INTERNATIONAL THEORY, RESEARCH AND REVIEWS IN

AGRICULTURE, FORESTRY AND AQUACULTURE SCIENCES

October 2023

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Genel Yayın Yönetmeni / Editor in Chief • C. Cansın Selin Temana

Kapak & İç Tasarım / Cover & Interior Design • Serüven Yayınevi

Birinci Basım / First Edition • © Ekim 2023

ISBN • 978-625-6760-18-9

Serüven Yayınevi / Serüven Publishing
Türkiye Adres / Turkey Address: Kızılay Mah. Fevzi Çakmak 1. Sokak
Ümit Apt No: 22/A Çankaya/ANKARA
Telefon / Phone: 05437675765
web: www.seruvenyayinevi.com
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Baskı & Cilt / Printing & Volume
Sertifika / Certificate No: 47083

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Chapter 1

DOES THE CONTRACT FARMING MODEL HELP IN THE PRODUCTION DECISION OF BIODIVERSITY FRIENDLY AGRICULTURAL PRODUCTS?: A CASE OF BUCKWHEAT

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INTRODUCTION

Endeavours to improve agricultural production especially in developing countries are key factors for the farmers who derive their livelihood from agriculture in rural areas (Lı et al., 2020). While small-scale farmers have the power to produce large amount crops in rural areas, they are compelled in a vicious cycle of low-intensity, subsistence farming, low yields and insufficient profits (Meemken and Bellemare, 2020). There are diverse restrictions for linking small scale farms to rural economies. Smallholder farmers often face risks when they lack the skills, production methods and financial financial opportunities necessary to supply the quality demanded by buyers (Reardon et al., 2009). A common literature provides the diversity of risks that prevent the pass of small-scale farms from subsistence to profitable production (Arouna et al., 2021). Among these are low price of agricultural products (Kocovic et al., 2016), a lack of research and development (Kirsten and Sartorius, 2002), access to markets (Meuwissen et al., 2019; Meemken and Bellemare, 2020), access to credit (McArthur and McCord, 2017). These factors cause significant poverty in many rural areas for the small-scale farmers (Barret, et al., 2012). These limits encourage growing interests of authorities in forming farmer groups as one of the essential steps in the implementation of sustainable agriculture (Abdul-Rahaman and Abdulai, 2018; Myeni et al., 2019). Tosovic-Stevanovic et al., (2021) have noted that it can be said that achieving sustainable agriculture will depend on the production of small-scale farmers. Bellon et al., (2020) raise concerns about prices and profitability of agricultural products. They find that prices can therefore be an important source of information for understanding small farmers' production decisions and the resulting welfare state. For this reason, in increasing the amount of agricultural production and the variety of products, ignoring economic factors for instance development based agricultural diversity, broader mix of crops, decision making process of the farmers, is insufficient. Inducements promote strategy for many small-scale farmers who want to grow and bring profit poly crops, maintaining actual crop diversity particularly in rural areas. At this point, contract farming is considered appropriate way out to address these challenges (Tuyen et al., 2022). As Angreheni et al. (2022) have stated in their study that an attempt to decreasing challenges in agricultural production for the small-scale farmers is by cooperating in the form of contract farming.

Contract farming applies an agreement between the buyer and the farmer to decrease risk for both sides. It also can support the quality of the commodities produced by the farmers. Because contract buyer can help farmers to facilitate production processes from input to output with the guaranteed quality of the product, access to credit, access to market, assured markets, better price, new technology transfers. Moreover, contract farming can provide improving farmers' skills and knowledge, lower transportation costs and reducing losses during the production (Tuyen et al., 2022). In spite of contract farming has got many potential benefits, it is faced with some challenges in practice. There can be a deception of agreed quantities and quality characterization. As it was stated in Wang and Liang’s (2022) research, contract farmers conceal their real efforts and buyers cannot discern whether contract farmers have put full endeavors or not. Another disadvantage of contract farming is contracting buyers might buy less commodity than the pre-agreed quantities. In a case study in Nigeria by Ogunleye and Ojedokun says that buyers have bought less cassava production than agreed quantities. In addition, buyers also might reject buying the products for not meeting required standards (Tuyen et al., 2022) so there is also monopoly exploitation in the side of buyers. They make decisions about what to produce, how much and which inputs to use. In this case, it will be possible for high price of inputs. This causes to fall contract farmers’ freedom so they lose their resilience in making decisions. As it is concluded in Martin and Mwaseba's research (2015), contract farmers lack self-government and have limited flexibility of decisions on production.

To promote biodiversity friendly crop cultivation in the research area of this study, buyers can be encouraged to form collaboration with small-scaled farmers based on contract agreements. Therefore, contract farming can be a method that should be applied for the commercialization and industrialization of the buckwheat cultivation with the biodiversity values.

Sustainable production in terms of conversion of lands into agriculture has been very popular subject in recent years. But the tendency in agriculture is going in the opposite, non-sustainable way. Agricultural production is also one of the main drivers of biodiversity damage. Beside biodiversity damage due to natural lands demolition, intensive agricultural production has led to a robust regression of farming areas. Morever, plenty farming areas come face to face pollution pesticides and fertilizers, and meet infertile lands and erosion due to unsustainable agricultural production. This is pressurizing not just biodiversity but also whole ecosystems (Erisman et al., 2016). Sustainable agricultural practices ensure a conformity between the abuse and biodiversity, the natural lands and the ecosystems. With this, the defiance is protect the lands while at the same time minimising effects on the ecosystem. The idea that agricultural production is subject to biodiversity that numerous species of plants and animals depend on sustainable agricultural areas is sign in the approach of strong agricultural practices. At present, this paper recommend to apply this biodiversity-based agriculture with the example of buckwheat cultivation. As stated by Small (2017), along the twentieth century, the boosting use of synthetic nitrogen-based fertilisers took the great advantage the buckwheat has a biodiversity friendly crop – its capacity to grow well on poor soils.

Small-scaled farmers included in this study cultivate mainly wheat, barley and corn from the edible grain of grass. So, in a prominent increase in cultivation of cereals at the expense of buckwheat, which can be an alternative cultivation for the small-scale farmers in the research area. Buckwheat has biodiversity values like being a cover crop, green manure crop, weed suppression, pollinator crop and crop rotation (Small, 2017). 'Cover crops' can be defined in several ways, but the meaning generally refers to vegetation for the moment planted to heal and develop the soil for the edible growing plants that are more valued for harvest like corn, wheat and barley in the research area. As it mentioned before, buckwheat grows well on unfertile soil. Furthermore, the buckwheat residuals dissociate fastly, making nutrients ready for use for following crops. Buckweheat is also occasionally used as a weed suppressant. At the same time, buckwheat is a good alternative production for the local farmers because it is focused on determining buckwheat with economically efficient traits such as early maturity, resistance to frost and lodging, high yield and lower-shattering (Zhang et al., 2004).

In this research, according to various decision process criteria, the most suitable buyer for the buckwheat farmers was thought as a contract buyers and the traditional buyers (non contract buyers). Due to the limited number of buckwheat farmers in the study area, only thirty farmers who are linked contract farming have been interviewed. As such, no comparative analysis could be established. Considering these restrictions, the basic research question formed as how the contract farming helps small-scale farmers to opt for biodiversity friendly buckwheat production.

MATERIAL AND METHODS

This research was obtained from the surveys conducted with the farmers who produce buckwheat with the contract farming model in the district and villages of Gümüşhane province in Turkey. There are some reasons to include Gümüşhane province in the scope of this research. In regions in Turkey not suitable for industrialization however open to improvement of agricultural production, increasing the production of biodiversity friendly crop like buckwheat is a good chance. It has been understood that growing of alternative crops by smallholder farmers without the need for advanced agricultural production methods is extremely effective for sustainable production.

Primary data was obtained from face to face interviews with the buckwheat producers. The survey was designed only for contract farmers and who were interviewed. We could not consider comparing the farmers according to the choice of contracting buyers and traditional buyers. Because there were only 30 farmers available and they were all involved in contract farming and these farmers interviewed in the research area in June and July 2021. As secondary data, farmer registration system from the Gümüşhane Agriculture and Forestry Directorate, the Turkish Patent Institute database, Food and Agricultural Organisation (FAO) and related literature was used. This research was conducted in accordance with the principles of the Declaration of Helsinki. Approval was obtained from Gümüşhane University Ethics Committee. (No. 2021/5).

In this research, the evaluations of the farmers about the contract farming options according to the risk criteria were examined. Risk criteria were determined as fair price, guaranteed purchase, low marketing costs, paying on time, logistics and reliability. The farmers participating in the interview were asked the alternative of buyers. To analyse this, Analytic Hierarchical Process (AHP) method was used. The aim here is to reveal the factors that are effective in determining advantages of the contract farming that the farmer cares about. AHP has been an important method for decision makers and researchers since it was first used; and it is one of the most widely used multi-criteria decision making instrument (Vaidya and Kumar, 2004). The decision-making process in the AHP method consists of three stages. These are decomposition, comparative evaluations and determination of priorities. In the application of AHP, the decision problems at the top of the hierarchy were determined first. The hierarchical process has been shaped within the framework of the determined purpose. The AHP process asks decision makers how priorities and preferences will affect decision criteria in each decision option provided (Alponce, 1997). After the hierarchical structure of the AHP was created, pairwise comparison matrices were constituted and the 1-9 skala was considered as the basis for determining the success of each criterion in achieving the goal. With the help of this skala, pairwise comparisons of criteria are made with each other.

The pairwise comparison of element i with element j is placed in the position of a_{ij} of the pairwise comparison matrix:

$$A=[a_{ij}]\begin{bmatrix} a_{11} & a_{12} \ldots\ldots\ldots & a_{1n} \\ a_{21} & a_{22} \ldots\ldots\ldots & a_{2n} \\ \vdots & & \vdots \\ a_{n1} & a_{n2} \ \cdots & a_{nn} \end{bmatrix} \quad a_{ij} *= a_{ij}/(\textstyle\sum_j^n a_{ij})$$

Priorities were determined and percentage distributions showing the importance values of the factors against each other were created. The following formula is used to generate these percentages:

$$w_i = \sum_{j=1}^{n} a_{ij} /n$$

a_{ij} *: Comparison matrix elements

n: number of factors

i,j: 1,2,3,……………..n

The mutual value of this comparing is placed as a_{ji} of A to protect consistency of decision. To compare, we involve a skala that shows how many times more significant or influential one factor in terms of the criterion. Table 1 provides the scale.

Table 1. The 9 point skala for pairwise comparing.

Significance	Description	Statement
1	Equivalent significance	Two judgments have the same degree of importance
3	Somewhat more important	One of the two judgments is of moderate importance to the other
5	More important	One of the two judgments is more strongly important than the other
7	Very important	One of the two judgments is more strongly important than the other
9	Absolute important	One of the two judgments is of extreme importance over the other
2,4,6,8	Intermediate values	They are the preferred values when there is indecision between two judgments.

Source: Adopted from Alphonce (1996)

Since the AHP method includes a hierarchical modeling, it should consist of at least three levels. For this reason, at the top of the hierarchy are the general purpose of the problem, and below the goal are the criteria and alternatives, respectively. Within the hierarchical structure of the AHP, there is the goal to be achieved at the top level, and the criteria affecting the goal at the next level. At the last level, there are alternatives for solving problems. AHP is shown in Figure 1.

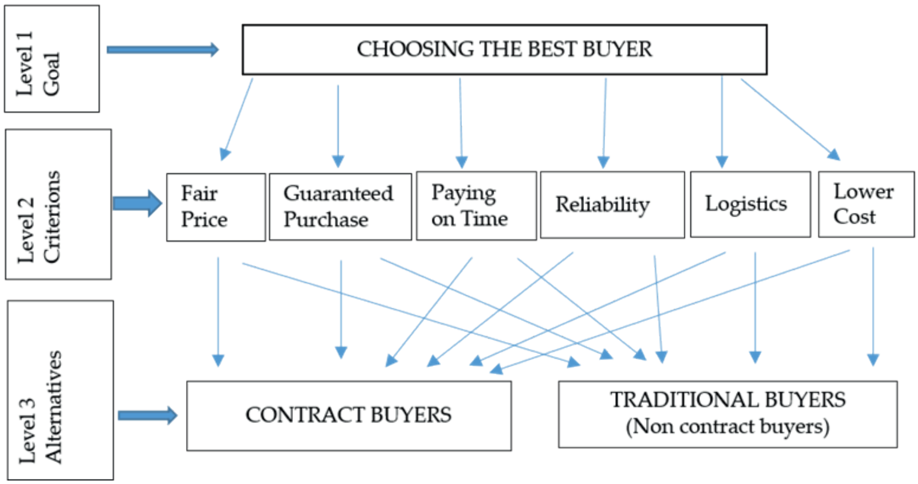

Figure 1. Hierarchy structure of the Analytical Hierarchy Process (AHP) model.

Forming of a hierarchy structure comprises describing whole elements at every level. Firstly, a goal is described. Our work is to analyse and identify how contract farming helps small-scale farmers to opt biodiversity friendly buckwheat in the research region. In following step, it is compared all factors at the same hierarchy level against factors from an upper hierarchy level. We identified six criteria as it can be seen in figure 1: C1- Fair Price of the buckwheat for the farmers, C2- Guaranteed purchase, C3-Paying on time, C4-Reliability, C5- Suitability of the buckwheat delivery location (logistics), C6-Low marketing cost. The most suitable criteria that correlate with the goal are listed here. After that we describe alternatives, where each of them correlates with the pre-described alternatives: A1-Contract buyer (integrator) that makes a contract with the producer (grower), A2-Traditional buyer. According to A1, we took into account the buyers like agribusiness firms which facilitate the contract farming wherein producers (grower) and buyers (integrator) agree with the contract about the production of an agricultural commodity. Buyers do not make any agreements with farmers, that we described through the alternative A2, where we comprised the following: local or city spot markets, wholesalers, retail chains,…etc….. . After all, the results are concluded in terms of criteria. The criterions are obtained (using above Saaty nine-point scale). The aim of this decision making process is to define the most efficient alternatives of buyers to help the farmers to decide to produce buckwheat. Tosovic-Stevanovic et al., (2021) have noted that the multi-criteria decision-making process makes it possible to rank the selected criteria by relevance to precisely determine small-scale farm economic performance based on the opinions of decision makers. The Super Decision package program was used when comparing the contracting buyers with the traditional buyers according to the determined criteria. In this context, the values in the matrices created for the pairwise comparison of both the criteria and the alternatives according to each criterion were entered in the Super Decision program and their weight were calculated.

