that exists in nature, and it also has a wide range of applications in molecular biology, gene-protein function analysis, and functional genomics research. This technology can be used to obtain transgenic plants resistant to stress factors, to develop defence mechanisms against diseases caused by pathogens (fungal, viral and bacterial), etc., made significant contributions in many fields. In terms of the future prospective along with the development of technological tools, a more detailed understanding of post-transcriptional gene regulation mechanisms in different plants under different conditions will be possible.

Compliance with Ethical Standards

Conflict of interest:

The authors declare that they have no conflict of interest.

Ethical approval:

For this type of study, formal consent is not required.

REFERENCES

ADAI, A., JOHNSON, C., MLOTSHWA, S., ARCHER-EVANS, S., MANOCHA, V., VANCE, V., & SUNDARESAN, V. (2005). Computational prediction of miRNAs in Arabidopsis thaliana. *Genome Research*, *15*(1), 78-91. 10.1101/gr.2908205

AMBION INC. (2007). RNA Interference Overview, The RNA Company.

AYAZ, G. B., ŞAHIN, Ö., & AYAZ, U. (2018). Epigenetik alanındaki tarım uygulamaları. *Madde, Diyalektik ve Toplum*, *3*, 254-262.

BARTEL, D. P. (2004). MicroRNAs: genomics, biogenesis, mechanism, and function. *Cell*, *116*(2), 281-297. https://doi.org/10.1016/S0092-8674(04)00045-5

BEDELL, J. A., BUDIMAN, M. A., NUNBERG, A., CITEK, R. W., ROBBINS, D., JONES, J., FLICK, E., RHOLFING, T., FRIES, J., BRADFORD, K., MCMENAMY, J., SMITH, M, HOLEMAN, H., ROE, B.A., WILEY, G., KORF, I.F., RABINOWICZ, P.D., LAKEY, N., MCCOMBIE, W.R., JEDDELOH, J.A, & MARTIENSSEN, R. A. (2005). Sorghum genome sequencing by methylation filtration. *PLoS Biology*, *3*(1), e13. https://doi.org/10.1371/journal.pbio.0030013

BERNSTEIN, E., CAUDY, A. A., HAMMOND, S. M., & HANNON, G. J. (2001). Role for a bidentate ribonuclease in the initiation step of RNA interference. *Nature*, *409*(6818), 363-366. https://doi.org/10.1038/35053110

BILLOUD, B., DE PAEPE, R., BAULCOMBE, D., & BOCCARA, M. (2005). Identification of new small non-coding RNAs from tobacco and Arabidopsis. *Biochimie*, *87*(9-10), 905-910. https://doi.org/10.1016/j.biochi.2005.06.001

BORA, G. (2020). Nöron Benzeri Hücre Hatlarında RNA Interferans Aracılı Gen İfadesi Baskılama Çalışmaları: in vitro SMA modelleri. *Osmangazi Tıp Dergisi*, *42*(2), 140-147. https://doi.org/10.20515/otd.497543

CARTHEW, R. W., & SONTHEIMER, E. J. (2009). Origins and mechanisms of miRNAs and siRNAs. *Cell*, *136*(4), 642-655. 10.1016/j.cell.2009.01.035

CUSHMAN, J. C., & BOHNERT, H. J. (2000). Genomic approaches to plant stress tolerance. *Current Opinion in Plant Biology*, *3*(2), 117-124. 10.1016/s1369-5266(99)00052-7

DEZULIAN, T., PALATNIK, J. F., HUSON, D., & WEIGEL, D. (2005). Conservation and divergence of microRNA families in plants. *Genome Biology*, *6*(11), 1-25. https://doi.org/10.1186/gb-2005-6-11-p13

ELITZUR, T., YAKIR, E., QUANSAH, L., ZHANGJUN, F., VREBALOV, J., KHAYAT, E., & FRIEDMAN, H. (2016). Banana MaMADS transcription factors are necessary for fruit ripening and molecular tools to promote shelf-life and food security. *Plant Physiology*, *171*(1), 380-391. https://doi.org/10.1104/pp.15.01866

FIRE, A., XU, S., MONTGOMERY, M. K., KOSTAS, S. A., DRIVER, S. E., & MELLO, C. C. (1998). Potent and specific genetic interference by double-stranded RNA in *Caenorhabditis elegans*. *Nature*, *391*(6669), 806-811. 10.1038/35888

FUKUSAKI, E. I., KAWASAKI, K., KAJIYAMA, S. I., AN, C. I., SUZUKI, K., TANAKA, Y., & KOBAYASHI, A. (2004). Flower color modulations of *Torenia hybrida* by downregulation of chalcone synthase genes with RNA interference. *Journal of Biotechnology*, *111*(3), 229-240. 10.1016/j.jbiotec.2004.02.019

GAN, D., DING, F., ZHUANG, D., JIANG, H., JIANG, T., ZHU, S., & CHENG, B. (2014). Application of RNA interference methodology to investigate and develop SCMV resistance in maize. *Journal of Genetics*, *93*(2), 305-311. 10.1007/s12041-014-0364-1

KHVOROVA, A., REYNOLDS, A., & JAYASENA, S. D. (2003). Functional siRNAs and miRNAs exhibit strand bias. *Cell*, *115*(2), 209-216. 10.1016/s0092-8674(03)00801-8

KIIRIKA, L. M., BERGMANN, H. F., SCHIKOWSKY, C., WIMMER, D., KORTE, J., SCHMITZ, U., & COLDITZ, F. (2012). Silencing of the Rac1 GTPase MtROP9 in *Medicago truncatula* stimulates early mycorrhizal and oomycete root colonizations but negatively affects rhizobial infection. *Plant Physiology*, *159*(1), 501-516. https://doi.org/10.1104/pp.112.193706

KIM, V. N. (2005). Small RNAs: classification, biogenesis, and function. *Molecules & Cells (Springer Science & Business Media BV)*, *19*(1), 1-15.

LEVITT, J. (1980). *Responses of plants to environmental stresses. Volume II. Water, radiation, salt, and other stresses* (No. Ed. 2). Academic Press.

LI, J. C., GUO, J. B., XU, W. Z., & MA, M. (2007). RNA interference mediated silencing of phytochelatin synthase gene reduce cadmium accumulation in rice seeds. *Journal of Integrative Plant Biology*, *49*(7), 1032-1037. https://doi.org/10.1111/j.1672-9072.2007.00473.x

LI, X., & ZHANG, Y. Z. (2005). Computational detection of microRNAs targeting transcription factor genes in Arabidopsis thaliana. *Computational biology and chemistry*, *29*(5), 360-367. 10.1016/j.compbiolchem.2005.08.005

LINDBO, J. A., SILVA-ROSALES, L., PROEBSTING, W. M., & DOUGHERTY, W. G. (1993). Induction of a highly specific antiviral state in transgenic plants: implications for regulation of gene expression and virus resistance. *The Plant Cell*, *5*(12), 1749-1759. 10.1105/tpc.5.12.1749

LU, S., SUN, Y. H., SHI, R., CLARK, C., LI, L., & CHIANG, V. L. (2005). Novel and mechanical stress–responsive microRNAs in *Populus trichocarpa* that are absent from Arabidopsis. *The Plant Cell*, *17*(8), 2186-2203. 10.1105/tpc.105.033456

NAPOLI, C., LEMIEUX, C., & JORGENSEN, R. (1990). Introduction of a chimeric chalcone synthase gene into petunia results in reversible co-suppression of homologous genes in trans. *The plant cell*, *2*(4), 279-289. 10.1105/tpc.2.4.279

PARK, W., LI, J., SONG, R., MESSING, J., & CHEN, X. (2002). Carpel Factory, a Dicer homolog, and *HEN1-1* a novel protein, act in microRNA metabolism in Arabidopsis thaliana. *Current Biology*, *12*(17), 1484-1495. 10.1016/s0960-9822(02)01017-5

PIRIYAPONGSA, J., & JORDAN, I. K. (2008). Dual coding of siRNAs and miRNAs by plant transposable elements. *Rna*, *14*(5), 814-821. 10.1261/rna.916708

PRATT, A. J., & MACRAE, I. J. (2009). The RNA-induced silencing complex: a versatile gene-silencing machine. *Journal of Biological Chemistry*, *284*(27), 17897-17901. 10.1074/jbc.R900012200

QIU, C. X., XIE, F. L., ZHU, Y. Y., GUO, K., HUANG, S. Q., NIE, L., & YANG, Z. M. (2007). Computational identification of microRNAs and their targets in *Gossypium hirsutum* expressed sequence tags. *Gene*, *395*(1-2), 49-61. 10.1016/j.gene.2007.01.034

SAVADI, S., PRASAD, P., KASHYAP, P. L., & BHARDWAJ, S. C. (2018). Molecular breeding technologies and strategies for rust resistance in wheat (*Triticum aestivum*) for sustained food security. *Plant pathology*, *67*(4), 771-791. https://doi.org/10.1111/ppa.12802

SCHAART, J. G., VAN DE WIEL, C. C., LOTZ, L. A., & SMULDERS, M. J. (2016). Opportunities for products of new plant breeding techniques. *Trends in Plant Science*, *21*(5), 438-449. https://doi.org/10.1016/j.tplants.2015.11.006

SUNILKUMAR, G., CAMPBELL, L. M., PUCKHABER, L., STIPANOVIC, R. D., & RATHORE, K. S. (2006). Engineering cotton seed for use in human nutrition by tissue-specific reduction of toxic gossypol. *Proceedings of the National Academy of Sciences*, *103*(48), 18054-18059. https://doi.org/10.1073/pnas.0605389103

SUNKAR, R., & ZHU, J. K. (2007). Micro RNAs and short interfering RNAs in plants. *Journal of Integrative Plant Biology*, *49*(6), 817-826. https://doi.org/10.1111/j.1744-7909.2007.00499.x

SUNKAR, R., GIRKE, T., JAIN, P. K., & ZHU, J. K. (2005). Cloning and characterization of microRNAs from rice. *The Plant Cell*, *17*(5), 1397-1411. https://doi.org/10.1105/tpc.105.031682

VAN DER KROL, A. R., LENTING, P. E., VEENSTRA, J., VAN DER MEER, I. M., KOES, R. E., GERATS, A. G., & STUITJE, A. R. (1988). An anti-sense chalcone synthase gene in transgenic plants inhibits flower pigmentation. *Nature*, *333*(6176), 866-869. 10.1038/333866a0

VAN ECK, J., CONLIN, B., GARVIN, D. F., MASON, H., NAVARRE, D. A., & BROWN, C. R. (2007). Enhancing beta-carotene content in potato by RNAi-mediated silencing of the beta-carotene hydroxylase gene. *American Journal of Potato Research*, *84*(4), 331-342. 10.1007/BF02986245

VELASCO, R., ZHARKIKH, A., TROGGIO, M., CARTWRIGHT, D. A., CESTARO, A., PRUSS, D., & VIOLA, R. (2007). A high quality draft consensus sequence of the genome of a heterozygous grapevine variety. *PloS One*, *2*(12), e1326. https://doi.org/10.1371/journal.pone.0001326

WAN, P., WU, J., ZHOU, Y., XIAO, J., FENG, J., ZHAO, W., & CHEN, J. Y. (2011). Computational analysis of drought stress-associated miRNAs and miRNA co-regulation network in *Physcomitrella patens*. *Genomics, proteomics & bioinformatics*, *9*(1-2), 37-44. 10.1016/S1672-0229(11)60006-5

WATANABE, T., TOTOKI, Y., SASAKI, H., MINAMI, N., & IMAI, H. (2007). Analysis of small RNA profiles during development. *Methods in enzymology*, *427*, 155-169. 10.1016/S0076-6879(07)27009-0

XIONG, A. S., YAO, Q. H., PENG, R. H., LI, X., HAN, P. L., & FAN, H. Q. (2005). Different effects on ACC oxidase gene silencing triggered by RNA interference in transgenic tomato. *Plant Cell Reports*, *23*(9), 639-646. 10.1007/s00299-004-0887-7

YANG, C., LI, D., LIU, X., JI, C., HAO, L., ZHAO, X., & ZHU, L. (2014). OsMYB103L, an R2R3-MYB transcription factor, influences leaf rolling and mechanical strength in rice (*Oryza sativa* L.). *BMC Plant Biology*, *14*(1), 1-15. 10.1186/1471-2229-14-158

ZAMORE, P. D., TUSCHL, T., SHARP, P. A., & BARTEL, D. P. (2000). RNAi: double-stranded RNA directs the ATP-dependent cleavage of mRNA at 21 to 23 nucleotide intervals. *Cell*, *101*(1), 25-33. 10.1016/S0092-8674(00)80620-0

ZILBERMAN, D., CAO, X., & JACOBSEN, S. E. (2003). Argonaute4 control of locus-specific siRNA accumulation and DNA and histone methylation. *Science*, *299*(5607), 716-719. 10.1126/science.1079695

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ORIGINAL ARTICLE

Agricultural wastes in climate change mitigation

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ABSTRACT

Today, among the wastes that harm the environment, there are many wastes such as cleaning agent wastes and expired drugs. In addition to these wastes, agricultural wastes are an important issue. The vast majority of agricultural wastes are wastes containing high cellulose. Agricultural wastes include tobacco plant waste, vineyard and fruit tree pruning residues, wheat straw, cob, cotton stalk, mushroom compost residues, corn stalk, husk, rice bran, pulp, lentil waste, wood shavings, bean straw, leather waste, soybean straw, wastes consisting of a dysfunctional irrigation system and plastic mulches. Gases especially causing greenhouse gas effect (carbon dioxide, methane, nitrous oxide and other) which are released by the destruction of agricultural and other wastes by burning, accumulate in the atmosphere, causing global warming and negatively affecting the climate. The study has been compiled with the aim of revealing solutions for the use or recycling of agricultural wastes that cause greenhouse gases when destroyed by incineration.

Keywords: Climate change, agricultural waste, environment, greenhouse gases, evaluation

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1. INTRODUCTION

In case of unconscious burning of agricultural wastes, gases such as carbon dioxide can accumulate in the atmosphere. These gases, which accumulate in the atmosphere and keep the rays reflected from the earth to the atmosphere and warm our world, are called greenhouse gases. If these greenhouse gases accumulate in the atmosphere in excessive amounts as a result of burning garbage and agricultural wastes from various sources other than natural ways, the amount of radiation they hold increases. In this case, global warming, which is an important climate problem, occurs due to the increase in gases that cause the greenhouse effect.

One of the important issues that should be prevented in agricultural areas is stubble burning. Burning stubble increases the emission of gases that cause greenhouse effect in the atmosphere and global warming. In addition, beneficial insects and organisms in the soil die by burning the stubble. Stubbles can be evaluated by mixing the stubble with the soil or using it as straw.

According to the type of agricultural waste, agricultural wastes can be reused today in packaging, biochar production, composting, fertilizer production and similar ways. Agricultural wastes such as animal manure, straw, fruit and vegetable wastes, waste paper can also be used in the production of vermicompost, which is an important fertilizer, in addition to compost. Plastic products such as pesticide packaging, irrigation system residues, and plastic mulches can be reused instead of incineration. Vegetable and animal wastes can be used as organic fertilizer and soil improver.

There are different methods in the evaluation of agricultural wastes in different agricultural products. In a study (Elbasiouny et al. 2020) about the administration of agricultural wastes for the reduction of climate change, mentioned that agricultural wastes increase due to population growth and that these wastes are disposed of with incineration or inappropriate methods. They stated that this situation harms the atmosphere in terms of wasting valuable resources as well as increasing greenhouse gas emissions. In their studies, they mentioned the importance of using these wastes as animal feeding, composting, bioenergy sources, bioplastics and building materials in order to prevent greenhouse gases and climate change. However, they mentioned that rice, corn, wheat or barley, cotton, sugar beet crops are the agricultural wastes in the highest amount.

Çolakoğlu, B. (2018), divided agricultural wastes into wastes that occur during or after animal production, wastes that occur during or after plant production and wastes that occur during or after the production of agricultural products. It was mentioned that agricultural wastes can be evaluated as renewable energy source (biomass, biogas fuels), compost, particle board, biodegradable plastic production, mulch, mushroom production, paper production, insulation construction material, heavy metal removal.

In another study (Doğan, N., 2005), cotton stalk and apricot kernel used as biosorbent in order to absorb copper (Cu) and lead (Pb) heavy metal ions from liquid solutions. It was determined that cotton stalk was more effective in removing both heavy metals than apricot kernels. In addition, it was observed that agricultural wastes remove Pb ions more effectively than Cu ions. It was found that the harmful effects of heavy metals on P. aeruginosa soil bacteria were reduced with the help of agricultural wastes. The aim of the study is to eliminate the lack of knowledge about the damages caused by the incineration of agricultural wastes to the environment and climate. In addition, contribute to eliminating the lack of knowledge about how these wastes can be used and to improve people's perspective on this issue.

2. PRODUCTION OF ORNAMENTAL PLANTS BY USE OF AGRICULTURAL WASTES

The evaluation of agricultural wastes in producing of ornamental plants is another issue. Ornamental plants are usually produced in pots, so a growing medium is needed.

Micro scale structure and physical, hydro physical designation of organic wastes of hazelnut husk, corn straw, pine bark, tea waste, wood chips, rice husk, waste mushroom compost, household waste compost were determined in a study (Öztekin, H. Ö., 2018) regarding the use of organic wastes in growing ornamental plants and in the result of study, domestic waste compost, waste mushroom compost, hazelnut husk, wood shavings were found suitable for use as growing media. In addition, it has been stated that corn straw, pine bark, tea waste and rice husk media can be used by adding certain amounts to the growing media.

In study made by Zulfiqar et al. (2019) by using *Dracaena deremensis* ornamental plant, growing environments were created by replacing mown grass, leaves and wheat straw biochar materials with 10% peat. They determined that the addition of biochar and compost materials to the peat/perlite medium increased the growth in vegetative part (height of plant, leaf number, area of leaf, fresh biomass) of *Dracaena deremensis* by 10-30% compared to the peat/perlite medium.

A study carried out by Jayasinghe et al. (2010) on using of substrates obtained from animal manure compost and synthetic aggregates in ornamental plant production as an alternative to peat. In their study, they determined that animal compost and synthetic aggregate based media were more effective on plant growth than control (peat) media in French marigold (*Tagetes patula*). They determined that the highest length of plant, number of flowers in per plant, shoot fresh weight, shoot dry weight, root length, root dry weight, root fresh weight values were obtained from animal manure compost and synthetic aggregate medium at the rates of 40% and 60%. They determined that the mentioned parameters in this medium (40% animal manure compost, 60% synthetic aggregate) had higher values, respectively, 27.01%, 42.86%, 37.09%, 67.29%, 5.14%, 45.58%, 34.26% compared to the control medium.

3. USE OF MUSHROOM COMPOST WASTE IN AGRICULTURAL PRODUCTION AND USE OF AGRICULTURAL WASTE IN MUSHROOM PRODUCTION

Baran et al. (1995) conducted a study to determine the physical and chemical features of agricultural wastes from tobacco dust, grape pomace and mushroom compost. They determined that the physical properties of agricultural wastes in their study were insufficient, however, their nutrient content was at a very high level. In addition, the organic matter contents of all agricultural wastes they used in their study were found to be high, grape pomace had the highest organic matter content. However, they determined that the aeration capacity of agricultural wastes consisting of tobacco dust, grape pomace and mushroom compost was insufficient and it was stated that these agricultural wastes could be mixed with environments with high aeration capacities such as peat and perlite and their aeration capacity could reach the desired level. In terms of salt content, they mentioned that tobacco dust and mushroom compost have high values.

Polat et al. (2004) conducted a study on the effects of using waste mushroom compost in lettuce cultivation on yield and quality. In their study, synthetic mushroom compost waste, which was kept in the open field for two years, was used in lettuce cultivation at doses of 1, 2, 4 tons/da. The authors determined that waste mushroom compost applications gave higher results in terms of average head weight, average marketable head weight, and total marketable product, compared to the control application.

Another issue is the usability of agricultural wastes in mushroom production. Fungi take in oxygen and give off carbon dioxide, that is, they breathe. More research is needed to determine whether the use of agricultural wastes in mushroom production instead of burning has a positive effect on the atmospheric greenhouse effect. However, when a material is burned, a large amount of carbon dioxide is suddenly released into the air. In mushroom production, there may be a slower release of carbon dioxide. Pasteurized, rotten or waste organic materials of vegetable and animal origin can be used in mushroom production. *Pleurotus spp*. production can be done using freshly cut logs as well as different composts. In this way, instead of using logs as wood, that is, as fuel, it is possible to evaluate them in a way that can contribute more economically. Another important issue here is how much efficiency will be obtained from which waste.

A large number of agricultural wastes can be used in mushroom cultivation.

In the study (Akyüz and Kırbağ, 2009), agricultural wastes consisting of wheat straw, cotton stalk, corn stalk, rice bran, lentil waste, bean stalk, soybean stalk, and leather waste were used for the production of *Pleurotus spp*, it was found that wastes from agriculture and industry were easily used in the production of *Pleurotus spp.* Within the scope of their study, the lowest yield (in 100 g compost containing 70% moisture) was 15 g and obtained from *P. eryngii'*s wheat straw + 5% leather waste, and the highest yield was 22 g and obtained *P. eryngii's* wheat straw-bean stalk (1 :1) + 5% rice bran.