RESULTS AND DISCUSSIONS

Some statistics on farmers producing buckwheat: The survey provided the data on socio-demographic characteristics of buckwheat farmers in the districts and villages of Gümüşhane province. The average age of farmers is found as 49 years. Observed by sex, the buckwheat farmers are about 97% men and 3.33% women. Contract farmers in 33% cases have finished primary school, 16.7% have completed secondary school, 23% have finished highschool and about 27% have first degree. The household size of the farmers changes between 2 and 9 persons. The average period of agricultural experience was determined as 21 years. On the other hand, the contract farming experience in buckwheat production varies between 1 and 3 years, with an average of 1.51 years. According to Gümüşhane Provincial Directorate of Agriculture and Forestry, buckwheat production started in 2019 so it is a new crop as a alternative product production for the farmers. That's why the experience of the farmers in buckwheat production obtained low for the interviewed contract farmers.

Comparison of contract buyers versus traditional buyers: The criterions defined in the previous section, the most suitable alternative where we include the contract buyers and the traditional buyers (non contract buyers) for the buckwheat farmers was determined. We identified the following six criteria: Fair price, guaranteed purchase, paying on time, reliability, suitability of the buckwheat delivery location (logistics), lower marketing costs. Using the abovementioned nine-point scale criterions are assessed. These criterions give weight coefficients, that are essential for choosing the buyer for the small-scale buckwheat farmers. The pairwise comparison of the criteria are given in Table 2.

After the pairwise comparison of criterions and the describing of weight vectors, the most appropriate criteria is reliability (%36), followed by paying on time (28%) and regular purchase (17%). Fair price (7%), product delivery location suitability (6%) and lower marketing costs (5%) reached much lower weights as it is given in Table 2. The results in Table 2 present that reliability (C4) and paying on time (C3) are the most important factors of 0.36 and 0.28 respectively, followed by fair price (C1), guaranteed purchase (C2), logistics

(C5) and lower marketing costs (C6). The value of these is within acceptable levels, suggesting a good indicator for AHP criteria according to Table 2. Kassem et al., (2020) indicated in their paper that communication plays a critical role in business success as a competitive advantage. Therefore, the reliability factor was the most preferred criterion by the contract farmers who produce the buckwheat in the preference order. It is understood that the criteria of reliability between the buyer and the contract farmer should be established to start contract farming or for sustainable agreements. Fair price (0.07), low marketing costs (0.05), suitability of the buckwheat delivery location (0.06) criteria were found to be close to each other and were the last preferred criteria. Whereas Bayramoğlu and Bozdemir (2017) stated in their study that price and cost advantage that the product provides is the primary criterion preferred by the farmers in producing the product. Kirsten and Sartorius (2002) also said that contract farming has been recognized for years as a system with significant potential to provide a way to integrate smallholder farmers into market and economy. In addition to the mentioned advantages of contract farming, there are also limiting factors for the farmers included in this research. When we examine the research area of this study, we see that the buckwheat cultivation is very new and studies on buckwheat production and yields, which are of interest to farmers, are very limited. Also, there were no option for the authors to compare the contract farmers and the non- contract farmers due to the whole of the farmers who are producing the buckwheat at present are contract farmers. Since this paper is a qualitative research with focus on contract farming. Therefore, this study can be presented as a qualitative work with focus on only contract farming and helps to promote newly introduced biodiversity friendly crop like buckwheat in the study region. There is only one contract buyer which is an entrepreneur in Kelkit district in Gümüşhane province. With this buyer, it is expected that the contract farming is a good chance for small-scale farmers while the promotion of biodiversity friendly buckwheat and availability of contract farming. According to the data obtained from this buyer, approximately 30 000-35 000 kg buckwheat was harvested and the buckwheat yield per hectare was 1100 kg in the total cultivated area in 2021 production season. Since the buckwheat production is new in the research area, no other official data were found regarding the cultivated area or production amount.

Table 2. Percentage of preference according to decision criteria.

Criterions	Price	Purchase	Paying on Time	Reliability	Logistics	Cost	Wi
Price	1	1/2	1/5	1/5	1	2	0,07
Guaranteed purchase	2	1	1	1/3	2	4	0,17
Paying on Time	5	1	1	1	5	4	0,28
Reliability	5	3	1	1	7	5	0,36
Logistics	1	1/2	1/5	1/7	1	1	0,06
Low Marketing Cost	1/2	1/4	1/4	1/5	1	1	0,05

Consistency Rate (CR): 0.02895 (CR≤0,10)

We describe alternatives, where each correlates with the pre-described alternatives: contract buyers and traditional (non-contract) buyers. The pairwise comparison of fair price, guaranteed purchase, paying on time, reliability, suitability of the buckwheat delivery location (logistics), low marketing cost have been made against two alternatives of buyers. When the consistency analysis of the pairwise comparison matrices of the alternatives is performed according to all criteria, it is seen that the consistency ratios remain within the limits (CR≤0.10). Considering the weight values of the alternatives, contract buyer was found to be the most appropriate for the farmers. Buckwheat growers give preference priority to the contract buyer at a rate of 75% in terms of fair price and low marketing costs (Table 3 and Table 8). In terms of regular purchase and timely payment (paying on time) criteria, contracting buyers have been preferred with the rate of %80 (Table 4 and Table 5). Taking into account the criterions of reliability and suitability of the product delivery location, the preference rate of contract buyer is 83% (Table 6 and Table 7).

Table 3. Pairwise comparison matrix and weights of alternatives for the fair price.

Criteria 1: Fair Price	Contract Buyer	Non-Contract Buyer	Wi
Contract Buyer	1	3	0,75
Traditional Buyer	1/3	1	0,25

Consistency Rate (CR): 0,00000 (CR≤0,10)

Table 4. Pairwise comparison matrix and weights of alternatives for regular purchase.

Criteria 2:Guaranteed Purchase	Contract Buyer	Non-Contract Buyer	Wi
Contract Buyer	1	4	0,80
Non-Contract Buyer	1/4	1	0,20

Consistency Rate (CR): 0,00000 (CR≤0,10)

Table 5. Pairwise comparison matrix and weights of alternatives for paying on time.

Criteria 3: Paying on Time	Contract Buyer	Non-Contract Buyer	Wi
Contract Buyer	1	4	0,80
Non-Contract Buyer	1/4	1	0,20

Consistency Rate (CR): 0,00000 (CR≤0,10)

Table 6. Pairwise comparison matrix and weights of alternatives for reliability.

Criteria 4: Reliability	Contract Buyer	Non-Contract Buyer	Wi
Contract Buyer	1	5	0,83
Non-Contract Buyer	1/5	1	0,17

Consistency Rate (CR): 0,00000 (CR≤0,10)

Table 7. Pairwise comparison matrix and weights of alternatives for logistics.

Criteria 5: Logistics	ContractBuyer	Non-Contract Buyer	Wi
Contract Buyer	1	5	0,83
Non-Contract Buyer	1/5	1	0,17

Consistency Rate (CR): 0,00000 (CR≤0,10)

Table 8. Pairwise comparison matrix and weights of alternatives for low marketing cost.

Criteria: Marketing Cost	Contract Buyer	Non-Contract Buyer	Wi
Contract Buyer	1	3	0,75
Non-Contract Buyer	1/3	1	0,25

Consistency Rate (CR): 0,00000 (CR≤0,10)

The next procedure involves the practice of multiplying the weights. The combination of all this makes it possible to carry out a general synthesis of the goal of choosing the best buyer for buckwheat farmers. In Figure 2, the priority values for the two alternatives are shown according to the evaluation results obtained with the Super Decision package program. According to the normalized priority values, the contracting buyer with a weight value of 0.807654 (81%) is in the first place. Non-Contracting buyer, on the other hand, rank second in priority with a weight value of 0.192346 (19%). This result reveals that the most suitable product sales channel for buckwheat producers is the contracting buyers.

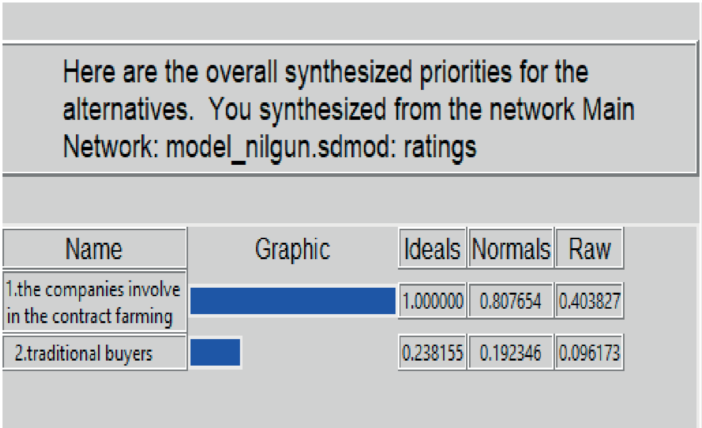

Figure 2. Priority values of alternatives

CONCLUSION

A large number of sustainable agricultural practices for biodiversity advantages from buckwheat are discussed in the previous section. Of course, all agricultural products are cultivated principally for economic, not agroecological reasons. That's why, in this study to understand the effect of the contract farming which can create positive economic impact on small-scale farmers, AHP method was employed. With this, we could say that contract farming can be an important source of income generation for the small-scale farmers. Also, the farmers' choice for biodiversity friendly buckwheat in their farming system counts on the values of buckwheat supporting their sustainability of the crop production. This paper focus on only contract farming and how it helps to promotes newly introduced biodiversity friendly crop like buckwheat in the study region. In this paper, the multi-criteria choice of the buyers for small-scale buckwheat farmers in Gümüşhane province was resulted. Two buyers were examined considering six criteria and the undermentioned conclusions acquired: Firstly, the criterion with the highest relevance for the examined farms is criterion C4- Reliability and criterion C-5 Suitability of Delivery Location (Logistics) with a rank of 0,83; secondly, the buckwheat producers give priority to the the contract buyer in terms of Criterion 2 and Criterion 3 with a rank of 0.80. As the third, when the buckwheat farmers consider the criteria of fair price (C1) and low marketing costs (C8), they give their preference to the contract buyer with a rank of 75%.

Considering the weight values of the alternatives, the buckwheat farmers give preference priority to the contracting buyer. Among the alternatives, according to the criterion of the buyer, the best buyer for the buckwheat producers is agribusiness firm (A1-contract buyer) with a rank 0.80.

The interest of buckwheat producers in the benefits of contract farming in the research area has resulted in their expectations from the firm that has contract with the farmers (contract buyer). The contract farming allows the buckwheat farmers to overcome the problems of the buckwheat cultivation. According to result of the AHP method application the farmers enter into contract production due to suitability of delivery location (logistics), reliability between contractor and grower, paying on time, guaranteed purchase of the buckwheat by the firm, lower marketing costs and fair price for the buckwheat. Contract farming could also improve access to related market. If marketing-guaranteed conditions can be established between the farmer and the firm which can be a major concern for the buckwheat producers, they are ready to give up their autonomy in order to cultivate this biodiversity friendly crop. A large number of biodiversity benefits from buckwheat are described earlier. In addition, it has been determined that there are some factors restricting contract farming for the buckwheat farmers in the research area. These restrictions include the loss of farmers' autonomy, the risk of increased production due to the buyer's need to fulfill their contractual obligations. If the contract buyer provides an insurance, contracting farmers can reduce production risk. In this respect, it is important to prepare a contract that will reduce the farmers' fears about contract farming.

It is possible to evaluate the performance of buckwheat farmers in the research area in more detail by adding criteria and alternatives that can play an important role in production planning, the stamina of farms and improving their production. With this, farmers' knowledge on biodiversity friendly buckwheat crop is important for conservation of buckwheat. As a result we could say that the buckwheat is a cereal crop recently promoted in the study area and the contract farming is making this biodiversity friendly crop production feasible.

Authorship Contribution Statement

ND and HA contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

Acknowledgement

This research was conducted in accordance with the principles of the Declaration of Helsinki Approval was obtained from Gumushane University Ethics Committee. (No. 2021/5).

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Chapter 2

SOUTHEASTERN ANATOLIA REGION INSECT FAUNA III (ORDER LEPIDOPTERA I: SUPERFAMILIES *Bombycoidea, Cossoidea, Drepanoidea, Gelechioidea*) OF TURKEY

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Introduction

Insects (Insecta) are the most numerous group of animals in the world, with over one million species that have been described (Price, 1997). Insects are difficult to study because they represent the most species-rich, yet one of the least known, of all taxa of living organisms, a problem that is compounded by a dearth of skilled entomologists. Although the number of described insect species is uncertain due to synonyms and the lack of a global list, most authorities recognize 900000-1000000 named morpho-species, representing 56% of all species known on Earth (Groombridge, 1992; Anonymous, 2003). Sensible estimates of the number of insects yet to be discovered range from another 1 million to 30 million species (Erwin, 1982-1991), although most predict around 2-8 million more species (May, 1990; Gaston, 1991; Stork, 1997; Ødegaard, 2000). Conservative estimates suggest that 50-90% of the existing insect species on Earth have still to be discovered, yet the named insects alone comprise more than half of all known species of organism.

Insects constitute the most diverse form of animal life in terrestrial ecosystems. Most species are innocuous and essential components of natural ecosystems. Because they are cold-blooded, the rates of key physiological processes in their life cycles are determined by environmental conditions, especially temperature and precipitation. In general, they have short generation times, high fecundity and high mobility (Moore & Allard 2008).

About 150,000 species of living Lepidoptera have been described in approximately 124 families. At the species level, this is about 17% of the world's known insect fauna. However, estimates suggest that there may be two or three times this number of species in the order.

The order Lepidoptera is divided into two as diurnal butterflies (Rhopalocera) and noctiurnal butterflies (Moths) (Heterocera). The antennae of the former are of the knob type; frenulum (bristle or bristles located at the bottom of the anterior edge of the second wing) is absent; the body is thin; they fly during the day. In the latter, the antenna is of different shapes; there is a frenulum; the body is thickly built; they fly at night. However, many systematists find it correct to divide Lepidoptera into 2 suborders, called Frenatae and Jugatae. In the Jugatae, the veining of both pairs of wings is similar and the wings are joined to each other by a small protrusion (Jugum). In Frenatae, the hind wings are smaller and less veined, and the two wings are joined to each other only by the frenulum, or they are attached to each other by the enlarged bottom of the hindwing.

Lepidoptera species utilize all parts of plants roots, trunk, bark, branches, twigs, leaves, buds, flowers, fruits, seeds, galls and fallen material. Larvae feeding in concealed situations wood borers, leaf and bark miners, casebearers, leaf tiers and leaf rollers usually belong to more primitive families; exposed feeders, especially those that feed by day, are from more recent lineages.

Butterflies and moths play an important role in the natural ecosystem as pollinators and as food in the food chain; conversely, their larvae are considered very problematic to vegetation in agriculture, as their main source of food is often live plant matter.

Turkey in fact seems to be like a small continent in terms of biological diversity. Despite the Anatolia is not a continent alone, it contains all properties of a continent that should have an ecosystem and habitat. Each of seven geographical regions in Turkey has a distinguishable climate, flora and fauna.

This study aims to determine insect species found in various ecologies on Southeastern Anatolia Region of Turkey.

Material and Methods

Entomology studies on insect species of Southeastern Anatolia Region (Adıyaman, Batman, Gaziantep, Diyarbakır, Mardin, Siirt, Şanlıurfa, Şırnak) in different ecological provinces were made between the years 1948-2020 (Figure 1).

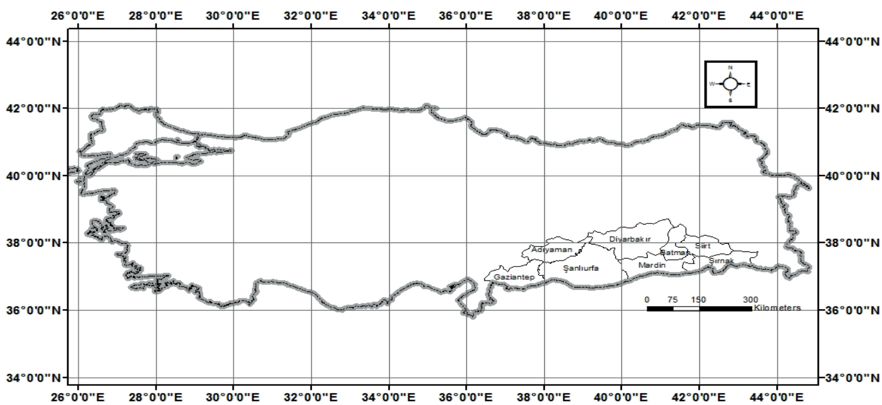

Figure 1. Sampling localities in the Southeastern Anatolia Region of Turkey.

In this study, I prepared for the inventory has reached the major advantage of the waterways:

-Currently in Turkey, published or unpublished entomology journals related to scanning,

-Giving more weight to faunistic studies, and in the meantime, the insect fauna of our country foreign scientific journals that publishes articles about scanning,

-Faculty of Agriculture, Faculty of Science and Regional Plant Protection Research Institute in the library of books on insect fauna and the screening of the booklet,

-The doctorate (PhD) and the master's thesis of entomology in the region on the scanning,

-Review of other studies on the insect fauna in the area.

In this study, I evaluated the information as described above were obtained.

It is also the addition of my current research and observations.

Results and Discussion

Surveys on insect species in various ecologies have been conducted in the provinces (Adıyaman, Batman, Gaziantep, Diyarbakır, Mardin, Siirt, Şanlıurfa, Şırnak) of Southeastern Anatolia region between the years 1948-2020. Almost 2600 species and subspecies almost 180 families belonging to 13 insect orders are defined owing to these studies. In this study: 34 species belonging to 4 superfamilies in the order Lepidoptera were determined. Species are given in systematic order. In addition, information was given about the distribution of Lepidoptera species in the Southeastern Anatolia Region and their host plants.

ORDER Lepidoptera

SUPERFAMILY Bombycoidea Latreille, 1802

FAMILY Saturniidae Boisduval, 1837

***Saturnia pyri* (Denis & Schiffermüller, 1775)**

Distribution of the studies area: Adıyaman, Diyarbakır, Mardin, Siirt, Şanlıurfa, **Host plant:** Almond (Maçan, 1986; Bolu et al., 2005a-b; Bolu & Çınar, 2005).

Figure 2. Different biological stages of Saturnia pyri (a-adult, b-egg, c-larva, d-prepupa and e-pupa (Coccon)).

FAMILY Sphingidae Latreille, 1802

***Acherontia atropos* (Linnaeus, 1758)**

Distribution of the studies area: Diyarbakır, **Host plant:** *Physalis angulata and Solanum melongena* (Bolu et al., 2015).

Figure 3. Adult stage (female) and different larva stages of Acherontia atropos.

***Agrius convolvuli* (Linnaeus, 1758)**

Distribution of the studies area: Diyarbakır, **Host plant:** Pistachio (Recorded by Halil Bolu).

Figure 4. Larva stage of Agrius convolvuli.

***Akbesia davidi* (Oberthür, 1884)**

Distribution of the studies area: Diyarbakır, Şanlıurfa, **Host plant:** Pistachio, Weeds (Ünlü et al., 1995; Recorded by Halil Bolu).

Figure 5. *Different larva (a) and pupa (b) stage of Akbesia davidi.*

***Hyles euphorbiae* (Linnaeus, 1758)**

Distribution of the studies area: Diyarbakır, Şanlıurfa, **Host plant:** Euphorbia (Ünlü et al., 1995; Recorded by Halil Bolu).

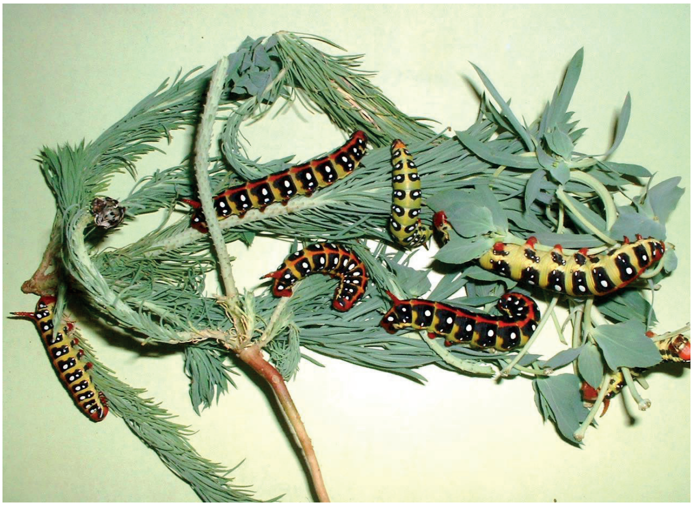

Figure 6. *Different larva stages of Hyles euphorbiae.*

Figure 7. *Adult stage of Hyles euphorbiae.*

***Hyles livornica* (Esper, 1780)**

Distribution of the studies area: Diyarbakır, **Host plant:** Euphorbia (Recorded by Halil Bolu).

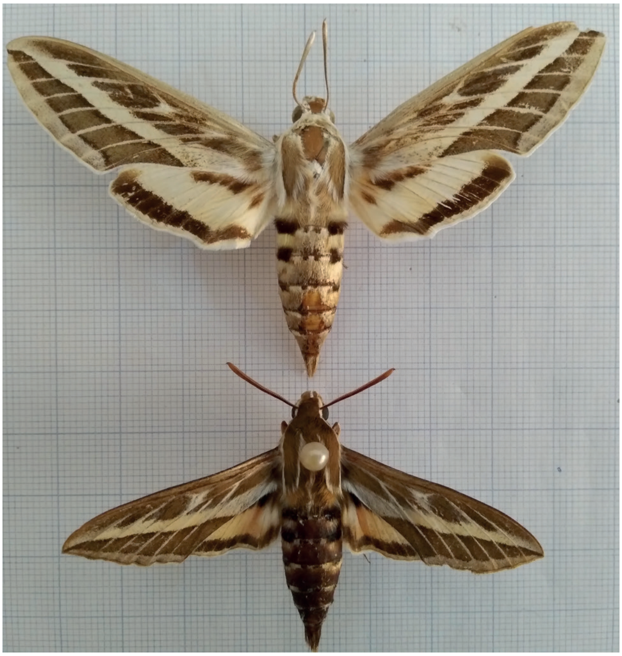

Figure 8. *Dorsal view of female (top) and male (bottom) individuals of Hyles livornica.*

***Laothoe populeti* (Bienert, 1870)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

Figure 9. *Dorsal (a) and ventral (b) view of the male individual of Laothoe populeti.*

***Macroglossum stellatarum* (Linnaeus, 1758)**

Distribution of the studies area: Diyarbakır, Şanlıurfa, **Host plant:** Weeds (Ünlü et al., 1995; Recorded by Halil Bolu).

Figure 10. *Dorsal (a) and ventral (b) view of female (top) and male (bottom) individuals of Macroglossum stellatarum.*

***Marumba quercus* (Denis & Schiffermüller, 1775)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

Figure 11. *Dorsal (a) and ventral (b) view of the female individuals of Marumba quercus.*

Figure 12. *Dorsal (a) and ventral (b) view of the male individual of Marumba quercus.*

Phlogophora meticulosa **(Linnaeus, 1758)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

Figure 13. *Dorsal (a) and ventral (b) view of Phlogophora meticulosa.*

Smerinthus kindermannii **Lederer, 1857**

Distribution of the studies area: Diyarbakır, Şanlıurfa, **Host plant:** Weeds (Ünlü et al., 1995; Recorded by Halil Bolu).

Figure 14. *Dorsal (top) and ventral (bottom) view of Smerinthus kindermannii.*

***Smerinthus ocellatus* (Linnaeus, 1758)**

Distribution of the studies area: Diyarbakır, **Host plant:** *Pinus nigra* (Sekendiz, 1974).

***Theretra alecto* (Linnaeus, 1758)**

Distribution of the studies area: Şanlıurfa, **Host plant:** Weeds (Ünlü et al., 1995).

SUPERFAMILY Cossoidea Leach, 1815

FAMILY Cossidae Leach, 1815

***Cossus cossus* (Linnaeus, 1758)**

Distribution of the studies area: Diyarbakır, **Host plant:** Willow (Recorded by Halil Bolu).

Figure 15. *Larva stages of Cossus cossus.*

***Zeuzera pyrina* (Linnaeus, 1761)**

Distribution of the studies area: Şanlıurfa, **Host plant:** Pomegranate (Mart & Altın, 1992).

FAMILY Sesiidae Boisduval, 1828

***Synanthedon myopaeformis* (Borkhausen, 1789)**

Distribution of the studies area: Diyarbakır, **Host plant:** Apple (Maçan et al., 1987a.; Bolu et al., 2005b).

Figure 16. *Dorsal (a) and ventral (b) view of the adult stage of Synanthedon myopaeformis.*

SUPERFAMILY Drepanoidea Boisduval, 1828

FAMILY Drepanidae Boisduval, 1828

***Cilix glaucata* (Scopoli, 1763)**

Distribution of the studies area: Diyarbakır, **Host plant:** Almond (Bolu et al., 2005a-b; Bolu & Çınar, 2005).

SUPERFAMILY Gelechioidea Stainton, 1854

FAMILY Autostichidae

***Syringopais temperatella* (Lederer, 1855)**

Distribution of the studies area: Diyarbakır, **Host plant:** Wheat (Duman, 2021).

FAMILY Gelechiidae Stainton, 1854

***Anarsia lineatella* Zeller, 1839**

Distribution of the studies area: Diyarbakır, **Host plant:** Almond (Bolu et al., 2005a; Bolu et al., 2005b; Bolu & Çınar, 2005).

***Ephysteris promptella* (Staudinger, 1859)**

Distribution of the studies area: Southeastern Anatolian Region, **Host plant:** Cereals (Adıgüzel, 1978).

***Gelechia pistaciae* Filipjev, 1934**

Distribution of the studies area: Adıyaman, Diyarbakır, Mardin, Siirt, Şanlıurfa, **Host plant:** Pistachio (Günaydın, 1978)

***Pectinophora gossypiella* (Saunders, 1844)**

Distribution of the studies area: Adıyaman, Diyarbakır, Mardin, Şanlıurfa, **Host plant:** Cotton (Özpınar & Yücel, 2002).

***Recurvaria nanella* (Denis & Schiffermüller, 1775)**

Distribution of the studies area: Adıyaman, Batman, Diyarbakır, Gaziantep, Mardin, Siirt, Şanlıurfa, **Host plant:** Almond, Apple, Apricot (Maçan et al., 1987a-b; Bolu et al., 2005a-b; Bolu & Çınar, 2005).

***Recurvaria pistaciicola* Danilevsky, 1955**

Distribution of the studies area: Adıyaman, Batman, Diyarbakır, Gaziantep, Mardin, Siirt, Şanlıurfa, **Host plant:** Pistachio (Günaydın, 1978; Mart & Karaat, 1990; Yanık, 1997; Bolu, 2002; Bolu et al., 2005b; Şimşek & Bolu, 2017).

SUPERFAMILY Geometroidea Leach, 1815

FAMILY Geometridae Leach, 1815

***Agriopis bajaria* (Denis & Schiffermüller, 1775)**

Distribution of the studies area: Diyarbakır, **Host plant:** Almond (Bolu et al., 2005a-b; Bolu & Çınar, 2005).

Figure 17. *Adult stage (male) of Agriopis bajaria.*

***Aleucis distinctata* (Herrich-Schäffer, [1839])**

Distribution of the studies area: Diyarbakır, **Host plant:** Almond (Bolu et al., 2005a-b; Bolu & Çınar, 2005).

Figure 18. *Dorsal (a) and lateral (b) view of the adult stage of Aleucis distinctata.*

***Camptogramma bilineata* (Linnaeus, 1758)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

***Gnopharmia stevenaria* (Boisduval, 1840)**

Distribution of the studies area: Diyarbakır, **Host plant:** Almond (Bolu et al., 2005a-b; Bolu & Çınar, 2005).

Figure 19. *Adult stage of Gnopharmia stevenaria.*

***Grammodes stolida* (Fabricius, 1775)**

Distribution of the studies area: Şanlıurfa, **Host plant:** Pomegranate (Mart & Altın, 1992).