In a study by (Kurt, Ş., 2008) vine pruning residue, wheat straw, rice straw, sesame stalk, 2 sawdust+bran, 2 vine pruning residue+bran, 2wheat straw+bran, 2 rice straw+bran, 2 sesame stalk+bran media were used in the cultivation of *Pleurotus ostreatus*, *Pleurotus sajor-caju* mushroom species and the fastest mycelial growth in *Pleurotus ostreatus* species was obtained from wheat straw (22.83 days), vine pruning residue (23.67 days), sesame stalk (26.22 days) media, and in *Pleurotus sajor-caju* species from wheat straw media. In addition the highest total yield and biological efficiency rate in both species were obtained from 2 wheat straw + bran medium and the lowest yield was determined in wheat straw medium in both species. Besides it was informed that the easy availability of these wastes according to the regions is important for the continuous production of mushrooms.

4. OTHER STUDIES ON THE USE OF AGRICULTURAL WASTES

Kara et al. (2021), examined the impacts of organic mulch practice using wheat straw on the physical properties of the soil. As a result of their study, they determined that 600 kg/da and 900 kg/da wheat straw practices increase the organic matter in the soil and increase the yield and quality in plant production.

Another agricultural waste obtained in significant quantities is obtained as a result of tobacco farming. Çerçioğlu, M., (2011) mentioned that agro-industrial wastes can be used instead of inorganic fertilizers and that the use of tobacco waste in sustainable agriculture can be an alternative to inorganic fertilizers. Within the scope of study, it was emphasized that importance of using tobacco waste as fertilizer in order to prevent the damage caused by the burning and disposal of tobacco plants and fabrication wastes, which are rich in organic matter. However, it was stated that tobacco dust should be used by composting in order to reduce the amount of nicotine. In addition, it has been mentioned in the study that the use of tobacco waste in the improvement of the physical and chemical structures of alkaline soils can be beneficial in terms of agriculture and the environment.

In addition, agricultural wastes can also be used in the production of chips, fiber and yarn. In a study (Arslan et al., 2007), it was mentioned that panels produced in different thicknesses and densities by gluing chips and fibers produced from agricultural wastes using various glues and boards obtained at different press temperatures can be alternatives to panel materials produced using wood chips and fibers. However, it has been mentioned that the high costs in the collection, transportation and storage of agricultural wastes prevent the use of agricultural wastes. Kalayci et al. (2016) mentioned that tons of pineapple leaf fibers, which is an important agricultural waste, appear as agricultural waste every year. Within the scope of their study, they stated that pineapple leaf fibers are an important textile material because the cellulose ratio is quite high. They mentioned that pineapple leaf fibers can be obtained by mechanical methods as well as biological methods and can be used in yarn production. They explained that the use of these fibers in the textile sector will contribute to sustainable agriculture.

Agricultural wastes can also be used as biofuels. Sumer et al. (2016) evaluated agricultural and animal wastes in terms of the potential for conversion to biochar in Türkiye. They determined that this potential is 3942654 tons in terms of agricultural and animal origin wastes. They stated that 77% animal, 22.5% garden and vineyard pruning wastes and 0.6% field agriculture wastes take place in the formation of biochar potential. Dayıoğlu, M. A., (2013) stated that biorefineries are facilities that have the necessary biomass conversion stages to produce different types of fuels, electricity and chemicals and it was stated that the fuels obtained by mixing certain amounts of biofuels with fossil fuels provide a neutral carbon dioxide cycle in terms of greenhouse balance. Additionally the biomass raw materials were stated as starch (corn, wheat, barley, rye, oat, potato), sugar (beet, sugarcane, sweet sorghum, cassava root), oil (sunflower, rapeseed, soybean, safflower, cotton, palm, peanut, jojoba, maize), lignocellulose (branched millet, flax, hemp, sorghum, poplar, willow, eucalyptus, miscanthus, woody plants, straw, stalk, cob, table, bark, husk, kernel, branch, pulp, wood shavings).

5. CONCLUSION

Prevention of stubble burning, utilization of agricultural wastes in the form of growing ornamental plants, improvement of alkaline soils of tobacco waste, use of agricultural wastes as biochar and biofuel are some of the stages of evaluation of agricultural wastes. In addition, it is seen that agricultural wastes are in a wide variety of numbers. Considering the multitude ways of utilization of agricultural wastes and the diversity of agricultural wastes, it seems possible that prevent excessive increase of greenhouse gases by evaluating these wastes with different methods instead of incineration. However, it is necessary to investigate how these wastes can be evaluated in which products. However, it should not be forgotten that the usage dose of these wastes differs in terms of the agricultural area to be used or the product to be produced. Producers need to be guided correctly in using a wide variety of agricultural wastes.

Compliance with Ethical Standards

Ethical approval:

For this type of study, formal consent is not required.

REFERENCES

AKYÜZ, M., KIRBAĞ, S. (2009). Bazı Tarımsal ve Endüstriyel Atıkların Pleurotus spp. Üretiminde Kompost Olarak Değerlendirilmesi. *Ekoloji* 18(70), 27-31.

ARSLAN, M. B., KARAKUŞ, B., GÜNTEKIN, E. (2007). Tarımsal Atıklardan Lif ve Yonga Levha Üretimi. *ZKÜ Bartın Orman Fakültesi Dergisi*. 9(12), 54-62.

BARAN, A., ÇAYCI, G., İNAL, A. (1995). Farklı Tarımsal Atıkların Bazı Fiziksel ve Kimyasal Özellikleri. *Mühendislik Bilimleri Dergisi* 1995. 1(2-3), 169-172.

ÇERÇIOĞLU, M. (2011). Sürdürülebilir Tarımda Tütün Atığı Kullanım Olanakları. U. Ü. *Ziraat Fakültesi Dergisi*, 2011. 25(2), 101-107.

ÇOLAKOĞLU, B. (2018). Tarımsal Atıkların Alternatif Kullanım Alanları Konusunda Üretici Eğilimleri. Namık Kemal Üniversitesi, Fen Bilimleri Enstitüsü, Tarım Ekonomisi Anabilim Dalı, Yüksek Lisans Tezi. 21-36.

DAYIOĞLU, M. A. (2013). Biyokütleden Sürdürülebilir Biyoyakıt Üretimi: Biyorafineri Yaklaşımı. *Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)* 2013, 9(4), 313-320.

DOĞAN, N. (2005). Ağır Metal Gideriminde Tarımsal Atık Kullanımı. İnönü Üniversitesi, Fen Bilimleri Enstitüsü, Biyoloji Ana Bilim Dalı, Yüksek Lisans Tezi, 1-37.

ELBASIOUNY, H., ELBANNA, B. A., AL-NAJOLI, E., ALSHERIEF, A., NEGM, S., EL-NOUR, E. A., NOFAL, A., SHARABASH, S. (2020). *Agricultural Waste Management for Climate Change Mitigation: Some Implications to Egypt*. © Springer Nature Switzerland AG 2020. A. M. Negm and N. Shareef (eds.), Waste Management in MENA Regions, Springer Water, https://doi.org/10.1007/978-3-030-18350-9_8.

JAYASINGHE, G.Y., LIYANA ARACHCHI, I.D., TOKASHIKI, Y. (2010). Evaluation Of Containerized Substrates Developed From Cattle Manure Compost And Synthetic Aggregates For Ornamental Plant Production As A Peat Alternative. 54(12), 1412-1418.

KALAYCI, E., AVINC, O. O., BOZKURT, A., YAVAŞ, A. (2016). Tarımsal Atıklardan Elde Edilen Sürdürülebilir Tekstil Lifleri: Ananas Yaprağı Lifleri. S.A.Ü. *Fen Bil. Der.*, 20(2), 203-221.

KARA, Z., SESVEREN, S., GÖNEN, E., KÖYLÜ, A. (2021). Organik Malç Uygulamalarının Toprağın Bazı Fiziksel Özellikleri Üzerine Etkileri. O.K.U. *Fen Bilimleri Enstitüsü Dergisi*.4(1), 91-95.

KURT, Ş. (2008). Değişik Tarımsal Artıkların Kayın Mantarı (Pleurotus Ostreatus, Pleurotus Sajor-Caju) Yetiştiriciliğinde Kullanım Olanakları. Çukurova Üniversitesi, Fen Bilimleri Enstitüsü, Doktora Tezi. 1-181.

ÖZTEKIN, M. H. (2018). Organik Atıkların Süs Bitkisi Yetiştirme Ortamı Olarak Kullanılabilirliğinin İncelenmesi. Sakarya Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi. 1-57.

POLAT, E., ONUS, A. N., DEMIR, H. (2004). Atık Mantar Kompostunun Marul Yetiştiriciliğinde Verim ve Kaliteye Etkisi. Akdeniz Üniversitesi, *Ziraat Fakültesi Dergisi*, 2004. 17(2), 149-154.

SÜMER, S. K., KAVDIR, Y., ÇIÇEK, G. (2016). Türkiye'de Tarımsal ve Hayvansal Atıklardan Biyokömür Üretim Potansiyelinin Belirlenmesi. *KSÜ Doğa Bil. Derg*. 19(4), 379-387.

ZULFIQAR, F., YOUNIS, A., ASIF, M., ABIDEEN, Z., ALLAIRE, S.E., SHAO, Q.S. (2019). Evaluatıon Of Contaıner Substrates Contaınıng Compost And Bıochar For Ornamental Plant Dracaena deremensis. Pak. *J. Agri. Sci.* 56(3), 613-621.

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ORIGINAL ARTICLE

Review of phase change materials as an environmental approach for postharvest fruit and vegetable cold storage

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ABSTRACT

Today, nearly half of food products are decreasing before reaching to consumer and data shows that one third of food never reaches to end consumer. It is known that % 50 of these are caused by technical errors, temperature management and reducing postharvest losses will play important role of world population in future. Therefore, preventing or minimizing loss of fresh fruits and vegetables has become important issue. Petroleum fuels and electrical energy cold storages are costly and causes environmental pollution. Recently, phase change material (PCM) is clean, environmentally friendly and renewable energy source and interesting material in energy systems. PCMs have ability to store ambient heat as latent heat energy and return the stored latent heat energy during rising and falling to ambient temperature. Accurate phase change temperature range PCMs work as low and high temperature barriers, providing maximum energy savings as an economical storage system and can prevent carbon (C) emissions by reducing environmental pollution. This study is a review of applicable thermal energy storage PCM materials for cold storage of postharvest fresh fruits and vegetables and aims reduce to C emission and energy saving.