***Nychiodes amygdalaria* (Herrich-Schäffer, 1848)**

Distribution of the studies area: Diyarbakır, Southeastern Anatolian Region, **Host plant:** Almond (Maçan, 1986; Bolu et al., 2005a-b; Bolu & Çınar, 2005).

Figure 20. *Larva stage of Nychiodes amygdalaria.*

Nychiodes divergaria Staudinger, 1892

Distribution of the studies area: Diyarbakır, **Host plant:** *Prunus persica*, *Prunus domestica* and *Prunus armeniaca* (Bolu, 2019).

Figure 21. *Egg (a), and larva (b) stages of Nychiodes divergaria.*

Figure 22. *Ventral (a), and Dorsal (b) view of female (top) and male (bottom) individuals of Nychiodes divergaria.*

***Lithostege farinata* (Hufnagel, 1767)**

Distribution of the studies area: Şanlıurfa, **Host plant:** *Berberis* sp. (Ünlü et al., 1995).

***Ophiusa algira* Linnaeus, 1766**

Distribution of the studies area: Şanlıurfa, **Host plant:** Pomegranate (Mart & Altın, 1992).

***Rhodometra sacraria* (Linnaeus, 1767)**

Distribution of the studies area: Şanlıurfa, **Host plant:** *Polygonum* sp., *Anthemis* sp. (Ünlü et al., 1995).

As a result, Southeastern Anatolia Region is a region bordering with neighboring countries. Therefore, it is a region rich in flora and fauna. It is necessary to protect and record this biodiversity. However, the random and uncontrolled entry of plant production materials from neighboring countries into the region creates negative effects in terms of "Plant Protection". In order to preserve the natural diversity and balance, quarantine rules must be carefully followed when planting materials are brought into the country by citizens or by import.

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Chapter 3

USE OF DIFFERENT SOLID MEDIA IN SOILLESS AGRICULTURE IN PLANT PRODUCTION

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INTRODUCTION

Considering the world population today, it is seen that the problem of hunger for humanity is increasing. Especially against the danger of hunger, it is necessary to obtain more efficiency from the existing agricultural areas. As a result of the chemical fertilizers, drugs and wrong cultural practices used in this process, it is not overlooked that agricultural areas are losing productivity day by day.

It is aimed to reach the targeted production figures by realizing the latest technological studies. "Soilless Agriculture" stands out as an important form of agriculture preferred in today's conditions in order to achieve high yield and quality values. Because, reasons such as deterioration of soil structure over time, accumulation of substances that may cause toxic effects in soils, deterioration of microbiological and biochemical balances, disruption of plant nutrient uptake mechanism and intensification of soil-borne diseases in intensively cultivated areas have led researchers to study some alternative environments other than soil, and as a result, soilless New techniques, expressed as aquaculture or soilless culture, have emerged. When soilless agriculture is compared with soil agriculture, it is possible to produce in areas where the soil is not suitable for vegetative production, to increase water use efficiency, to ensure that plants are fed in a controlled manner, to increase yield, to increase quality, to reduce required labor force, to facilitate irrigation, and to facilitate production without the need for environmental sterilization or easy production. It has advantages such as providing opportunities (Jones ,1983).

In general, the aim of soilless agriculture is to provide the development of plants with a nutrient solution, to meet the nutrient and water requirements of the plants without creating a stress environment and to realize this process in the most economical way.

Soilless agriculture is being adopted with an increasing rate in our country as well as in the whole world, especially by producers who cannot get the expected efficiency from greenhouse cultivation.

Materials used in greenhouse cultivation can be of inorganic and organic origin, such as peat, perlite, pumice, zeolite, synthetic foams, rock wool, sawdust, bark, vermiculite.

These growing materials are used alone or mixed with each other in certain proportions. In most cases, inorganic origin is preferred because of the microbiological transformations of the growing materials used and their more openness to contamination. Soilless agriculture shows a rapid increase in the world, especially in countries where greenhouse cultivation is developed. The Netherlands ranks first among these countries. In recent years, the areas of soilless agriculture have been increasing rapidly in the Mediterranean countries, where greenhouse areas are high. Turkey ranks 4th in the world and 2nd in Europe in terms of greenhouse assets.

While the greenhouse production areas were 540 thousand decares in 2002, reaching 855 thousand decares with an increase of 58 percent in 2021, production for export was made with the soilless agriculture method on 14 thousand decares, which corresponds to 1.6 percent of the total greenhouse area. Mersin, İzmir, Manisa and Afyonkarahisar are among the areas where soilless culture greenhouses are concentrated. When we look at the soilless farming systems, it is seen that it is divided into three as aquaculture, aeroponic and solid material (substrate) culture. Solid material culture is used more widely, especially in soilless farming systems in Turkey.

Among the most important reasons for this are the lower initial investment cost of the substrate and the fact that it creates a buffering environment around the root zone. Substrates used in soilless agriculture are divided into two groups as organic and inorganic. Examples of organically used substrates are peat, coconut fiber, sawdust, bark, rice husk and peanut shell.

Inorganic substrates are also divided into two as natural and artificial materials. Natural inorganic substrates such as perlite, zeolite, pumice, sand, gravel, volcanic tuff and vermiculite, as well as rock wool, glass wool, polystyrene and polyurethane foam are examples of synthetic growing substrates. In general, it is estimated that approximately 150,000 m^3 of substrate is used per year in the current situation.

Considering the world's perlite reserve, it has more than 50% of the total reserve in Turkey (7.7 billion m^3). In addition to its positive features such as being light and sterile in terms of its features, high aeration capacity, keeping water and nutrients in a way that plants can easily take, being chemically inert and having a neutral pH, perlite is abundant in Turkey as a material, which is the reason for preference in soilless agriculture. stands out. In addition to these, perlite, which is sterile in the first use, must be sterilized in long-term use. On the other hand, there is no waste problem at the end of aquaculture. Another solid material naturally found in soilless agriculture is zeolite, which is a good soil conditioner for the conditions in which it is used, thanks to its high cation exchange capacity. (Clinoptilolite) In scientific studies on the use of zeolite as a solid material in soilless agriculture, it has been determined that it provides an increase in yield, reduces fertilizer consumption, reduces nitrate and nitrite accumulation in plant tissues, and reduces the amount of nitrate nitrogen and potassium washed from the area where the plants are located. However, since it is a heavy substrate, it is not preferred to be used alone during cultivation in soilless agriculture (Gül 2012a; Gruda et al. 2013).

Another material with a high potential for use in soilless agriculture in Turkey is pumice. The presence of rich pumice deposits (3 billion m^3) in different regions of Turkey and the extraction of pumice from these deposits in the form of open mining is very important in terms of soilless agriculture. It is preferred due to its positive aspects such as being resistant to physical and chemical factors without requiring any fabrication, keeping its physical properties unchanged for a long time, having a porous structure, being sterile, and being reusable after sterilization. The fact that it can be used as a substrate only as a result of grinding and screening before aquaculture and that it is sold at very reasonable prices in the regions where it is extracted increases the use of pumice (Alparslan et al. 1998).

Effects of different substrates on the crop production in soilless agriculture

Many studies have been carried out on the environments where cultivation will be carried out in soilless agriculture. The main purpose of these studies was on the effective use of soil alternative materials. It is also important to evaluate the effects of these materials and nutrient solutions on plant growth. In recent years, different materials have been used together with soil as a growing medium in agricultural activities. In some growing media, inorganic materials such as pumice, perlite and zeolite are used alone or in mixtures of each other.

Soilless agriculture is the realization of all kinds of agricultural production in stagnant or flowing nutrient solutions, in nutrient solution or on substrates fed with nutrient solutions. The purpose of soilless agriculture; to ensure the development of plants with the help of nutrient solution, to meet the nutrient and water requirements of plants without causing stress, and to realize this with non-exaggerated expenditures (Sevgican, 1999).

The advantages and disadvantages of soilless agriculture are summarized in a study. Advantages; Since the soil is inactivated, there is no need for processes such as tillage, washing, disinfection, agricultural production can be carried out in salty, sweet, desert areas that are not suitable for plant cultivation, there is a homogeneous distribution of nutrients in the root environment, there is no water stress problem for plants. It is suitable for automation, there is no problem with soil-borne diseases and pests and weeds, earliness is more pronounced and yield is higher than soil-based agriculture. The disadvantages of soilless agriculture are that some soilless farming methods require great technical equipment, the producer of soilless agriculture must have special knowledge and experience, problems related to plant nutrition arise, and these systems lack some features resulting from the soil's role as a buffer. An ideal growing mix; It should have good aeration and drainage, appropriate bulk density, moisture characteristics, reaction, electrical conductivity, cation exchange capacity, balanced and optimum nutritional element and the level of providing these elements. The growing mix should have properties that will reduce the frequency of irrigation as well as provide good drainage conditions. The ability of the medium to maintain its continuity between its stability and mass over time, its convenience and cost are other parameters to be considered. In order to provide these parameters, inorganic materials such as pumice, perlite and zeolite, which are plant growing media materials, are used.

Irrigation cost is lower in soilless agriculture than in soil. So much so that the amount of water used in hydroponic cultivation to produce the same amount of food can decrease to 1/20 of cultivation in soil (Lakkireddy et al. 2012). This enables the controlled use of existing resources, especially in our world where water resources are decreasing day by day (Olympos, 1999). In his study examining the current and future situations of tomato and strawberry production in the developing hydroponic agriculture sector in the Mediterranean Region; Although there are many reasons to switch to soilless agriculture today, he argued that these lands should be used as a priority in places where there are fertile lands, and he stated that the effort and care shown in soilless agriculture should be shown to the soil and the productivity of the soil should be benefited. (Özkan ,2014). Since all conditions are kept under control in soilless agriculture and the necessary conditions for aquaculture are optimized, the yield is higher. Studies have shown that soilless cultivation increases the yield by 20-25% compared to cultivation in soil in the greenhouse and 4-10 times compared to open field conditions (Resh ,2013).

The effectiveness of the fertilizer used in soil cultivation depends on many factors. Soil texture, pH, lime content, salinity, nutrient levels etc. factors affect the effectiveness of the fertilizer given (Akgül ,2010). For this reason, it is generally necessary to use 50-80% more fertilizer than the plant need in soil cultivation (Resh, 2013).

However, since all the nutrients needed by the plant in soilless agriculture are given in the form of nutrient solution under optimum conditions, the efficiency of fertilizer is much higher, but the use of fertilizer is much less (Savvas et al. 2013).

Substrate culture is the most preferred method in commercial cultivation in large areas in soilless agriculture. System cost is lower than others. Many materials of organic, inorganic or synthetic origin can be used as a growing medium (Gül et al. 2008).

(Chen et al. 1980) stated that pumice and perlite and their mixtures in certain volumes can be used as greenhouse growing media due to their suitable properties such as particle size, porosity, water holding capacity, aeration capacity and hydraulic conductivity.

(Varış, 1998) stated that the pH in the solution affects the solubility and uptake rate of the nutrients, that the pH in the perlite bag being above 6.5 causes the precipitation of especially calcium, phosphorus and manganese. He stated that most of the plants would not survive because the cell membranes became permeable and destroyed. For this reason, he stated that the pH in the perlite bag should be kept between optimum 5.0-6.5. (Cinkılıç,1997) investigated the effects of different nutrient sources and solutions on growth and yield of tomatoes grown with perlite bag culture. The results of two different growing seasons were compared. According to the results in the first growing period, it was reported that the number of early normal fruit and yield were higher in perlite culture than in soil, and also, as the percentage of NH_4^-N increased, the number of blossom end rotten fruit and yield increased.

In tomato cultivation where four different media [(1) Perlite, (2) Volcanic Tuff, (3) 4:1 Perlite+Peat, (4) 4:1 Volcanic Tuff+Peat] are mixed, the evapotranspiration value of plants grown in open system in spring and autumn periods is Perlite. and Perlite+Peat mixture was higher than Volcanic Tuff and Volcanic Tuff+Peat mixture. (Tüzel and Meriç, 2001).

Zeolites are basically defined as hydrated aluminum silicates with a crystalline structure of alkali and alkaline earth elements (Gül, 2012a). Although it is not possible to determine the world's zeolite reserves with numbers, zeolite occurrences began to be detected after the 1950s and were widely seen in almost all continents. Cuba, USA, Russia, Japan, Italy, South Africa, Hungary and Bulgaria are among the important countries in terms of world zeolite reserves. (Çetinel ,1993), Besides the use of zeolite in agriculture, it is also widely used in industrial areas such as pollution control, energy storage, animal husbandry, health and mining (Mumpton 1999; Sevgican 2003). It is also applied in petrochemical industry and nuclear waste treatment fields. It is used as a medically purified oxygen generation and microorganism immobilizer (Mishra and Jain, 2011). It has different uses as a soil conditioner in agriculture, such as ; a source of P, K and NH_4 in unproductive soils and substrates, reducing nitrogen losses and nitrate contamination, and increasing the availability of water (Papadopoulos et al. 2008).

(Peoples and Freney ,1995) reported that clinoptilolite is a zeolite mineral with a high cation exchange capacity and easily adsorbs NH_4^+ due to its ion exchange properties in its surface area, which reduces losses in nitrogen-rich animal manures. Turkey's zeolite reserves are in large volumes such as 48.5 billion tons. (Büyükakyol, 1988), existing zeolite deposits in Turkey are located in Ankara (Polatlı, Nallıhan, Beypazarı), Kütahya-Saphane, Manisa-Gördes, İzmir-Urla, Balıkesir-Bigadiç and Cappadocia regions. (Kocakuşak et al. 2001). It has been determined that zeolites produced in Turkey are rich in potassium and calcium, and clinoptilolite, which is rich in potassium in agricultural terms, acts as a slow potassium-giving fertilizer. (Köksaldı, 1999) therefore it has useful fertilizer feature (Pisarovic et al. 2003). It also retains excess water in the environment. Thanks to its high cation exchange capacity, it retains nutrients within itself, prevents them from being washed away from the environment, and enables the use of fertilizers effectively with the controlled release of the nutrients it holds (Allen and Ming, 1995). (Burriesci et al. 1984), in his study; They determined that zeolite increases and facilitates water and fertilizer availability in spinach plant production. (Harland et al. 1999) investigated the possibilities of reuse of clinoptilolite, a type of zeolite, in pepper cultivation in soilless agriculture. During the production period, the plants were fed with the complete nutrient solution, the nutrient solution drained from the plants was accumulated and given to the plants again.

The zeolite is steam sterilized after each production cycle. At the end of two growing seasons, the feeding regime was changed and fresh solution was given to the plants at each irrigation. When plant growth, yield and quality were examined, it was determined that the reuse of clinoptilolite did not have a negative effect. After the first 3 years of the experiment, it was determined that the nitrate nitrogen level in the leaves and the drainage solution decreased, while the sodium amount increased. In a study conducted in a polyethylene-covered tunnel greenhouse, lettuce (Lactuca Sativa L.) grown in different perlite and zeolite (clinoptilolite) mixtures (1+0.1+3.1+1.3+1.0+1 v:v) growth, plant nutrient content and drainage solution element amounts were measured. As a result of the research, it was determined that the use of zeolite increased the N and K content in plant growth and tissues, and decreased the amount of K excreted in the drainage solution. The same team of researchers reported that zeolite increased the development of head salad plants compared to perlite, and reduced nitrite and nitrate accumulation in plant tissues (Gül et al. 2005). (Polat et al. 2005), in a study conducted to examine the effects of clinoptilolite on yield and quality in lettuce cultivation, compared different doses of clinoptilolite (0, 40, 60, 80 kg da^{-1}) and the control group (clinoptilolite and no fertilizer were applied). The use of clinoptilolite in lettuce cultivation, together with fertilization, positively affects yield and plant growth; It was concluded that 80 kg da^{-1} clinoptilolite application increased the total yield by about 15% compared to 0 kg da^{-1} application under controlled irrigation conditions. (Fecondini et al. 2011), 3 tomato cultivars (Idoll, Grandela, Secolo) in soilless culture, rock wool+coconut fiber, perlite+coconut fiber+zeolite (70/30 v/v) and perlite+zeolite mixture (70/30 v/v)) were grown in the greenhouse and at the end of the harvest, the fruits were counted and weighed. While zeolite and coconut fiber mixture had no effect on 'Secolo' and 'Idoll' cultivars, it was determined that 'Grandela' yields better performance in perlite+zeolite mixture than perlite. (Yılmaz et al. 2017) in their study titled tomato cultivation in soilless agriculture, in their study using different soilless culture media, stated that the use of 100% zeolite has a negative effect on tomato cultivation, and using zeolite in a mixture with other material will create more positive results, In addition, in the study where the same researchers examined the effects of different materials (vermicompost, peat and zeolite) and their mixtures in different ratios on seedling yield and quality parameters in soilless tomato cultivation in the greenhouse; It has been reported that 65% Peat + 15% Zeolite + 20% vermicompost values were determined as the most suitable material composition for tomato cultivation and 100% zeolite medium was not suitable for soilless tomato cultivation.

(Harland et al. 1999), the reuse possibilities of clinoptilolite, a type of zeolite, in pepper cultivation were investigated, the plants were fed with a complete nutrient solution, and the drained nutrient solution was collected and reapplied to the plants. In the study in which clinoptilolite was sterilized with steam after each production period, when plant growth, yield and quality parameters were examined, it was determined that the reuse of clinoptilolite did not have a negative effect. Abak and (Çelikel ,1995) comparatively investigated the effects of peat, sand, pumice, and mushroom compost waste environments on yield, earliness and quality of eggplant in rock wool and soil (control) cultivation. In the study, they reported that peat, pumice and mushroom compost waste, which are potential substrates in Turkey, can be used successfully with a good feeding program and can yield more products from the soil.

(Azam et al. 2012) investigated the effects of soil zeolite application on flowering and plant growth in eggplant plant. As a result, zeolite applications increase plant growth and nitrogen and potassium fertilizer efficiency, regulate water retention and infiltration, preserve nutrients for long-term use by plants, increase soil quality and crop yield, reduce nutrient loss from soil, help absorption of toxic metals in the soil, less irrigation. They determined that it requires the use of arsenic and chemical fertilizers, that it removes arsenic from groundwater to be used in irrigation, thus reducing the arsenic uptake of plants from the soil, it does not have a significant effect on the height of the plants, and it increases the number of flowers. In order to examine the effects of zeolite application on plant morphology, yield and yield components in soybean (Glycine max), zeolite application at 3 different rates (0 g, 20 g, 40 g) was compared in 3 different soil types. 2 different soybean varieties (cv. Enrei, dwarf type; cv. Harosoy, pole type) were used in the study. The effect of zeolite amounts on yield was found to be significant and maximum leaf area and plant weight were determined in 40 g zeolite application, and the highest yield was obtained from 20 g zeolite application for both cultivars (Khan et al. 2011). Soilless culture of Gerbera (Gerbera jamesonii.) yielded higher yields on Perlite+Zeolite (P/Z ratio 1:1) than other mixes due to adequate aeration and improved water holding capacity (Issa et al. 2001). In a study on the cultivation of cloves (Caryophyllaceae Dianthus), Researchers; They stated that when zeolite is used as a substrate by mixing it with different materials in certain proportions than using it alone, there is a significant increase in plant yield, stem length and diameter. (Kazaz et al. 2010) .

Pumice is a very light colored, sparkling rock. As a result of the eruption of the lava, it is thrown out with gases, it cools in the air and the spaces formed due to the gas escape form the rock.It is a very light, usually floatable, volcanic glass material composed of silicon dioxide, aluminum oxide and potassium oxides. (Bilgin et al. 1990). In a study to determine the water retention characteristics of pumice, it was determined that four different grain sizes (>4 mm, 4-2 mm, 2-1 mm and <1 mm) at different tensions (0, 10, 50, 100, 333 and 15 000 cm). water column) water contents were examined. The aeration capacity, easily usable water and buffering capacity values of the pumice were determined. According to these values, it was noted that the groups with 2-1 mm and <1 mm grain sizes of the pumice used in the research were at optimum values as plant solid growing material mix. (Erpul and Bayramin, 2004). Turkey also has an important potential in terms of many industrial raw materials and underground resources. On the other hand, approximately 40% (more than 7.4 billion m^3) of the world pumice reserves, which is around 18 billion m3, is located in Turkey (Çevikbaş and İlgün, 1997).

(Hartman and Zengerle,1979) revealed that growing tomatoes in bags with pumice mixtures is more economical than growing in soil, and diseases and pests are reduced. (Dinc et al. 1984) tried pumice and organic soil in tomato production. Researchers have stated that pumice provides 15 days earliness and yields higher than soil. For this reason, they emphasized that pumice can be used in tomato cultivation. (Economakis and Daskalaki, 2000) used different substrates (fine perlite, coarse perlite, pumice) with different volumes (6 and 8 l per plant) and different usage times (first or third use) in an unheated glass greenhouse with 10% (v /v) zeolite added media) in tomato (cv. Baya) cultivation.

The effect of usage time and bag volume on total yield was not significant. It was determined that the addition of zeolite increased the yield compared to the use of only pumice. It was determined that the average fruit weight increased in pumice+zeolite medium, followed by fine perlite. (Akgül, 2015), in his study comparing the substrate mixtures (sand+peat, pumice+peat, perlite and pumice) for soilless apple seedling cultivation; reported that it gave more positive results with pumice+peat medium and produced 4 times more seedling production compared to soil production. (Baştaş and Tangolar ,2018) in their study, the highest yield was recorded in Perlite: Peat medium and 4682 g $omca^{-1}$ in grapes obtained from different applications. Perlite:Peat; the lowest cluster weight was obtained from Pumice medium with 211.7 g.

CONCLUSION

Yield and profit per unit area increase in plant production using soilless farming systems. Since the system is controllable, the amount of residue in the products obtained is reduced to the minimum level. It is thought that the ease of harvesting, the ability to obtain products in all seasons, the high yield, the tendency towards soilless agriculture will increase and plant breeding will become widespread with these systems. As a result of different techniques applied in Turkey, it has been understood that the failure rate of the system is higher than that in the substrate culture and the substrate culture is more suitable for the greenhouse environment in a problem that may be experienced in aquaculture. As materials used in solid media cultures, inorganic and organic materials such as peat, perlite, pumice, zeolite, synthetic foams, rock wool, sawdust, bark, vermiculite can be mixed and used.

Türkiye is among the world's leading countries in agricultural production. However, the divided soil structure in agricultural areas, erosion and drought problems in some regions reduce the yield. It is thought that agriculture should be given due importance and both producers and consumers should be informed about soilless agriculture. Since the appearance of the products grown with the soilless agriculture method is uniform and beautiful, the prejudice of bad product or not natural should be broken. Since soilless agriculture can be done both in the open and under cover, it is necessary to choose the most suitable place according to the product to be produced and the area where the facility will be established. Since there are many fertile agricultural lands in Turkey, it should be noted that the areas where soilless farming systems will be established are inefficient, arid and stony, and fertile lands should be approached with the sensitivity shown against soilless agriculture. The number of researches for product diversification should be increased and aquaculture should be supported and developed in soilless agriculture.

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Chapter 4

TEMPERATURE-HUMIDITY INDEX AS INDICATOR OF HEAT STRESS

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Introduction

Today, one of the most important environmental problems that threaten the lives of living things in our world is global warming and climate change, which occur in parallel with the increases in greenhouse gas emissions. This phenomenon causes significant changes in temperature and relative humidity values, as in all climate parameters (Ilhan, 2018). As it is known, the living need physiologically appropriate climatic, physical, biological and chemical environmental conditions in order to maintain their living comfort and productivity. Changes in these conditions, especially increases in temperature and relative humidity values because of global warming and climate change, cause living beings to undergo heat stress, deteriorate their living comfort and yield losses. Sensitivity to environmental temperature and humidity differs for humans and different animal species. Therefore, in order to take precautions against heat stress, it is necessary to know the living thing and the appropriate environmental conditions for it very well and to define critical levels (Yuksel and Sisman 2015, Dimov et al. 2020).

Heat Stress

In simple terms, heat stress can be described as the inability to provide thermal comfort and disruption of vital activities of the living being as a result of the climatic characteristics of the environment (temperature, humidity, air movement and solar radiation etc.) in which the living creature lives goes beyond appropriate limits. As with all living things, farm animals and especially cattle raised for the purpose of providing animal foods, which have an important place in human nutrition, are negatively affected by heat stress in terms of health and productivity. In cattle exposed to heat stress, respiration accelerates, evaporation and sweating increase, if adequate and necessary precautions are not taken, body temperature begins to increase, weight gain slows down or stops as nutrition decreases, the immune system weakens, fertility decreases and a significant loss of productivity occurs (Isık et al. 2016, Kocaman and Sisman 2019, Dimov et al. 2020). In a study conducted by Ray et al. (1992) to determine the economic magnitude of the effects of heat stress on animal health, production, and performance in the American dairy industry, they determined that the annual loss due to heat stress was around 5-6 billion dollars.

The most important problem in cattle affected by heat stress is the inability to maintain the balance between the heat generated in the body and the spread of this heat to the environment. In other words, when the animal cannot lose enough heat to maintain a constant body temperature, it reduces feed consumption in order to reduce basal heat production after feed digestion and metabolic activities, and productivity loss occurs. In general, the higher the productivity of a cattle, the higher the basal heat production released because of feed digestion and metabolic activities. For this reason, since high-productivity animals produce more heat, they are more affected by environmental factors that create heat stress than low-productivity animals. In other words, they are at more risk (West 2003).

The main effect of heat stress in cattle is observed as body temperature rising above normal values. Environmental factors that create this effect are variables such as temperature, relative humidity, solar radiation, air movement and precipitation. Therefore, many indices have been developed in which different environmental parameters are used to determine the magnitude of heat stress. These indexes are generally called Temperature-Humidity Index (THI) and were developed to minimize losses due to heat stress as an air safety index. In calculating the indexes, some environmental climate data such as dry bulb temperature, wet bulb temperature, dew point temperature and relative humidity are used, and an attempt is made to get an idea about the level of heat stress according to the calculated value. THI is defined as a number that represents the magnitude of heat stress in a single value as the combined effect of temperature and humidity (Bohmanova et al. 2007, Dikmen and Hansen 2009).

Heat stress is an important factor that negatively affects not only the health of animals but also their productivity, thus directly affecting the success of the livestock enterprise. Therefore, determining how heat stress has changed from past to present through temperature humidity index values and how it will continue in the future is very important for successful animal production. Thus, it may be possible to develop structural measures, policies and strategies to reduce the negative effects of heat stress on health, productivity and functional characteristics (Smith et al. 2013).

Thermoneutral Zone and Thermal Comfort Zone

Thermoneutral zone (TNZ) can be defined as the zone where minimum heat production occurs at normal rectal temperature. Within the TZN, maximum yield can be obtained with minimum physiological expenditure. TNZ in cattle is related to the heat and water balance of the animals, the TNZ range varies depending on age, species, breeding status, feed consumption, feed composition, heating period, production amount, special housing conditions, tissue and surface insulation and behavior (Yousef 1985, Johnson 1987, McArthur and Clark 1988, Behera et al. 2020). McDowell et al. (1976) state that the prerequisite for achieving maximum productivity in cattle is to maintain a constant body temperature in the TNZ.

Thermal comfort zone can be understood as the temperature range in which vital functions occur optimally. Thermal zones are shown representatively in Figure 1 (Habeeb et al. 2018).

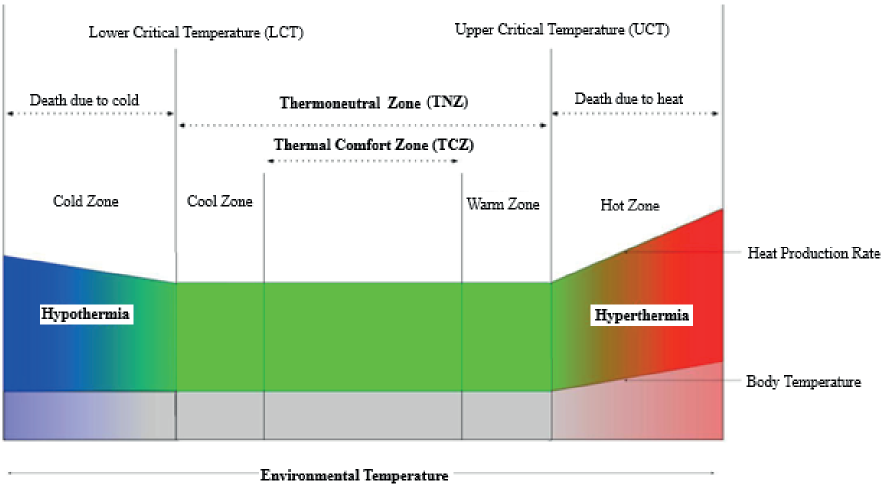

Figure 1. *Thermoneutral Zone and Thermal Comfort Zone (Habeeb et al. 2018).*

As seen in Figure 1, TNZ is the region bordered by the lower critical temperature and the upper critical temperature. In this region, the lower critical temperature is defined as the ambient temperature at which the animal must increase the metabolic heat production rate to maintain the body's thermal balance during rest, and the upper critical temperature is defined as the ambient temperature at which thermoregulatory evaporative heat loss processes are activated (Yousef 1985, Curtis 1981).