Keywords: Phase change material, Thermal energy storage, Cold storage, C emission, Energy saving

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1. INTRODUCTION

World population will reach 9.6 billion by 2050 and consequently % 70 more food production will be required (Krishnan et al., 2020). As parallel with increase world population, demand for vegetables and fruits is also increasing. According to United Nations Food and Agriculture Organization (FAO) 2016 data, 865.8 million tons of fresh fruit production in 65.2 million hectares and 1 billion tons of fresh vegetables were produced in 57 million hectares of land in the world. Especially tomato is most produced vegetable that was 182,301,395 tons in 2017 (FAO 2019a). Almost half of cultivated products are lost before they even reach consumption stage. In the future, post-harvest reducing play an important role on world pop- ulation (Gustavsson et al., 2011). From this point of view, preventing or at least minimizing loss of fresh fruits and vegetables becomes an important issue. The loss rate of fresh fruits and vegetables, which are perishable products, %50 reaches result of disruptions and misapplications in harvest-transport-cooling-packaging-storage-transportsales chain (Sorhocam, 2020). Most factors (processing, storage and transport conditions) play important role in deterioration reactions of fruits and vegetables on their transport from grower to consumer. If these factors are not properly controlled, there will be large post-har- vest losses (Table 1). Changes in fresh products cannot be stopped, but it is possible to minimize losses with low temperature, relative humidity control, appropriate packaging and transporta- tion measures (Ahmad and Siddiqui, 2015). On the other hand, thermal energy storage (TED) materials, can be used efficiently when lack of resources to produce energy or with cooling systems that are opened at 4-5hour intervals. PCM design and implementation of food safety sys- tem has attracted great interest in recent years. Using these technologies minimizing food waste enables optimal planning of distribution networks and this reduces the carbon emissions of the entire supply chain.

2. SOME FRUIT AND VEGETABLE POSTHARVEST LOSSES

Increasing shelf life of products, including thermal or refrigerated packaging methods, from production center to point of consumption and main parts of cold chain, which is a logistics system that provides most ideal conditions for perishable products to maintain its quality that are as follows:

•Food processing (eg freezing of some processed foods)

•Cold storage (short or longterm storage of frozen foods)

•Distribution (refrigerated shipping and temporary storage in temperature controlled conditions)

•Marketing (in wholesale markets, retail markets and food service businesses, it is the placing of the product in warehouses and showcases with refrigerators or freezers (Postharvest, 2017).

If storage and transportation conditions are not followed in cold chain from the grower to consumer, post-harvest losses increase. Lowering temperature and controlling relative humidity can reduce losses (Ahmad and Siddiqui, 2015). Moisture loss, bruising and subsequent spoilage are types of spoilage that cause fresh fruit and vegetables to be discarded (Kitinoja and Al-Hassan, 2010; Ray and Ravi, 2005). Production and marketing losses are experienced in stages between the production and consumption of all fresh fruits and vegetables, especially tomatoes and for example Turkey marketing loss of 12 billion TL/year than fresh fruit and vegetables (FAOSTAT, 2019). Cold storage applications have become inevitable and necessary to reach markets. Depending on these developments; world cold storage capacity has reached 552 million m3 (Salin, 2010; Cantek, 2016). Post-harvest product losses in developed countries are less than in yet developing countries (Table 1, 2) (Erkan, 2021).

Table 1. Postharvest product losses in fresh fruits and vegetables in *developed* countries (Erkan, 2021)

Products	Loss Rates (%)
Leaf salad, iceberg	11.7
Cucumber	7.9
Sweet pepper	10.6
Tomato	14.7
Potato	4.9
Apple	1.7
Pear	4.1
Peach	12.6
Strawberry	22
Orange	10-12

Table 2. Postharvest product losses in fresh fruits and vegetables in developing countries (Erkan, 2021).

Products	Loss Rates (%)
Lettuce, Leaf salad	62
Cabbage	37
Cauliflower	49
Tomato	20-50
Onion	16-35
Potato	5-40
Apple	14
Peach	28
Grape	20-95
Citrus	23-33
Banana	20-80

3. COLD STORAGE APPLICATIONS AND ENERGY USE TO POSTHARVEST FRUIT AND VEGETABLES

It is known that nearly fifty percent of these losses are caused by technical errors related to control and temperature management. Cold air technologies are important in logistics and temperature of sensitive food products. Microbiological and chemical deterioration occur with temperature fluctuations in cold chain so as mostly at transportation vehicles or transportation transitions (İzer, 2017). Although insulating cooling equipment is used to reduce this risk, there is no latent heat storage feature at low temperatures. After harvest, fruits and vegetables survive and perform all functions of a living tissue (Joas and L´ecaudel, 2008). Increasing the quality of fresh fruits and vegetables cannot be changed, provided that naturalness is preserved in terms of technology, it is only preserved (Tigist, 2013). The postharvest treatment methods that must be followed to maintain this quality are as follows; methylcyclopropene (1-MCP), calcium Chloride (CaCl2) application, modified atmosphere packaging (MAP), tomato postharvest heat treatment, cooling storage (Arah et al., 2016).

The determination of harvest maturity stage depends on desired market target and time required to fruit market. The most effective factor in hardness change after fruits harvest is ambient temperature and temperature rises, the hardness values decrease rapidly. For this reason, strength of harvested fruits can be increased by moving them from field or garden to a cool place (Mercan, 2005). Although plants produce pathogenic bacteria, pectolytic and softening enzymes, most of bacteria that cause soft rot in many products belong to certain Erwinia species (Aysan et al., 2003). Erwinia carotovora subsp. carotovora (Jones) Dye and Erwinia carotovora subsp. atroseptica (van Hall) Dye (soft rot): They are most important bacterial diseases that cause damage to many crops, especially tomatoes and peppers. One of the most easily recognized mold fungi is Alternaria ssp. (Kadakal et al., 2011). These patho- gens are spread by splashing water on soil, wind, harvest and postharvest processes. Bacteria pass- es from a rotten product to healthy product by flow. Packaging fresh fruits and vegetables can reduce food losses with better and smarter packaging design to keep food fresh longer.

Therefore, suitable packaging systems should be designed (Elik et al., 2019). In developing countries, lack of cooling system is seen as main cause of postharvest losses (FAO, 2013).

The world cold storage capacity has reached 552 million m3. In this capacity, India (133 million m3), USA (114 million m3) and China (76 million m3) occupy top three places and Turkey ranks 13th with Spain, which has same capacity, with a capacity of 7 million m3. While total growth was % 5 in 17 countries where cold air investments are concentrated growth was % 10 in Turkey, India, Peru and China. Cooling; for perishable horticultural crops, it reduces respira- tion, reduces spoilage and natural ripening rates, slows down ripening by reducing transpiration, water loss, wrinkling, as well as ethylene produc- tion, reduces activities of microorganisms, black- ening, loss of texture, taste and nutritional value (Kitinoja and Kader, 2015). Cooling systems consume electrical energy, about % 40 of total energy consumption (Sarafoji et al., 2021). Traditionally, vapor compression refrigeration cycles are used in cold stores (Üçgül, 2009). In this cycle, energy required for compression work in compressor is met by electrical energy. Among other energy sources, electrical energy is seen as cleanest source in terms of environmental impact. However, this is not case when electrical energy is considered as a source of generation. In many countries around the world, electrical energy is still produced in thermal power plants and using fossil fuels. This situation reveals that there is an indirect environmental polluting effect in electrical energy. For example, Turkey produces approximately % 75 of its electricity in thermal power plants that use fossil fuels (UNDP, 2006; Tarakcıoğlu, 1984; TUSIAD, 1998). The indirect environmental impact arising from use of electrical energy is a subject that must be examined.

Examination of export problems of South African fruit producers from Cape Town port with refrigerated ship containers over the port, it has been determined that one of the important factors in quality of fruits and product losses is temperature changes they are exposed to when the refrigerated container is loaded from cold storage while on truck and containers are plugged into power source during transfer of containers from truck to ship at port. In addition, design of cooling system in refrigerated ship containers is sufficient to maintain a certain temperature but because it is not sufficient for cooling, the importance of loading the fruits into these containers at recommended coldness. İmportance of initial cooling and critical importance of maintaining temperature reached here throughout entire transport are expressed in same research (Goedhals-Gerber et al., 2015).

Temperature is main determining factor for shelf life and product quality in food cold chain. As an alternative, active refrigerator boxes can be used, provided batteries are charged and active cold pack box systems that can cool provided that cold packs are replaced or dry ice is added and replaced to control system batteries (Rong et al., 2011). Especially in domestic transportation, non-refrigerated vehicles are used, so cold chain/ air conditioning cannot be applied. The solution proposal is; It is envisaged to expand vehicle tracking systems and heat recording devices in fresh fruit and vegetable transportation, especially refrigerated vehicle transportation and to ensure traceability of products. In a different study total logistics cost of okra after harvest was calculated as 2,191,978.56 TL/500kg (Çakır, 2019) and cost of an integrated ice store in a 3ton chiller was subtracted and amortization period was determined for a "partial storage" application. Cold storage system electricity consumption in 8 hours can cost amounting to 4,971,700 TL to 41.5 kWh (Basaran and Erek, 2001). Mechanical systems used in refrigerated transportation are not shut down under any circumstances and desired set interval value is not exceeded, two drivers are used, thus preventing cold chain from being broken since electrical energy taken from vehicle is not cut off. In short-term transportation applications, driver is obliged to leave vehicle in working condition during meals or short-term stays.

In addition, fuel consumption increases as a high cooling load is brought to refrigerated vehicle (Kılıç, 2018). Conventional vapor compression refrigeration systems cause 0.585 kg of carbon dioxide (CO2) to be released into the atmosphere to produce 1kWh cold effect, also cost for 1kWh cooling effect is 0.016 Euro/kWh (SE) for ejector system and 0.178 Euro/kWh (SE) for con- ventional cooling system (Üçgül, 2009).

4. PCMS ROLE IN ENERGY USE AND ITS IMPACT ON C EMISSIONS

Heat energy can be stored as sensible, latent and thermochemical energy. Latent heat storage is most interesting method. PCMs are substances that can absorb and store heat during the phase change process and dissipate this stored heat in case of reverse phase change (Tao et al., 2008; Boan, 2005). The phase change is basically caused by temperature change caused by heat source coming from stable state of substance. In latent heat storage technique, PCMs have energy storage/release function during phase change at specified temperature. PCMs have an important place with high energy storage, isothermality and controlled phase change (Zalba et al., 2003; Kenisarin and Mahkamov, 2007).

Many organic and inorganic PCMs and their mixtures (Fig.1) are used in solar heating (water, building etc.) and temperature regulation in textiles, thermal management of electronics, biomedical and biological transport systems, etc. PCMs have high impact strength and chemical resistance (Alkan et al., 2006). PCMs are nowadays used in solar energy storage, heat pumps, heating and air conditioning in buildings, heat distribution systems, etc. widely used in the fields. Studies on PCM microcapsules have increased in the last 10 years (Gulfam et al., 2020).