When the ambient temperature drops below the subcritical temperature, the non-evaporative heat loss from the animal to the environment increases, so the metabolic heat production rate increases and the energy obtained from the nutrients is used for heating and the yield reduces. Although different values are given in the literature as the lower critical temperature in cattle breeding, it is generally accepted to be between 4-7 °C (Mutaf and Sönmez 1984, Ekmekyapar 1991, Roenfeldt 1998, Yuksel and Sisman 2015, Sahin and Ugurlu 2017).

At ambient temperatures above the upper critical temperature, the evaporative heat loss from the animal through sweating and respiration becomes insufficient and body temperatures increase. When this thermal load exceeds the evaporative heat loss capacity, if the body temperature rise is not controlled, it leads to death due to hyperthermia (Kadzere et al. 2002). Evaporative heat loss of animals is a function of ambient temperature and humidity, and increasing of the temperature and humidity separately or especially together cause evaporative heat loss of the animal to decrease further, and cause to have difficulty in maintaining its body temperature and to be harmed. In cattle breeding, the upper critical temperature is generally accepted to be between 23-26 °C (Roenfeldt 1998, Yüksel ve Şişman 2015, İlhan 2018).

Critical, appropriate and optimum temperature values given by different researchers for cattle are given in Table 1.

Table 1. *Optimum, suitable, lower and upper critical temperature values for cattle*

Lower Critical Temperature (°C)	Optimum Temperature (°C)	Suitable Temperature (°C)	Upper Critical Temperature (°C)
-6 (Sainsbury & Sainsbury 1988)	**10 - 20** (Sainsbury & Sainsbury 1988; FAO 2016)	**4 - 24** (FAO, 2016)	**25** < (Sainsbury & Sainsbury 1988; FAO 2016)
-15 (WMO 1989)	**5 - 15** (WMO 1989)	**5 - 25** (Roenfeldt, 1998)	**27**< (WMO 1989; Brouček, 1997)
-10 (Noton, 1982; FAO 2016)	**10 - 15** (Balaban & Şen, 1988; Ekmekyapar, 1991)	**4 - 24** (Ekmekyapar 1991)	**24**< (Ekmekyapar 1991)
-12 (Young, 1981)	**10 - 15** (Maton et al. 1985)	**0 - 20** (Wathes et al. 1983)	**28**< (Wathes et al. 1983
-25 (Radostits & Blood 1985)	**0 - 20** (Brody 1955)		**21 - 25** (Brody 1955)
-13 (Webster 1981)	**7 - 15** (Demir, 1992; Yuksel & Sisman 2015)	**0 - 24** (Demir 1992)	**25**< (Radostits and Blood 1985; Yuksel & Sisman 2015)

Temperature-Humidity Index (THI)

Temperature-Humidity Index (THI)is an index developed by using different climate elements for quantification the magnitude of heat stress in order to minimize losses caused by heat stress in farm animals.

The best indicator of an animal's heat load and heat stress level is body temperature, but in practice, measuring and monitoring the body temperature of every animal in commercial enterprises where large herds are raised is not possible (Mader, 2003). For this reason, the THI was developed as the Livestock Weather Safety Index (LWSI) in order to classify the level of heat stress, monitor and reduce losses due to heat stress. The THI is defined as a single numerical value that represents the combined effects of air temperature and humidity associated with the level of heat stress (Bohmanova et al. 2007). This index is widely used as a practical indicator of heat stress in livestock farms around the world, especially in warm and hot regions.

In the calculation of THI, the focus was on temperature and relative humidity data, which are among the climate parameters effective on heat stress, and other parameters such as wind speed and solar radiation were generally ignored due to difficulties in obtaining data (Habeeb et al. 2018). The tolerance of animals to high air temperatures depends on the amount of air humidity. Because the rate of heat loss from the body through evaporation at high temperatures is inversely proportional to the amount of water vapor in the atmosphere (Dimov ve ark. 2020).

Many equations for calculating the THI have been developed or modified in the last 50 years. In these equations developed by different researchers for cattle, dry bulb (average or maximum temperature), wet bulb and dew point temperatures and the relative humidity of the air were generally used together. These equations developed for the calculation of THI are given below.

1. $THI = 0,4\ (T_{db} + T_{wb})\ 1,8 + 32 + 15$ (Thom, 1959)

2. $THI = (T_{db}\ 0,15 + T_{wb}\ 0,85)\ 1,8 + 32$ (Bianca, 1962a)

3. $THI = (T_{db}\ 0,35 + T_{wb}\ 0,65)\ 1,8 + 32$ (Bianca, 1962b)

4. $THI = 1,8\ T_{db} - (1\text{-}RH)\ (T_{db} - 14,3\ ) + 32$ (Kibler (1964)

5. $THI = 0,72\ (T_{db} + T_{wb}) + 40,6$ (NRC, 1971a)

6. $THI = (1,8\ T_{db} + 32) – [(0,55 – 0,0055\ RH)\ (1,8 + T_{db} – 26,8)]$ (NRC, 1971b)

7. $THI = (0,55\ T_{db} + 0,2\ T_{dp})\ 1,8 + 32 + 17,5$ (NRC, 1971c)

8. $THI = 9/5\ T_{max} + 32 - 11/2\ (1 - RH_{min})(9/5\ T_{max} - 26)$ (NOAA, 1976)

9. $THI = T_{db} + (0,36\ T_{dp}) + 41,2$ (Yousef, 1985)

10. $THI = T_{db} - [(0,31 - 0,31\ RH)\ (T_{db} - 14,4)]$ (for Buffalo) (Marai et al. 2001)

11. $THI = (0,8\ T_{db}) + (RH)\ (T_{db} – 14,4) + 46,4$ (Mader et al., 2006)

12. $THI = 3,43 + 1,058\ T_{db} – 0,293\ RH + 0,0164\ T_{db} RH + 35,7$ (Berman et al., 2016)

In equations,

T_{db}: Dry bulb temperature (°C)

Twb: Wet bulb temperature (°C)

Tdp: Dew point temperature (°C)

T_{max}: Maximum temperature (°C)

RH: Relative humidity (%)

RHmin: Minimum relative humidity (%)

The limit values given by different researchers for the purpose of classifying the SNI values calculated from these equations developed for cattle are given in Table 2.

Table 2. *SNI limit values defined by different researchers*

Researcher	SNİ Limit Values				
Thom (1959)	**70-74** Uncomfortable	**75-79** Very Uncomfortable	**80<** Serious Discomfort		
Kibler (1964)	**<72** Comfortable Zone	**72<** Heat Stress Zone			
NRC (1971a)	**70** Stres Threshold	**74** High Stress Threshold	**78** Extreme Stress Threshold		
NRC (1971b)	**72** Stres Threshold	**79** Moderate Stress Threshold	**89** Severe Stress Threshold		
NOAA (1976)	**68-72** Mild Stress	**72-75** Stress Zone	**75-78** Alert Zone	**79- 83** Danger Zone	**84<** Emergency Zone
McDowell et al (1976)	**70** Stres Threshold	**71-78** Stressful Zone	**78<** Extreme Stress Zone		
Yousef (1985)	**72** Stres Threshold	**78** Severe Stress Threshold	**82** Emergency Threshold		
Amstrong (1994)	**71** Stress Threshold	**72-79** Mild Stress	**80-89** Moderate Stress	**90<** Severe Stress	
Mader et al. (2006)	**74** Stress Threshold	**75-78** Alert Zone	**79-83** Danger Zone	**84<** Emergency Zone	
Marai et al. (2001) (For buffalo)	**22,2** Stress Threshold	**23,3** Severe Stress Threshold	**25,6** Denger Threshold		
Collier et al. (2012)	**68** Stress Threshold	**72-79** Moderate Stress	**80-89** Severe Stress	**90-98** Emergency Stress	
Costa et al (2015)	**70-72** Alert Zone	**72-78** Critical Zone	**79-83** Danger Zone	**83<** Emergency Zone	
Habeeb et al. (2018)	**68-72** Mild Stress	**72-75** Stress Zone	**75-79** Alert Zone	**79-84** Danger Zone	**84<** Emergency Zone
Janni (2019)	**68-71** Stres Threshold	**72-79** Mild - Moderate Stress	**80-89** Moderate - Severe Stress	**90-99** Severe Stress	

As can be seen from examining Table 2, the majority of researchers gave the heat stress threshold between 68-71 and defined the range 72-79 as Mild-Moderate stress, the range 80-89 as Severe stress, and the range 90-98 as Dangerous stress zone (Figure 2).

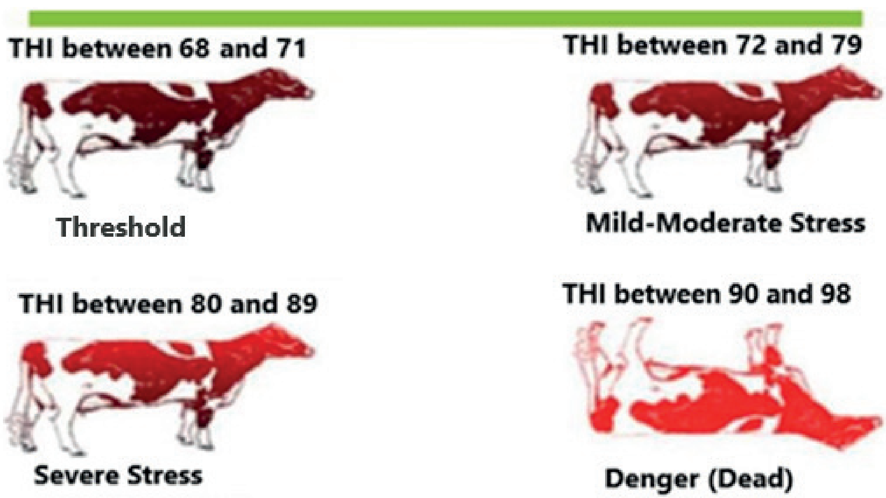

Figure 2. *Heat Stress Zones*

Since different parameters are used in SNI calculations for cattle, tables showing SNI limit values depending on environmental factors have been developed. SNI limit values calculated by Renaudeau et al. (2012) using dry bulb temperature and dew point temperature data are given in Table 3, and SNI limit values calculated by Collier et al (2012) using dry bulb temperature and relative humidity data are given in Table 4.

Table 3. *SNI limits based on dry bulb and dew point temperature data (Renaudeau et al. 2012).*

Air dry-bulb temperature (C)	Dew-point Temperature (C) 0	3	6	9	12	15	18	21	24	27	30
20	61	62	63	64	66	67	68				
22	63	64	65	66	68	69	70	71			
24	65	66	67	68	70	71	72	73	74		
26	67	68	69	70	72	73	74	75	76		
28	69	70	71	72	74	75	76	77	78	79	
30	71	72	73	74	76	77	78	79	80	81	82
32	73	74	75	76	78	79	80	81	82	83	84
34	75	76	77	78	80	81	82	83	84	85	86
36	77	78	79	80	82	83	84	85	86	87	88
38	79	80	81	82	84	85	86	87	88	89	90
40	81	82	83	84	86	87	88	89	90	91	92
Legend		Non-stress				Mild-moderate				Severe	
		Threshold				Moderate severe					

Table 4. *SNI limits based on dry bulb and dew point temperature data (Collier et al. 2012)*

Temperature		% Relative Humidity																				
°F	°C	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
72	22.0	64	65	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72	72
73	23.0	65	65	66	66	66	67	67	68	68	68	69	69	70	70	71	71	71	72	72	73	73
74	23.5	65	66	66	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74
75	24.0	66	66	67	67	68	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75
76	24.5	66	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76
77	25.0	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76	77
78	25.5	67	68	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	76	77	77	78
79	26.0	67	68	69	69	70	70	71	71	72	73	73	74	74	75	76	76	77	77	78	78	79
80	26.5	68	69	69	70	70	71	72	72	73	73	74	75	75	76	76	77	78	78	79	79	80
81	27.0	68	69	70	70	71	72	72	73	73	74	75	75	76	77	77	78	78	79	80	80	81
82	28.0	69	69	70	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80	81	81	82
83	28.5	69	70	71	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	82	83
84	29.0	70	70	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83	83	84
85	29.5	70	71	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84	84	85
86	30.0	71	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
87	30.5	71	72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84	85	85	86	87
88	31.0	72	72	73	74	75	76	76	77	78	79	80	81	81	82	83	84	85	86	86	87	88
89	31.5	72	73	74	75	75	76	77	78	79	80	80	81	82	83	84	85	86	86	87	88	89
90	32.0	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90
91	33.0	73	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89	90	91
92	33.5	73	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90	91	92
93	34.0	74	75	76	77	78	79	80	80	81	82	83	85	85	86	87	88	89	90	91	92	93
94	34.5	74	75	76	77	78	79	80	81	82	83	84	86	86	87	88	89	90	91	92	93	94
95	35.0	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
96	35.5	75	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94	95	96
97	36.0	76	77	78	79	80	81	82	83	84	85	86	87	88	89	91	92	93	94	95	96	97
98	36.5	76	77	78	80	80	82	83	83	85	86	87	88	89	90	91	92	93	94	95	96	98
99	37.0	76	78	79	80	81	82	83	84	85	87	88	89	90	91	92	93	94	95	96	98	99
100	38.0	77	78	79	81	82	83	84	85	86	87	88	90	91	92	93	94	95	96	98	99	100
101	38.5	77	79	80	81	82	83	84	86	87	88	89	90	92	93	94	95	96	98	99	100	101
102	39.0	78	79	80	82	83	84	85	86	87	89	90	91	92	94	95	96	97	98	100	101	102
103	39.5	78	79	81	82	83	84	86	87	88	89	91	92	93	94	96	97	98	99	101	102	103
104	40.0	79	80	81	83	84	85	86	88	89	90	91	93	94	95	96	98	99	100	101	103	104
105	40.5	79	80	82	83	84	86	87	88	89	91	92	93	95	96	97	99	100	101	102	103	105
106	41.0	80	81	82	84	85	87	88	89	90	91	93	94	95	97	98	99	101	102	103	104	106
107	41.5	80	81	83	84	85	87	88	89	91	92	94	95	96	98	99	100	102	103	104	106	107
108	42.0	81	82	83	85	86	88	89	90	92	93	94	96	97	98	100	101	103	104	105	107	108
109	43.0	81	82	84	85	87	89	89	91	92	94	95	96	98	99	101	102	103	105	106	108	109
110	43.5	81	83	84	86	87	89	90	91	93	94	96	97	99	100	101	103	104	106	107	109	110
111	44.0	82	83	85	86	88	90	91	92	94	95	96	98	99	101	102	104	105	107	108	110	111
112	44.5	82	84	85	87	88	90	91	93	94	96	97	99	100	102	103	105	106	108	109	111	112

Threshold   Mild-Moderate   Moderate-Severe   Severe

The health and productivity characteristics of cattle exposed to heat stress deteriorate depending on the severity of the stress and yield losses occur. The changes observed in the health and productivity of animals exposed to different levels of heat stress on a dairy farm are given in Table 5. While there is no significant yield loss in the mild and moderate stress zone (HNI 72-79), significant yield losses occur especially from the heat stress level above 79.

Table 5. *Effect of heat stress on dairy cattle (Anonymous, 2016)*

Stress Level	THI	Comments
None	<72	-
Mild-Moderate	**72-79**	Dairy cows will adjust by seeking shade, increasing respiration rate and dilation of the blood vessels. The effect on milk production will be minimal.
Moderate-Severe	**80-89**	Both saliva production and respiration rate will increase. Feed intake may be depressed and water consumption will increase. There will be an increase in body temperature. Milk production and reproduction will be decreased.
Severe	**90-98**	Cows will become very uncomfortable due to high body temperature, rapid respiration (panting) and excessive saliva production. Milk production and reproduction will be markedly decreased.
Danger	**>98**	Potential cow deaths can occur.

In a study conducted by Bouraoui et al. (2002) on the relationship between SNI and milk yield on the Mediterranean coast of Tunisia, it was determined that when the SNI value in lactating black pied dairy cattle increased from 68 to 78, milk yield decreased by 21% and feed consumption decreased by 9.6%. In addition, in the same study, it was determined that for each unit of SNI increase above 69, the daily milk yield loss per cow was 0.41 kg.

As reported by Collier et al. (2006) and Vermunt et al. (2010), the total milk yield of cows exposed to heat stress during a lactation in the summer decreases by 10% to 25%.

St-Pierre et al. (2003) determined the milk yield loss after calculated the time exceeding the daily SNI threshold value (SNI>70) in dairy farming in America, and the equivalent of this loss on the US scale determined $897 million annually.

In a study conducted by İlhan (2018) on dairy farms in the Marmara region, he determined that the daily maximum SNI values increased up to 82 in the summer months and that the average daily loss per animal in milk yield was 4.11 kg under these conditions.

Yield losses that will occur when cattle are exposed to heat stress can be estimated depending on the SNI values and the duration of heat stress. For this purpose, St-Pierre et al. (2003) developed the equation given below to calculate milk loss due to heat stress in the United States.

$$Qm = 0{,}0695 \cdot (SN\dot{I}_{max} - SN\dot{I}_{tresh}) \cdot 2 \cdot D$$

In equation,

Qm : Milk loss (kg)

D : Ratio of total daily stress time to 24 hours ($SNI_{max} > SNI_{tresh}$)

SNI_{max} : Maximum SNI value during the day

SNI_{tresh} : SNI threshold value for heat stress (Acceptable $SNI_{tresh}=70$)

Result

Today, global warming and climate change, the effects of which we feel more and more every day, also threaten the sustainability and profitability of animal production, which has an important place in human nutrition. Increasing temperature and humidity as a result of global warming will cause the deterioration of climatic environmental conditions that affect the health and productivity of farm animals. Predicting SNI data and developing measures based on these data is of great importance in preventing heat stress and productivity losses in farm animals that will be exposed to more temperature and humidity. For this reason, in this section, the equations developed to calculate SNI values have been tried to be explained.

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Chapter 5

A REVIEW OF THE USE OF MEALWORMS AS AN ALTERNATIVE PROTEIN SOURCE IN AQUACULTURE

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1. INTRODUCTION

The rising global population has made the production of animal-derived protein supply exceedingly crucial in terms of food and nutritional security (Gomez et al., 2019). Worldwide, fish is the most affordable and readily available animal protein source (Zlaugotne et al., 2022). Aquaculture is also among the fastest-growing food industries, and it makes significant contributions to the food industry as a source of animal protein (Maulu et al., 2022). In aquaculture, feed is the most critical input and output issue, with the increasing production quantity leading to a substantial increase in feed requirements (Tacon, 2020). Nevertheless, of the species being raised, nutrition is the most essential dynamic in all aquaculture operations. The nutrient content is the most significant factor in determining the metabolic and physiological events of organisms (Marousek et al., 2023). Fish meal and fish oil, which are the primary protein and lipid sources in the nutrition of aquatic animals, are obtained from wild-caught fish. Increasing feed demand due to its development in aquaculture has also increased the need for fishmeal and fish oil (Oliva-Teles et al., 2015). According to the 2022 (FAO) report, 81% of 21 million tons of harvested products were used in the production of fishmeal and fish oil (FAO, 2022).

However, the oceanic or marine resources used for fish feed production will prove insufficient to meet the rising demand due to the increased production of aquaculture (Arru et al., 2019). They are currently challenged by issues of sustainability in freshwater and marine resources, changing climatic events, stock depletion (Mousavi et al., 2020), fluctuations and rising prices of fish meal and fish oil, as well as decreasing availability (Llagostera et al., 2019). These factors have led humanity to explore alternative protein sources to meet the needs of the global food sector (Henry et al., 2018a; Bandara, 2018). In this regard, the mealworms (MW) *Tenebrio molitor* has already garnered global interest as an alternative protein source to fish meal in the scope of natural nutrition and offers a promising solution (Mousavi et al., 2020).

Fish meal and fish oil are indispensable feed ingredients in the aquaculture feed production sector with their high protein content (73%), essential amino acids, especially high unsaturated fatty acids, high digestibility and consumable properties (Zlaugotne et al., 2022). However, the decline in natural stocks and the resulting increased costs of sourcing fishmeal have prompted aquaculture producers to seek environmentally friendly and ecologically sustainable alternative sources for protein in the feeds currently used (Oliva-Teles et al., 2015). To be a viable alternative, the selected feed ingredient must possess specific attributes, including consistent quality, broad availability, and lower cost, among others (Sogari et al., 2019).

The accessibility and affordability of plant-based protein have enabled its utilization as an alternative to excellent nutrition properties in fish feeds (OlivaTeles et al., 2015; Cavrois-Rogacki et al,. 2022). However, the absence of fishmeal and oil in fish feeds has led to growth and health issues in fish. Additionally, the incorporation of plant-based proteins in fish feeds in recent years has led to an economic increase in plant protein availability, fostering competition across several sectors such as agriculture, biodiesel production, and human consumption (Hossain et al., 2023). The utilization of plant-based protein sources in fish feeds remains relevant and ongoing research continues. Moreover, the utilization of blood meal, meat and bone meal, feather meal derived from poultry by-products, and animal protein meals has witnessed an increase in their incorporation within aqua feed formulations (Gasco et al., 2014).

Producers and researchers, in their quest for alternative sources in fish feeds, have highlighted the suitability of insects to fulfill this need, considering evaluations related to fish growth performance, food safety, and minimal environmental impact (Gasco et al., 2020). On May 24, 2017, the European Union approved the usage of insect species such as the black soldier fly (*Hermetia illucens*), housefly (*Musca domestica*), mealworm (*Tenebrio molitor*), lesser mealworm (*Alphitobius diaperinus*), and cricket (*Gryllus* sp) in fish feeds, under specific proportions and limitations (Magalhaes et al., 2017; Woodgate et al., 2021). The yellow mealworm (*Tenebrio molitor*) has been reported as one of several candidate species with significant potential for commercial production among insects (Heckmann et al., 2018; Arru et al., 2019; Chen et al., 2023).

2. THE BIOLOGY AND LIFE CYCLE OF MEALWORMS

The species most frequently employed as an alternative protein source in the production of aquatic products is *Tenebrio molitor*, which is commonly referred to as mealworm or yellow mealworm (YMW) (Makkar et al., 2014). The YMW, also used in the diets of pets, is the most intensively produced insect species in Europe and the Far East (Hong et al., 2020). Preferring dark and humid environments as their habitat, the life cycle of YMW consists of four stages. The life cycle of this species begins with the egg stage (Matyja et al., 2020). The larvae, which hatch from the eggs within 4-12 days, remain in this stage for 9-12 days and require 3-4 months to mature. Larvae are typically white during this stage. Following this stage, the larva sheds its skin and enters the pupal stage, which is known as the metamorphosis stage. The final stage is the adult stage, during which they acquire the ability to reproduce (Zhang et al., 2019; Selaledi et al., 2020) (Figure 1).

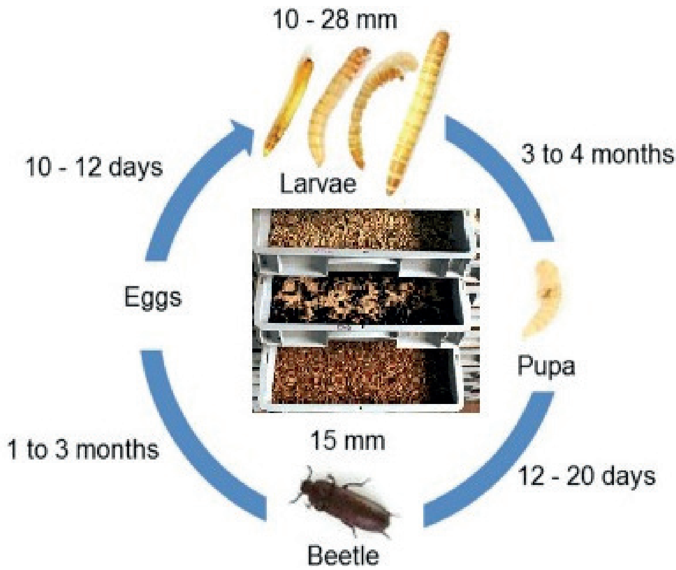

Figure 1. The life cycle of mealworm (darkling beetle) Tenebrio molitor (Ong et al., 2018; Dreyer et al., 2021).

Adult YMW are 12-200 mm in length and can reproduce up to 6 times a year under favorable conditions (Makkar et al., 2014). Originating from Europe and spread worldwide, YMW feed on grains and grain by-products, earning them the name "stored product pests." In addition to cereal products, their diet includes chicken manure and feathers, processed meat products, and insect detritus (Langston et al., 2023). YMW can be cultivated using bedding materials made from processed plant debris in plastic containers or in cultivation environments prepared with bedding containing bran and yeast. While the nutritional composition varies, an optimal temperature of around 28°C and a humidity level of 70% are reported for YMW production (Henry et al., 2018a; Trukhanova et al., 2022). In their native environments, YMW function as a natural dietary source for predatory fish species (Henry et al., 2015).

3. NUTRITIONAL VALUE OF MEALWORMS

While *Tenebrio molitor* is primarily utilized in poultry nutrition due to its favorable feed conversion ratio, sustainable protein source characteristics, and elevated protein content, it has begun to be employed as a substitute for protein sources like soybean meal and fish meal within feed formulations in the field of aquaculture (Benzertiha et al., 2019), digestibility, aroma, and functional attributes (Choi et al., 2018). Furthermore, its utilization has been growing both in aquaculture feed and human consumption, driven by its nutritional value. Additionally, the wide distribution of many species within its family is noteworthy (Makkar et al., 2014).

When analyzing the life cycle of the mealworm, it becomes evident that the initial larvae stage displays a nutritional composition of 20% protein, 13% fat, 2% fiber, and 62% moisture. Conversely, desiccated mealworms exhibit a distinct composition, comprising 53% protein, 28% fat, 6% fiber, and 5% moisture (Mariod, 2020). This demonstrates the adequate nutritional composition of insect feed for incorporation into fish diets. The diversity of insect species, habitats, developmental stages, feeding habits, and other characteristics likely influence the nutritional value of insects, and various studies have suggested that insect feeds could serve as alternatives to fish diets (Barroso et al., 2014).

Studies have shown that mealworm larvae are rich in proteins and amino acids (Table 1), especially oils, unsaturated fatty acids, vitamins (biotin, pantothenic acid, and folic acid) and minerals (zinc and selenium), and their usability in marine and freshwater fish, especially in the juvenile period period (Biancarosa et al., 2019; Gasco et al., 2020; Mazlum et al., 2021). In addition, they act as a good source of unsaturated fatty acids, including high oleic, linoleic and linolenic acid contents, as well as saturated fatty acids characterized by myristic, palmitic and stearic acids (Mattioli et al., 2021).