Preparation of new generation materials with modified PCM studies, for example, a new PCM was synthesized by connecting polyethylene terephthalate to polyethylene glycol (Gungor Ertugral and Alkan, 2021). In solid-liquid phase change, food packaging containing PCM in solid state can minimize temperature fluctations that can occur foodstuff (Johnston et al., 2008) also provides insulation by preventing chang- ing ambient temperature from reaching food for a long time. Organic and inorganic PCMs have been tried by many researchers to elicit maximum thermal efficiency available (Sathishkumar et al., 2020). PCM system was used to home refrigerator and compressor worked 3,566 hours a day and operating time was reduced by 45 minutes compared to previous year and it was observed that carbon dioxide emissions were reduced by % 17.4 and fossil fuel consumption by 28 kg and 12 liters per day, respectively (Zarajabad and Ahmadi, 2018). Functional food packaging materials and petroleum, electricity, etc.

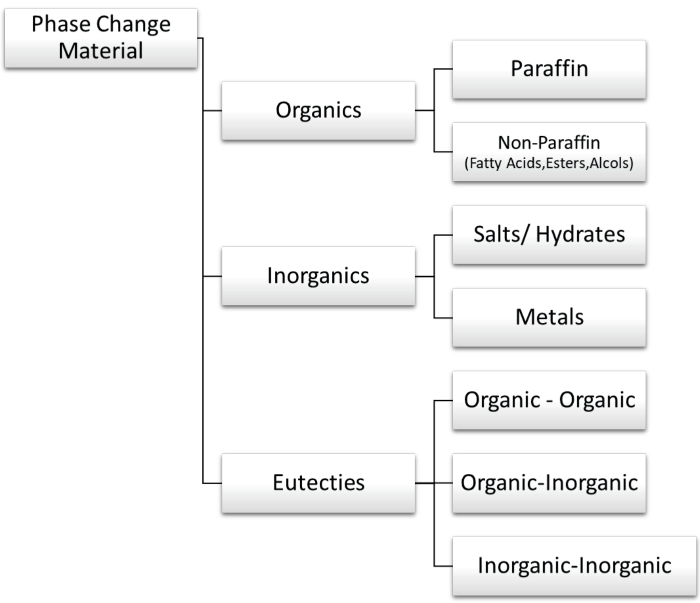

Figure 1. Classification of PCMs (Tatsidjodoung et al., 2013).

It is possible to preserve quality and safe food by using as little energy sources as possible. For this purpose, the interest in environmentally friendly, new generation, smart packaging materials that can keep food cold for a certain period time, which is beneficial to the global economy as parallel.

5.APPLICABLE PCMS TO COLD STORAGE OF POSTHARVEST FRUIT AND VEGETABLES

Appropriate PCM selection is save energy for cold chain during storage and transportation of foods. Preservation of storage temperature in range of 8-10 °C suitalbe to ripe tomatoes and it is also best storage temperature range for potatoes, citrus fruits, star fruit, melon, okra, pineapple and zucchini (Cantwell, 2001).

Various PCMs can be used as packaging material to keep temperature constant by using minimum external energy source in cold chain applications of postharvest fruits and vegetables whose storage temperatures vary between 5-18°C (Table 3).

It has been observed that a PCM plate integrated in a vertical structure reduces energy consumption by about 10 times, when plate thickness increases by 6 mm, the compressor run time ratio decreased from % 36 to % 26 (Ezan et al., 2017) and Rubitherm brand PCMs used in storage boxes for cold chain applications that have been effective in cooling (Du et al., 2020).

6. CONCLUSIONS

In recent years, PCMs have been developed in field of microencapsulation, shape stabilization and materials as nanomaterials. PCM technology has been widely studied in building, cooling, thermal management of electronic equipment and various other fields. With selection of the appropriate PCM, especially commercially available paraffin PCMs, postharvest fruits and vegetables can be stored for a long time without need for another energy source, and even in case of a solar-powered system, it is possible to build a warehouse that can cool with % 100 green energy. A system developed with smart materials without using electricity and petroleum fuel can be completely environmentally friendly. If these new generation smart materials are applied to refrigerated vehicles and continuous cooling units in food logistics, it is possible to reduce the C emulsion because less petroleum fuel and electricity will be consumed. In this way, the operating principle close to raw material, which is important for fruit and vegetable industry can be changed by cheap and economical trans- portation systems. Decrease in transportation costs, which are reflected in food prices in con- sumer society, cheaper food consumption can be achieved and opportunity for healthy nutrition increases. Green energy systems supported by natural energy sources such as solar energy or wind energy supported by PCMs instead of petroleum-derived fuels that cause environmental pollution can provide economical food consumption and a clean environment.

Table 3. Applicable PCMs preservation for postharvest fruit and vegetable

PCM	Tm˚C	Latent Heat (J/g)	
Tetrahydrofuran	5	280	Yang et al., 2018.
n-Tetradecane	5.5	226	Sharma, 2004.
Formic Acid	7.8	247	Sharma, 2004.
Polyethyleneglycol 400	8	99.6	Sharma, 2004.
Dimethyl adipate	9.7	164.6	Yang et al., 2018.
n-Pentadecane	10	205	Sharma, 2004.
D2O	3.7	318	Sharma, 2004.
LiClO4.3H2O	8	253	Sharma, 2004.
NH4Cl.Na2SO4.10H2O	11	163	Sharma, 2004.
Caprylic acid + 1-dodecanol (70:30) 6.52 171.06	6.52	171	Zuo et al.,2011
Caprylic alcohol + Mynstyl alcohol (73.7:26.3 by mass)	6.9	169	Wu et al., 2015.
Lauryl alcohol + Octanoic acids (40.6:59.4)	7	179	Hu et al., 2011.
Capric acid and lauric acid (65:35 by mole) + Pentadecane (50:50 by volume)	10	158	Dimaano and Watanabe 2002.
Capric acid and lauric acid (65:35 by mole) + Pentadecane (70:30 by volume)	11	149	Dimaano and Watanabe 2002.
C5H5C6H5 + (C6H5)2O (26:73.5)	12	98	Sharma, 2004.
Capric acid and lauric acid (65:35 by mole) + 0.10 mol Cineole	12	112	Roxas-Dimaano and Watanabe, 2002.
Capric acid and lauric acid (65:35 by mole) + 0.10 mol Methyl Salicylate	13	127	Dimaano and Watanabe 2002.
Capric acid and lauric acid (65:35 by mole) + Pentadecane (90:10 by volume)	13	142	Dimaano and Watanabe 2002.
Capric acid and lauric acid (65:35 by mole) + 0.10 mol Eugenol	13	118	Dimaano and Watanabe 2002.
Capric acid + Lauric acid-oleic acid	15	109	Jia et al., 2019

Table 3 (continue). Applicable PCMs preservation for postharvest fruit and vegetable

PCM	Tm°C	Latent Heat (J/g)	
Lauric + 1-dodecanol (29:71)	17	175	Kumar et al., 2017
Capric acid + Lauric aci (65:35 by mole)	18	140	Dimaano and Watanabe 2002.
Myristic + 1-dodecanol (17:83)	18	181	Kumar et al., 2017
31% Na2SO4 + 13% NaCl + 16% KCl + 40% H2O	4	234	Sharma, 2004.
K2SO4 + Carboxymethyl cellulose + (NaPO3)6 + borax + boric acid (76 + 10.3+ 3.6 + 2 + 3.2 + 0.1 + 2.4 + 2.4)	8.2	114	Liu et al., 2007
55% CaCl2 ·6H2O + 55% CaBr2 ·6H2O 14.7 140 [28] NaOH (3/2) H2O	15	140	Cabeza et al., 2011
Rubitherm T3(RT3) Paraffin	3	198	Rubitherm, 2021
RT4 Paraffin	4	182	Rubitherm, 2021
RT5 Paraffin	5.2	158	Rubitherm, 2021
RT6 Paraffin	6	175	Rubitherm, 2021
MPCM (6) Paraffin	6	167	Microteklabs,2021
ClimSel C7 Organic	7	130	Climator, 2021
PureTemp 8 Organic	8	180	Puretemp, 2021
PCM-OM08P Organic	8	190	Zhang et al., 2021
PCM-OM11P Organic	11	260	Zhang et al., 2021
A8 Organic	8	150	Epsltd, 2021.
RT 8 Organic	8	180	Rubitherm, 2021
RT 9 Organic	9	160	Rubitherm, 2021
A9 Organic	9	140	Epsltd, 2021.
RT10 Organic	10	150	Rubitherm, 2021
RT 10 HC Organic	10	195	Rubitherm, 2021
S1 0 Organic	10	155	Cristopia, 2021
PureTemp 12 Organic	12	185	Puretemp, 2021
RT12 Organic	12	150	Rubitherm, 2021

REFERENCES

AHMAD, M. S., & SIDDIQUI, M. W. (2015). Factors affecting postharvest quality of fresh fruits. In *Postharvest quality assurance of fruits* (pp. 7-32). Springer, Cham. https://link.springer.com/chapter/10.1007/978-3-319-21197-8_2

ALKAN, C., SARI, A., & UZUN, O. (2006). Poly (ethylene glycol)/acrylic polymer blends for latent heat thermal energy storage. *AIChE journal*, *52*(9), 3310-3314. https://aiche.onlinelibrary.wiley.com/doi/epdf/10.1002/aic.10928

ARAH, I. K., AHORBO, G. K., ANKU, E. K., KUMAH, E. K., & AMAGLO, H. (2016). Postharvest handling practices and treatment methods for tomato handlers in developing countries: A mini review. *Advances in Agriculture*, *2016*. https://doi.org/10.1155/2016/6436945

Available online: www.cristopia.com (accessed on 1 September 2021).

Available online: www.epsltd.co (accessed on 1 September 2021).

Available online: www.puretemp.com (accessed on 1 September 2021).

Available online: www.climator.com (accessed on 1 September 2021).

Available online: www.rubitherm.eu (accessed on 1 September 2021).

Available online: www.microteklabs.com (accessed on 1 September 2021).

AYSAN, Y., KARATAS, A., & CINAR, O. (2003). Biological control of bacterial stem rot caused by Erwinia chrysanthemi on tomato. *Crop Protection*, *22*(6), 807-811. https://doi.org/10.1016/S0261-2194(03)00030-9.

BAŞARAN, T., & EREK, A. (2001). Bir Soğu Deposunun Ekonomik Analizi. *IV. Ulusal Tesisat Mühendisliği Kongresi ve Sergisi*.http://www1.mmo.org.tr/resimler/dosya_ekler/9774cc26d95f2b3_ek.pdf.

BOAN, Y. (2005). Physical mechanism and charactarization of smart thermal clothing. *The Hong Kong Polytechnic University, PhDThesis, Hong Kong*. https://theses.lib.polyu.edu.hk/bitstream/200/1884/1/b18967693.pdf

BO, H., GUSTAFSSON, E. M., & SETTERWALL, F. (1999). Tetradecane and hexadecane binary mixtures as phase change materials (PCMs) for cool storage in district cooling systems. *Energy*, *24*(12), 1015-1028. https://doi.org/10.1016/S0360-5442(99)00055-9

CABEZA, L. F., CASTELL, A., BARRENECHE, C. D., DE GRACIA, A., & FERNÁNDEZ, A. I. (2011). Materials used as PCM in thermal energy storage in buildings: A review. *Renewable and Sustainable Energy Reviews*, *15*(3), 1675-1695. https://doi.org/10.1016/j.rser.2010.11.018

CANTEK, 2016. Dünya Soğuk Hava Depo Kapasitesi. CANTEK GROUP Şubat Bülteni 2016/3. https://www.turktob.org.tr/dergi/makaleler/dergi17/TTOB_Dergi17_WEB-28_31.pdf

CANTWELL, M. (2001). Properties and recommended conditions for long-term storage of fresh fruits and vegetables. *Storage Recommendations, Department of Plant Sciences, University of California,Davis*.https://www.carolinafarmstewards.org/wp- content/uploads/2015/05/Properties-and-Recommended-Conditions.pdf

ÇAKIR, G. (2019). *Tarımsal ürünler tedarik zinciri yönetimi: Amasya çiçek bamyası uygulaması* (Master›s thesis, Maltepe Üniversitesi, Sosyal Bilimler Enstitüsü). http://openaccess.maltepe.edu.tr/xmlui/handle/20.500.12415/2992

DIMAANO, M. N. R., & WATANABE, T. (2002). The capric–lauric acid and pentadecane combination as phase change material for cooling applications. *Applied Thermal Engineering*, *22*(4), 365-377. https://doi.org/10.1016/S1359-4311(01)00095-3. https://doi.org/10.1016/S1359-4311(01)00095-3

DU, J., NIE, B., ZHANG, Y., DU, Z., & DING, Y. (2020). Cooling performance of a thermal energy storage-based portable box for cold chain applications. *Journal of Energy Storage*, *28*, 101238. https://doi.org/10.1016/j.est.2020.101238

ELIK, A., YANIK, D. K., ISTANBULLU, Y., GUZELSOY, N. A., YAVUZ, A., & GOGUS, F. (2019). Strategies to reduce post-harvest losses for fruits and vegetables. *Strategies*, *5*(3), 29-39. https://www.btb.org.tr/images/raporlar/13/main.pdf

ERKAN M. "Bahçe Ürünlerinde Depolama ve Muhafaza". https://baib.gov.tr/files/downloads/PageFiles/e9a02402-d812-401a-8fe3-bea324c1003b/Files/urun%20depolama%20ve%20paketlem%20(2).pdf. Son erişim tarihi:26. Ekim.2021

EZAN, M. A., DOGANAY, E. O., YAVUZ, F. E., & TAVMAN, I. H. (2017). A numerical study on the usage of phase change material (PCM) to prolong compressor off period in a beverage cooler. Energy conversion and management, 142, 95-106. https://doi.org/10.1016/j.enconman.2017.03.032

FAO. 2013. Report of the Expert Consultation Meeting on Food Losses and Waste Reduction in the Near East Region: Towards a Regional Comprehensive Strategy, Egypt, 33p.

FAO 2019a, https://www.fao.org/documents/card/en/c/ca6030en/, Son erişim: 25.03.2022.

FAOSTAT, http://www.fao.org/faostat/en/#data/QC/visualize, Son erişim tarihi: 19 Mayıs 2019.

GOEDHALS-GERBER, L. L., HAASBROEK, L., FREIBOTH, H., & VAN DYK, F. E. (2015). An analysis of the influence of logistics activities on the export cold chain of temperature sensitive fruit through the Port of Cape Town. *Journal of Transport and Supply Chain Management*, *9*(1), 1-9. file:///C:/Users/COMU/Downloads/goedhalsgerber_analysis_2015.pdf

GUSTAVSSON, J., CEDERBERG, C., SONESSON, U., VAN OTTERDIJK, R. M., & MEYBECK, A. A. (2011) Global food losses and food waste: extent, causes and prevention. *FAO Rome*, 38. https://www.fao.org/3/I2697E/i2697e.pdf

GULFAM, R., OREJON, D., CHOI, C. H., & ZHANG, P. (2020). Phase-change slippery liquid-infused porous surfaces with thermo-responsive wetting and shedding states. *ACS Applied Materials & Interfaces*, *12*(30), 34306-34316. https://pubs.acs.org/doi/pdf/10.1021/acsami.0c06441.

GÜNGÖR ERTUĞRAL, T., & ALKAN, C. (2021). Synthesis of thermally protective PET–PEG multiblock copolymers as food packaging materials. *Polymers and Polymer Composites*, *29*(9_suppl), S1125-S1133. https://doi.org/10.1177%2F09673911211045683

GAO, H. T. (2011, May). Investigation on organic phase transition materials in Energy Storage Air Conditioning system. In *2011 International Conference on Materials for Renewable Energy & Environment* (Vol. 1, pp. 669-672). IEEE. https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5930898

HU, X. C., WU, H. J., & ZHOU, X. Q. (2011). Crystallizing characteristics of binary mixtures of Dodecanol/Caprylic acid for phase change cool storage. *Journal of Guangzhou University (Natural Science Edition)*. http://en.cnki.com.cn/Article_en/CJFDTOTAL-GUDZ201102013.htm

İZER, D. A. (2017). Soğuk Zincir Lojistiği İçinde Risklerin Azaltilmasinda Yeni Teknolojiler.file:///C:/Users/COMU/Downloads/SOGUK_ZINCIR_LOJISTIGI_ICINDE_RISKLERIN%20(1).pdf

JIA, X., ZHAI, X., & CHENG, X. (2019). Thermal performance analysis and optimization of a spherical PCM capsule with pin-fins for cold storage. *Applied Thermal Engineering*, *148*, 929-938. https://doi.org/10.1016/j.applthermaleng.2018.11.105

JOAS, J., & LÉCHAUDEL, M. (2008). A comprehensive integrated approach for more effective control of tropical fruit quality. Stewart Postharvest Review, 4(2), 1-14. https://access.portico.org/stable?au=phx64r67x6b

JOHNSTON, J. H., GRINDROD, J. E., DODDS, M., & SCHIMITSCHEK, K. (2008). Composite nano-structured calcium silicate phase change materials for thermal buffering in food packaging. Current Applied Physics, 8(3-4), 508-511. https://doi.org/10.1016/j.cap.2007.10.059

KADAKAL, Ç., ARTIK, N., & SEBAHATTIN, N. A. S. (2011). Domates doku ve küf karakteristikleri, domates ürünlerinde küf sayimi ve küfü azaltma olanakları. *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, *7*(2), 251-260. https://dergipark.org.tr/en/download/article-file/191366

KENISARIN, M., & MAHKAMOV, K. (2007). Solar energy storage using phase change materials. *Renewable and sustainable energy reviews*, *11*(9), 1913-1965. https://doi.org/10.1016/j.rser.2006.05.005

KRISHNAN, R., AGARWAL, R., BAJADA, C., & ARSHINDER, K. (2020). Redesigning a food supply chain for environmental sustainability–An analysis of resource use and recovery. *Journal of cleaner production*, *242*, 118374. https://doi.org/10.1016/j.jclepro.2019.118374

KILIÇ, G. A. (2018). Endüstriyel soğutma uygulamalarında ötektik soğutucuların etüdü ve parametrelerinin incelenmesi. https://dspace.balikesir.edu.tr/xmlui/bitstream/handle/20.500.12462/3285/G%C3%BClenay_Alevay_K%C4%B11%C4%B1%C3%A7.pdf?sequence=1&isAllowed=y

KITINOJA, L., & ALHASSAN, H. Y. (2010). Identification of appropriate postharvest technologies for small scale horticultural farmers and marketers in sub-Saharan Africa and South Asia-Part 1. Postharvest losses and quality assessments. In *XXVIII International Horticultural Congress on Science and Horticulture for People (IHC2010): International Symposium on 934* (pp. 31-40). https://doi.org/10.17660/ActaHortic.2012.934.1

KITINOJA, L., & KADER, A. A. (2015). Measuring postharvest losses of fresh fruits and vegetables in developing countries. *PEF white paper*, *15*, 26. http://www.postharvest.org/PEF_White_Paper_15-02_PHFVmeasurement.pdf

KUMAR, R., VYAS, S., & DIXIT, A. (2017). Fatty acids/1-dodecanol binary eutectic phase change materials for low temperature solar thermal applications: design, development and thermal analysis. *Solar Energy*, *155*, 1373-1379. https://doi.org/10.1016/j.solener.2017.07.082

LIU, J. H., LIU, R. H., WANG, C. H., & LIANG, Y. N. (2007). Thermodynamics test of Na2SO4· 10H2O phase change compound system. *Energy Conserv*, *9*, 13-14. http://en.cnki.com.cn/Article_en/CJFDTOTAL-JNJN200709004.htm

MERCAN, T. (2005). Organik gübreleme yapılarak tarım ilacı çok kullanılmadan ve klasik yöntem uygulanarak üretilen domatesler ile bunlardan elde edilen bazı ürünlerin kalitelerinin belirlenmesi. https://acikerisim.uludag.edu.tr/bitstream/11452/5218/1/198676.pdf

POSTHARVEST. (2017). Meyve ve Sebzelerin Depolama ve Nakliye Uygulamaları Eğitim Materyali. "Gıda Zincirindeki Hasat Sonrası Kayıpları Azaltmak için Yenilikçi Yaklaşımlar". 2017-1-TR01-KA202-045709. http://www.postharvestproject.com/uploads/outputs/57acfd7e-db50-4466-bfe4-1700e847f9e3.pdf. Son erişim tarihi: 26 Ekim 2021.

RAY, R. C., & RAVI, V. (2005). Post harvest spoilage of sweetpotato in tropics and control measures. *Critical reviews in food science and nutrition*, *45*(7-8), 623-644. https://www.tandfonline.com/doi/pdf/10.1080/10408390500455516

ROXAS-DIMAANO, M. N., & WATANABE, T. (2002). The capric and lauric acid mixture with chemical additives as latent heat storage materials for cooling application. *Energy*, *27*(9), 869-888. https://doi.org/10.1016/S0360-5442(02)00024-5

ÜÇGÜL, İ. (2009). Soğuk depolama için güneş enerjili ejektör soğutma sistemi uygulamasının termodinamik çevresel ve ekonomik analizleri. *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, *15*(2), 269-277. https://dergipark.org.tr/en/download/article-file/190925

RONG, A., AKKERMAN, R., & GRUNOW, M. (2011). An optimization approach for managing fresh food quality throughout the supply chain. *International Journal of Production Economics*, *131*(1),421,429. https://doi.org/10.1016/j.ijpe.2009.11.026https://www.sciencedirect.com/science/article/pii/S0925527309004290.

SALIN, V. (2010). Global cold storage capacity report. *Report for the International Association oRefrigeratedWarehouses.Alexandria:IARW*.https://login.totalweblite.com/Clients/wscbanet/database- 01%20 2010%20cold%20storage%20capacity%20report.pdf.

SARAFOJI, P., MARIAPPAN, V., ANISH, R., KARTHIKEYAN, K., & REDDY, J. (2021). Performance study of solar photovoltaic cold storage system using phase change materials. *Materials Today: Proceedings*, *46*, 9623-9629. https://doi.org/10.1016/j.matpr.2020.07.116

SATHISHKUMAR, N., KUMAR, V. A., GOKULNATH, M., & RAJ, G. K. (2020). Performance analysis of palmitic acid coated PCM storage container. *Int. J. Res. Rev*, *7*(3). http://www.ijrrjournal.com/IJRR_Vol.7_Issue.3_March2020/Abstract_IJRR0067.html

SHARMA, S. D., KITANO, H., & SAGARA, K. (2004). Phase change materials for low temperature solar thermal applications. *Res. Rep. Fac. Eng. Mie Univ*, *29*(1), 31-64. https://www.eng.mie-u.ac.jp/research/activities/29/29_31.pdf

SORHOCAM.COM. "Hasat sonrası kayıplar", https://www.sorhocam.com/konu.asp?sid=1124&meyve vesebzelerin-muhafazasi.html. Son erişim tarihi: 26 Ekim 2020.

TARAKCIOĞLU, I. 1984. Tekstil Proses İşlemlerinde Enerji Tüketimleri ve Ekonomisi, Uludağ Üniversitesi. Tekstil Müh. Böl. Yayınları, 18. https://acikerisim.uludag.edu.tr/bitstream/11452/2596/1/284812.pdf.

TAO, Y., LI, X., & WU, B. (2008, October). An Effective PCM Based Environment Compensation Approach in Speech Processing for Mobile e-Learning Platform. In *2008 Third International Conference on Pervasive Computing and Applications* (Vol. 2, pp. 772-775). IEEE. https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4783713

TATSIDJODOUNG, P., LE PIERRÈS, N., & LUO, L. (2013). A review of potential materials for thermal energy storage in building applications. *Renewable and Sustainable Energy Reviews*, *18*, 327-349. https://doi.org/10.1016/j.rser.2012.10.025

TIGIST, M., WORKNEH, T. S., & WOLDETSADIK, K. (2013). Effects of variety on the quality of tomato stored under ambient conditions. *Journal of food science and technology*, *50*(3), 477-486. https://link.springer.com/article/10.1007/s13197-011-0378-0.

TUSIAD, 1998, "21. yy. Girerken Turkiye'nin Enerji Stratejisinin Degerlendirilmesi" TUSIAD-T/98-12/239.

UNDP, (2006). GEF Destek Programı (SPG), Küresel İklim Değişiklikleri için Yerel Çözümler ve SPG Yaklaşımı, TTGV., ART Tanıtım LTD. Şti. 8-12.

ÜÇGÜL, İ. (2009). Soğuk depolama için güneş enerjili ejektör soğutma sistemi uygulamasının termodinamik çevresel ve ekonomik analizleri. *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, *15*(2), 269-277. https://dergipark.org.tr/en/download/article-file/190925

WU, W., TANG, H., MIAO, P., & ZHANG, H. (2015). Preparation and thermal properties of nano-organic composite phase change materials for cool storage in air-conditioning. *CIESC J*, *66*, 1208-1214. http://dx.doi.org/10.11949/j.issn.0438-1157.20141252

YANG, T., SUN, Q., WENNERSTEN, R., & CHENG, L. (2018). Review of phase change materials for cold thermal energy storage. *Journal of Engineering Thermophysics*, *39*(3), 567. file:///C:/Users/COMU/Downloads/Yang_2018_Review_of_Phase_Change_Materials_for%20(4).pdf

ZALBA, B., MARIN, J. M., CABEZA, L. F., & MEHLING, H. (2003). Review on thermal energy storage with phase change: materials, heat transfer analysis and applications. *Applied thermal engineering*, *23*(3), 251-283. https://doi.org/10.1016/S1359-4311(02)00192-8

ZARAJABAD, O. G., & AHMADI, R. (2018). Numerical investigation of different PCM volume on cold thermal energy storage system. *Journal of Energy Storage*, *17*, 515-524. https://doi.org/10.1016/j.est.2018.04.013

ZHANG, X., SHI, Q., LUO, L., FAN, Y., WANG, Q., & JIA, G. (2021). Research Progress on the Phase Change Materials for Cold Thermal Energy Storage. *Energies*, *14*(24), 8233. https://doi.org/10.3390/en14248233

ZHAO, Y., ZHANG, X., XU, X., & ZHANG, S. (2020). Development of composite phase change cold storage material and its application in vaccine cold storage equipment. *Journal of Energy Storage*, *30*, 101455. https://www.sciencedirect.com/science/article/pii/S2352152X20304564

ZUO, J., LI, W., & WENG, L. (2011). Thermal performance of caprylic acid/1-dodecanol eutectic mixture as phase change material (PCM). *Energy and Buildings*, *43*(1), 207-210. https://doi.org/10.1016/j.enbuild.2010.09.008

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ORIGINAL ARTICLE

The effect of climate change on agricultural production in Bulgaria

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ABSTRACT

Plant organisms are phenological indicators of weather and climate and are often used as a non-instrumental tool for its analysis. The reactions of crops, their growth and development are a direct result of environmental conditions. Solar radiation, air temperature and precipitation are the main factors that determine their productivity. In search of the environment-plant connection, the science of agricultural meteorology emerged. This publication systematizes some of the main challenges facing agriculture and the main measures for adapting the sector to modern climatic conditions. Climate change and fluctuations lead to changes in the conditions of growth and development of agricultural crops. This has a direct bearing on the way the world produces, distributes and consumes food. Climate is directly related to the way and prospects for global production needed to sustain the human population. The population of people in the world is expected to reach to 10 billion by 2050. This poses a huge challenge to the global community on how to feed an additional 2.3 billion people through environmentally friendly methods and climate change.

Keywords: Climate change, agricultural production, Bulgaria

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1. INTRODUCTION

At the beginning of the 21st century (as of 2017) in Bulgaria, scientists from the National Institute of Meteorology and Hydrology (NIMH) report an increase in average air temperature by 0.8 °C as compared to the period between 1961-1990, as well as a change in precipitation distribution (Unlike the end of the last century, when the upward trend was well expressed in Northeastern Bulgaria (Kirova & Alexandrov, 2019) not given in references section), research now shows rising temperatures in southern and southeastern Bulgaria, defined as an area of frequent droughts in which cultivation of spring crops is risky in terms of humidification conditions in general. There has been an increase in the number of hot days (t max. <32 ^{0}C) in recent decades. In most stations there was a statistically significant trend of increasing the number of hot days by an average of 3 (4) full days per decade. On icy days, which are related to the nature of winter, there is a statistically significant decrease of 2 to 3 full days (Gospodinov, I. ed. (2020) because precise, local studies related to the conditions of the individual regions are needed here. In this direction, the researches in the field of agrometeorology and agroclimatology are also oriented. This leads to a change in the length of the potential growing season, faster accumulation of the required temperature sums and shortening of the interphase periods, which affects the yield of agricultural crops, irrigation, selection of appropriate types and varieties of crops.

The agricultural sector is focusing on environmentalists, as food production is one of the main causes of global environmental change: agriculture accounts for 40% of world land production and food is responsible for 21% of global greenhouse gas emissions and 70% of freshwater use. In the context of several key drivers of change (demographic and economic growth, changing consumption patterns, technological progress, integration of global trade or climate change), all of which will affect the agricultural value chain, the agri-food sector will have to adapts to this growing demand for food, while tackling the challenges of sustainability and health.

2. CLIMATE CHANGE IN BULGARIA AND THEIR CONNECTION WITH AGRICULTURAL SECTOR

Some climate models simulate an increase in air temperature for Bulgaria in the 21st century by between 2 ^{0}C and 5 ^{0}C when doubling the amount of carbon dioxide in the atmosphere. The projections are for more precipitation during the cold half of the year, in the period of moisture accumulation, when the plants do not have vegetation. During the warm half of the year the precipitation will maintain its levels or will decrease, which will increase the intensity and frequency of droughts and torrential rains. Modern climate forecasts are indicative and provide guidelines for the development of sectors.

The agri-food industry is a key pillar of the Bulgarian economy. It accounts for approximately 20% of total industrial production.

It has a strong impact on both domestic and foreign trade, affecting Bulgaria's export earnings, domestic consumption and the overall living standard of the population. The value of the sector's final production was recorded as EUR 5.4 billion in 2018 (Table 1), which marks a 38% increase since 2010.

Table 1. Annual production value of food and beverage manufacturing in Bulgaria

	2010	2011	2012	2013	2014	2015	2016	2017	2018
Production value (EUR million)	3 945	4 222	4 380	4 511	4 476	4 690	5 025	5 321	5 456

Source: Eurostat, 2019

The accession of Bulgaria to the EU in 2007 has significantly affected the Bulgarian agri-food sector.(Kirova, M., Montanari, F., Ferreira, I., Pesce, M., Albuquerque, J.D., Montfort, C., Neirynck, R., Moroni, J., Traon, D., Perrin, M., Echarri, J., Arcos Pujades, A., Lopez Montesinos, E., Pelayo, E., (2019).) Enterprises in the sector, which were already subject to privatization, buy-outs and foreign direct investments, needed to comply with much stricter food safety regulations and to adapt to higher levels of competition from the common market. Like the agriculture sector, this has resulted in restructuring and consolidation. Increased investments into technologies, know-how and marketing have been necessary for the continued competitiveness of Bulgarian agri-food enterprises.

On-farm processing is the most popular in the fruit and vegetable, dairy and meat sub- sectors. These farmers sell directly to consumers (e.g., in dairy, it is now common to have vendor machines with fresh milk to be placed in villages and daily re-charged from the dairy farm). As a next step, their marketing strategies cover contracting with local (in villages or small town) small-sized supermarkets and the careful expansion of sales, first, regionally, and then in more regions or nation-wide. The setting up of farm direct sales markets (where also processed food could be sold) is rather difficult at the moment, with the Wednesday market at the Ministry of Agriculture, Food and Forestry in Sofia being the most prominent and successful example. The RDP is yet to open the relevant measure, which can be a turning point for many small-scale farm processors as well as the farmers.

The agri-food sector exports a total of 160 markets worldwide. In 2018, Bulgaria's total exports were recorded as EUR 28.6 billion, of which 11.8% (EUR 3.4 billion) were from the agri-food sector. While this marked a year- on-year increase of 3.8%, exports have been relatively stable over the longer term. The top agri-food exports are cereal and vegetable products, at EUR 1.9 billion, and foodstuffs (baked goods, chocolate, canned vegetables, etc.), at EUR 1.3 billion. EU countries are the main customers for Bulgarian agriculture and agri- food goods due to the more favourable trade conditions within the European Single Market. In 2018, the trade of agriculture goods with the EU increased by 5.3% as compared to 2017, and accounted for 75% of Bulgaria's total agriculture exports.

3. THE FORMULATED MEASURES FOR ADAPTATION ACTIVITIES IN BULGARIA

According to a study, conducted by the European Parliament's Committee on Agriculture and Rural Development in 2019, following measures are recommended:

➢methods of genetics and selection;

➢ usage of crops having higher nutritional value;

➢ IoT (Internet of things) technologies for collecting and publishing information about production processes and the farm;

➢agricultural automation;

➢automatic management, monitoring and analysis of soils, areas, health status;

➢optimization of agricultural processes;

➢transparency, efficiency and accountability in the chain from producer to consumer.

➢In our country, the efforts include blue-green government policies aimed at investing in precision research and sustainable development in the sector.

Seventy percent of the water resources are formed at higher altitudes and forest vegetation, 60% of which meet the needs for irrigation. Irrigation is an active measure of impact that is needed both in relation to drought and in general. The expected warming and reduction of precipitation amounts, especially, in the warm half of the year, directly affect water quantities. Due to the condition of the irrigation facilities, irrigation is not used rationally. Several initiatives stand out in this direction like;

➢The main goal of the SuWaNu project is to develop technologies offering services for transnational cooperation within "research-oriented clusters", including universities, local authorities, research centers, technology-based companies, enterprises, farmers and agricultural associations related to waste treatment,

➢ These services will provide and facilitate the exchange of knowledge on water and food alternatives for all project members, create business opportunities in the field of focusing and further expand the support of stakeholders from countries outside the consortium, while providing solutions to the above-mentioned problems facing in Europe (Mention the source here).

➢Project proposals from Irrigation Systems "EAD", project proposals from irrigation associations and other legal entities for the restoration of existing hydro-ameliorative irrigation facilities. The first will support only projects submitted by the company. The total amount of financial assistance under this procedure is EUR 45,419,274. The maximum amount for one project is 6 million euros. The second eligible candidates are legal entities established and registered under the Irrigation Associations Act (LAA) and entered in the register of Irrigation Associations and legal entities, as well as established and registered Cooperatives Act. The total amount of financial assistance under the procedure is EUR 5,046,586. The maximum amount of eligible costs for the entire period of implementation of the RDP 2014-2020 per applicant is 1.5 million euros.

The National Program "Intelligent Plant Breeding", funded by the Ministry of Education and Science (MES) for a period up to 2024 and with a total budget of BGN 4.5 million provides through targeted scientific and applied research related to the application of artificial intelligence in agriculture, to reduce costs for farmers, improve soil management and water quality. The aim is to reduce the use of fertilizers and pesticides, greenhouse gas emissions, improve biodiversity and create a healthier environment for farmers and citizens.

The second program "Intelligent Animal Husbandry" envisages the creation of innovative methods and tools for intelligent and efficient development of animal husbandry with reduced human resources and reduced environmental effects. Researchers and breeders will have easy and controlled online access to tools, resources and tools for collaboration, to high-performance information and communication technologies for calculations. They will have the ability to connect, store data, access virtual research ecosystems and client networks.

4. ANALYSIS OF DEMAND FOR FINANCE

The potential total demand for finance combines both met and unmet demand. The met demand consists of the value of all applications for finance which were approved by the financial institutions in the relevant year. The unmet demand consists of the assumed value of applications rejected by a financial institution, offers of credit refused by agri-food enterprises, alongside cases where farmers are discouraged from applying for credit due to an expectation of rejection or refusal (Mention the source here).

The lending market for the agri-food sector is less concentrated than for the agriculture sector. While Unicredit Bulbank also dominates lending to the sector (around 20% share), other important players include DSK Bank, United Bulgarian Bank, Eurobank and Raiffeisenbank, each of them having around 10% of the market.

Financial products

While banks view the agri-food sector as being less risky than agriculture, the agri-food sector still receives more loan rejections as compared to other sectors of economy. This is caused by the fact that, in general, their businesses are connected to the agriculture business cycle and are therefore exposed to similar risks (e.g., weather, seasonality), although processors can mitigate these risks since they can also

Based on the agri-food survey, the unmet demand for the agri-food sector in Bulgaria is estimated at EUR 178.5 million.

According to the agri-food survey, most of the funding in the agri-food sector comes from self-fundings (87%). The importance of banks in meeting financial needs is below the EU 24 average for all loan products Hata! Köprü başvurusu geçerli değil.Hata! Köprü başvurusu geçerli değil.. Interviews with agri-food enterprises confirmed that the main reason why they rely on their own funds is to ensure full control over their business risk. These considerations explain why the majority of enterprises had not applied for external finance. Of the 33% of agri-food enterprises that applied for bank financing in 2018, long-term loans (17%), credit lines (14%) and medium-term loans were the most popular products.

The level of non-performing loans (NPL) in Bulgaria has been on a declining trend but remains higher than the EU average. According to figures from the National Bank of Bulgaria, NPLs as a share of total loans had decreased to 5.94% in 2019. The share of NPLs to non-financial corporations was slightly above those levels and stood at 6.8%. While the NPL ratio for loans to non-financial corporations was 17.15% at the beginning of 2016 (Mention the source here).

Large-sized agri-food firms have contributed to the high NPL ratio. Banks mentioned that not all investments made by their agri-food clients have had a positive return. Increased volatility on local and foreign markets has resulted in lower cash flows and in the crippling of the enterprises' ability to pay their instalments.

As indicated above, while interest rates have been decreasing over the last few years (write the years here like 0000-0000), they remain at relatively high levels. This is particularly the case for short-term credit. Interest rates have also been fluctuating recently, making financial planning challenging for agri-food enterprises. Long-term loans show a downward trend in interest rates and at present keep the lowest ever rates, at approximately 2.8% (for local currency loans).

Some of the small-sized enterprises are relying on informal credit providers to re-finance their debt, paying high interest rates and often being impacted by hidden terms in the contracts.

Banks require collateral for loans. They primarily accept buildings, land and facilities but, in general, all assets that can be easily converted into cash and for which the banks can have access to the legal titles are acceptable. For new entrants that are establishing their own start-ups and do not possess any assets, banks require property of the owner (real estate in urban areas) or contracted financial aid under the measures of RDP. For medium and long-term investment loans, agri-food entrepreneurs often cannot provide the required collateral. They remain interested in guarantees providing higher than the current guarantee rate and of bigger supply (Mention the source here).

The main criteria that influence the decisions of the agri-food companies in choosing the most suitable financing partner are 96 the longer grace periods and lower interest rates they could be offered (Mention the source here). This finding indicates that, when it comes to larger-sized enterprises, there is competition among the finance providers. This also means that large-sized agri-food enterprises can shop around for the best offers in terms of interest and fees, maturity, collateral and repayment schedule.

Product features and accompanying lending policies do not adequately reflect the business cycles of banks' clients. Banks are often unaware of the slow ramp-up time of investments, and the subsequent returns from them, per sub-sector, because of the time needed to establish agri-food assets and production facilities.

Moreover, banks do not have a tailored marketing strategy for agri-food SMEs and are unaware of how to approach in a best way with this client segment, as indicated in interviews with agri-food enterprises. This means that enterprises are not being made aware of new credit products available to them. The main communication tools that banks use are personal advisors who are responsible for providing information about new products and services.

5. CONCLUSIONS

Firstly, climate change is already affecting people and ecosystems: dangerous events caused by changing weather patterns, including floods, droughts, forest fires and extreme heat are becoming more common around the world. Climate change directly affects food and water security. Any warming can lead to reduce yields in conditions of growing demand for food and raw materials.

Secondly, among the causes of climate change are anthropogenic activities such as changes in the structure and use of land, which cause approximately a quarter (23%) of human emissions; food production, deforestation and desertification are among the causes of climate change on land; degraded lands do not have the ability to absorb carbon and can actually release carbon.

Climate change and human activities can harm the earth to the point where it becomes a net source of carbon emissions, and soil is also an element that can have a significant effect on climate change depending on management decisions. More than 2.7 billion people worldwide are affected by desertification, which means that nearly 1/3 of the world's population has lost productive land, to be used for agricultural purposes. Proper soil management can be applied to depleted soils in an area slightly larger than Europe, improving people's livelihoods and economic opportunities.

Thirdly, to adequately respond to climate challenges, action is needed to protect ecosystems, because approximately 72% of the icy land is affected by human activity. Among the conclusions made is the thesis (Dries L., N. Noev & J. F. M. Swinnen,(2009), that maintaining wild and free from human pressure areas is crucial to saving biodiversity and reducing emissions.

It is necessary to change the culture and healthy diet, associated with the reduction of waste. If food waste is reduced, an additional one billion people will be provided with food. Reducing the consumption of food of animal origin can contribute to reducing pollution from livestock.

The agricultural sector is focusing on environmentalists, as food production is one of the main causes of global environmental change: agriculture accounts for 40% of world land production and food is responsible for 21% of global greenhouse gas emissions. And 70% of freshwater use. In the context of several key drivers of change (demographic and economic growth, changing consumption patterns, technological progress, integration of global trade or climate change), all of which will affect the agricultural value chain, the agri-food sector will have to adapts to this growing demand for food, while tackling the challenges of sustainability and health.

REFERENCES

BORISOV, P., R. KOLAJ, C. YANCHEVA, & S. YANCHEVA, (2019), Influence of the common agricultural policy on Bulgarian agriculture, Bulgarian Journal of Agricultural Science, 25(3), 439–447.

DRIES L., N. NOEV & J. F. M. SWINNEN,(2009), Institutional Change, Contracts, and Quality in Transition Agriculture: Evidence from the Bulgarian Dairy Sector, Eastern European Economics, vol 47(4), p. 62-85.

KIROVA, M., MONTANARI, F., FERREIRA, I., PESCE, M., ALBUQUERQUE, J.D., MONTFORT, C., NEIRYNCK, R., MORONI, J., TRAON, D., PERRIN, M., ECHARRI, J., ARCOS PUJADES, A., LOPEZ MONTESINOS, E., PELAYO, E., (2019). Research for AGRICommittee – Megatrends in the agri food sector, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels.

ГОСПОДИНОВ, И. РЕД. (2020). Състояние на климата, атмосферата, въздуха и водите и агрометеорологичните условия в България през 2019 г.

BULGARIAN MINISTRY OF AGRICULTURE, FOOD AND FORESTRY, (2015), 'Bulgaria – Rural Development Programme Report.

EUROSTAT, (2019), Farm Structure Survey, https://ec.europa.eu/eurostat/documents/2995521/9028470/5-28062018-AP- EN.pdf/8d97f49b-81c0-4f87-bdde-03fe8c3b8ec2.

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