Table 1. A Comparative Assessment of Amino Acid Profiles in Mealworms (MW) Fed on Different Sources: Comparing with Soybean Meal and Fish Meal (FM)

Amino acids	**MW**					**FM**	**Conv. SBM**
Essential	**1**	**2**	**3**	**4**	**5**	**6**	**6**
Arginine	3.03	nd	3.60	1.81	3.93	4.10	3.57
Histidine	5.55	6.65	nd	1.77	0.65	1.54	1.54
Isoleucine	4.95	13.10	4.12	1.31	2.65	2.73	2.21
Leucine	8.13	22.06	2.96	2.96	4.74	7.77	3.86
Lysine	4.59	15.81	2.67	2.49	4.89	4.87	3.11
Methionine	0.70	6.01	1.76	0.57	1.16	1.85	0.68
Phenylalanine	2.99	13.09	3.06	3.07	3.01	2.64	2.55
Threonine	3.31	12.66	1.47	1.44	2.3	2.75	1.98
Valine	7.72	18.91	0.65	2.32	3.99	3.27	2.17
Non essential							
Alanine	12.79	24.83	4.53	3.92	3.09	4.19	2.16
Aspartic acid	8.68	15.44	4.30	3.71	4.61	5.77	5.50
Cystine	nd	12.69	nd	0.24	2.14	0.65	0.77
Glutamic acid	11.90	39.19	6.44	4.98	6.93	8.41	8.86

Glycine	10.43	17.06	3.67	2.87	4.67	5.03	2.13
Proline	7.67	20.01	2.67	3.04	5.95	3.08	2.74
Serine	3.67	13.61	2.38	2.49	4.91	2.59	2.41
Tyrosine	3.88	21.46	3.86	4.47	1.88	2.01	1.55

1: Laconisi et al., 2017; 2: Wu et al., 2020; 3: Jajic et al., 2020; 4: Melenchon et al., 2022; 5:Zhang et al., 2022; 6:Hong et al., 2020; Conv. SBM: Coventional Soybean Meal; nd: not described

4. SAFETY ASPECTS OF MEALWORM AS FOOD

As interest in alternative protein sources continues to rise, mealworms (*Tenebrio molitor*) have garnered attention as a potentially sustainable and nutritious food option (Akhtar and Isman, 2018; Liceaga et al., 2022). Evaluating the safety aspects of mealworm consumption is paramount to ensure consumer health and foster broader acceptance. Extensive research has been devoted to assessing the microbiological safety, chemical composition, allergenicity, and potential health benefits of mealworms intended for human consumption (Cunha et al., 2023). Microbiological safety is a cornerstone of any food source. Comprehensive investigations have revealed that mealworms exhibit relatively low levels of harmful microorganisms, positioning them as a safer option compared to traditional livestock (Pöllinger-Zierler et al., 2023). Rigorous processing methods, such as blanching or freeze-drying, further mitigate microbial risks while maintaining the nutritional quality of mealworms (Yan et al., 2023). Moreover, studies by Johnson et al. (2021) have confirmed that mealworms exhibit low levels of heavy metal accumulation, demonstrating their potential to serve as a safe source of essential nutrients. Allergenicity assessment is crucial, particularly given the increasing prevalence of food allergies. While mealworms belong to the arthropod family, instances of allergic reactions are rare. Notably, the cross-reactivity of allergenic proteins between mealworms and common allergens like shellfish remains minimal, reducing the likelihood of triggering allergies in sensitive individuals (Barre et al., 2019). Furthermore, preliminary studies have explored potential health benefits of mealworm consumption. The presence of bioactive compounds, such as antimicrobial peptides, in mealworms has raised interest in their immunomodulatory properties. Recent work by Martínez et al. (2018) suggests that certain peptides derived from mealworms might exhibit anti-inflammatory effects, warranting further investigation into their potential health-promoting attributes.

5. ECONOMIC ASPECTS OF USING MEALWORMS IN AQUACULTURE

According to the statistical report on aquaculture and fisheries published by the Food and Agriculture Organization (FAO) in 2022, the total global fish production reached 178.6 million tons, with aquaculture accounting for almost half of this at 87.5 million tons and the total amount of fishing reached 90. 265 tons in 2020 (FAO, 2022).

Although it has rich nutritional content, there is some controversy regarding its fatty acid content. While some researchers report that it has sufficient fatty acid content (Barroso et al., 2014), some researchers have suggested that it is quite different from the fishmeal profile (Fabrikov et al., 2021). The fish then adapts their fatty acid profile to the diet. In this case, it leads to lower than desired PUFA levels and a decrease in n-3/n-6 ratios in fish meat. Since these n-3 and PUFA levels are extremely important for human health, it may lead to a decrease in consumption. As a solution to this problem, it has been stated that the fatty acid profiles can be improved by reducing the fat of insect flours before adding them to the feed or by feeding them with diets consisting of fish wastes (Llagostreda et al., 2019).

Although the presence of chitin in their exoskeleton has been suggested as one of the problems to be overcome for the use of insect meal, some researchers have suggested that this situation may vary according to the species because some fish have a chitinase enzyme that can digest this chitin (Coutinho et al., 2021). On the other hand, some researchers have stated that chitin can show prebiotic properties at a low rate, thus improving the microbiota and having a significant effect on fish development and health. It has also been stated that enterprises can produce chitin-free fishmeal if desired (Llagostreda et al., 2019) (Table 1). For the reasons mentioned above, mealworms have been used as an alternative protein source in the feed industry in aquaculture (Sharifinia et al., 2023). Several articles have reviewed the use of mealworms in aquaculture, focusing on their potential as feed sources.

Various articles have examined the utilization of mealworms in aquaculture, with a focus on their potential as feed sources. These studies have also explored the feasibility of substituting fish meal with mealworms, especially in the context of aquaculture (Henry et al., 2015; Gasco et al., 2018; Nogales-Mérida et al., 2019; Hameed et al., 2022). These articles encompass their impacts on growth and the physicochemical properties of flesh, along with consumer acceptance. While the literature on replacing fishmeal with insects holds promise, the findings have been somewhat inconclusive (Henry et al., 2015).

In studies on rainbow trout, some researchers report that replacing 25% to 50% of fishmeal with mealworms yields comparable growth performance to trout fed with fishmeal (Gasco et al., 2014; Melenchon et al., 2022). The choice of insect species leads to variations, with the most common ones being mealworms (*Tenebrio molitor*) and black soldier fly prepupae (*Hermetia illucens*), exhibiting variations depending on the insect's life stage, lipid content, rearing conditions, processing methods, and the life stage of the fish (Renna et al., 2017). Compared to other insects, black soldier fly larvae display a fundamental amino acid profile akin to that of fishmeal (Henry et al., 2015). Renna et al. (2017) underscore that the transition from fishmeal to insect meal does not appear to affect rainbow trout survival, growth performance, condition indices, somatic indexes, or fillet quality parameters.

Experiments concerning European sea bass are relatively less abundant (Gasco et al., 2016; Henry et al., 2018b). Gasco et al. (2016) demonstrated that substituting 25% of fish meal with mealworms (while maintaining isoproteic diets) did not have adverse effects on weight gain, although growth reduction was observed at 50%. Trials involving juvenile seabass aimed to assess the repercussions of incorporating full-fat mealworm larvae into the diet, resulting in a deterioration of final body weight, weight gain, specific growth rate, and feed intake (Gasco et al., 2016).

Several investigations have probed into consumer acceptance of farmed fish raised on insect-based diets. An Italian researcer revealed that nearly 90% of consumers exhibited a favorable attitude towards insect-based feed, indicating that substantial alterations in purchasing habits may not be requisite (Mancuso et al., 2016). Similar findings were reported for the Scottish salmon farming sector in the United Kingdom, where only 10% of consumers expressed opposition to the inclusion of insect larvae (grubs) in fish feed. However, consumers were unwilling to pay a premium for products derived from insect-fed fish (Popoff et al., 2017). A study conducted with German consumers indicated that the majority of respondents displayed indifference to the utilization of insect-based protein in trout production, with a small, sensitive segment (23%) anticipating a reduction in consumption unless fish prices were lowered (Ankamah-Yeboah et al., 2018). These findings suggest that the environmental impact of mealworm production, particularly in terms of energy demand, may surpass that of other protein sources currently employed in animal feeds (Thevenot et al., 2018).

6. USE OF MEALWORM IN FISH DIETS

In recent years, the exploration of alternative protein sources for aquaculture feed has gained significant momentum. Among these alternatives, mealworms (*Tenebrio molitor*), the larvae of darkling beetles, have emerged as a promising candidate due to their unique nutritional composition and versatile production methods (Frooninckx et al., 2022). Mealworms offer a well-balanced nutrient profile, characterized by high protein content, essential amino acids, and beneficial fatty acids. This nutrient richness aligns with the dietary requirements of many fish species, positioning mealworms as a valuable dietary component (Gasco et al., 2014; Mazlum et al., 2021; Sharifinia et al., 2023).

As a result of the aforementioned reasons, mealworms have been explored as an alternative protein source in fish feed. They have been tested in various species, including African catfish (*Clarias gariepinus*) (Ng et al., 2001), rainbow trout (*Oncorhynchus mykiss*) (Gasco et al., 2014), tilapia (*Oreochromis niloticus*) (Sanchez-Muros et al., 2016), yellow catfish (*Pelteobagrus fulvidraco*) (Su et al., 2021), common carp (*Cyprinus carpio*) (Gebremichael et al., 2022) in freshwater, and sea bass (*Dicentrarchus labrax*) (Gasco et al., 2016), gilthead sea bream (*Sparus aurata*) (Piccolo et al., 2017), red porgy (*Pagellus bogaraveo*) (Iaconisi et al., 2017), Atlantic salmon (*Salmo salar*) (Biancarosa et al., 2019) in marine environments, as well as shrimp species like Pacific white shrimp (*Litopenaeus vannamei)* (Choi et al., 2018; Sharifinia et al., 2023), giant freshwater prawn species (*Macrobrachium rosenbergii*) (Feng et al., 2019). aquarium fish species known as Mandarin fish (*Siniperca scherzeri*) (Sankian et al., 2018), and narrow-clawed crayfish (*Pontastacus leptodactylus*) (Mazlum et al., 2021).

The versatility of mealworm cultivation contributes to their attractiveness as a sustainable feed ingredient. These larvae can thrive on a variety of organic substrates, including agricultural by-products, kitchen waste, and even organic residues from food processing industries (Moruzzo et al., 2021). This adaptability not only minimizes waste by transforming it into valuable protein but also reduces the strain on traditional feed resources. As the world grapples with the challenges of feeding a growing population while minimizing environmental impact, such resource-efficient options take on even greater significance (Sampathkumar et al., 2023).

Research findings highlight the positive effects of mealworm inclusion in fish diets. For instance, studies involving rainbow trout have demonstrated improved growth rates and feed conversion efficiency when mealworms are incorporated into the feed regimen (Melenchon et al., 2022). Similarly, tilapia (*Oreochromis* spp.) fed diets containing mealworms have exhibited enhanced nutrient utilization and overall performance (Tubin et al., 2020). These findings suggest that mealworms can not only serve as a protein source but also contribute to optimizing the nutritional value of aquaculture diets (Basto et al., 2020).

However, the integration of mealworms into aquaculture diets is not without challenges. The determination of optimal inclusion levels is a crucial aspect, as excessively high inclusion can alter feed palatability and digestibility (Hameed et al., 2022; Zlaugotne et al., 2022; Chen et al., 2023). Moreover, potential anti-nutritional factors within mealworms need careful assessment to ensure they do not negatively affect fish health. Research efforts are underway to address these challenges and develop strategies for harnessing the benefits of mealworms without compromising feed quality (Kim et al., 2019).

Beyond their direct application in fish diets, mealworms also hold potential in waste management systems. The ability to convert organic waste into high-quality protein via mealworm rearing displays a circular approach to resource utilization. This aligns with the principles of a circular economy, wherein waste is transformed into a valuable resource, benefiting both the environment and industries reliant on protein sources (Peng et al., 2021).

Consequently, insects have emerged as viable alternatives to fish meal, fish oil, and soybean meal. Their applicability, particularly during the juvenile stages of marine and freshwater fish, has been emphasized (Barroso et al., 2014; Gasco et al., 2016; Coutinho et al., 2021; Chen et al., 2023).

8. EFFECTS OF MEALWORM ADDED TO FEEDS ON FISH GROWTH

The incorporation of mealworms (*Tenebrio molitor*) into fish feeds has garnered considerable attention as a strategy to enhance fish growth and optimize nutritional outcomes. Research exploring the effects of mealworm supplementation on fish growth has yielded promising results across diverse aquatic species. For instance, studies by Heckmann et al. (2018) investigating the impact of mealworm inclusion in rainbow trout diets reported significant improvements in growth rates and feed conversion efficiency. Similarly, in experiments conducted by Tubin et al. (2020) with tilapia, the incorporation of mealworms led to enhanced growth parameters, attributed to the well-balanced nutritional composition of mealworms, encompassing high-quality protein and essential amino acids.

Furthermore, the utilization of mealworms in fish feeds contributes to the broader framework of sustainable aquaculture. The inclusion of mealworms reduced the reliance on traditional protein sources, effectively lessening the environmental impact associated with conventional feed ingredients (Peng et al., 2021). This aligns with the sustainability objectives of the aquaculture industry, wherein novel protein sources like mealworms play a crucial role in mitigating resource constraints while promoting efficient growth (Sankian et al., 2018).

Notably, the effects of mealworm inclusion in fish feeds extend beyond growth parameters. Recent investigations by Henry et al. (2018b) explored the influence of mealworm supplementation on fish health and immune response. The results revealed that diets enriched with mealworms contributed to improved immune system activity and disease resistance, shedding light on the potential immunomodulatory properties of mealworm-based feeds (Ido et al., 2019).

However, challenges persist in determining optimal inclusion levels and assessing potential anti-nutritional factors within mealworms. Integrating findings from on anti-nutritional factors, which highlighted the need for careful consideration of certain compounds that might influence nutrient absorption, is paramount for refining mealworm incorporation strategies (Ojha et al., 2021).

9. FUTURE DIRECTIONS

Feeding the growing global population sustainably is of utmost importance, and edible insects can contribute to this endeavor. Applying circular economy concepts, particularly in the production of sustainable and renewable protein sources like algae, microalgae, fungi, and insects, poses a challenge for the future of humanity. Redesigning the food production chain is necessary, and this will inevitably involve the systematic reuse of by-products, residuals, and agricultural food waste in compliance with regulations. As mealworms and other insects yield new products and benefits, they can contribute to reducing losses and enhancing circularity. From foods to feeds, and even chemicals to fertilizers, mealworms can be cultivated to obtain valuable products, sometimes serving multiple purposes. By cultivating mealworms, all production chains can increase environmentally friendly outcomes while meeting the rising demand for goods. Insect farming, especially mealworm cultivation, can enhance circular economies in both developed and developing countries. Improvements in personalized marketing strategies and consumer awareness will assist the entire process.

Today, fishmeal is used as a protein source in aquaculture fish feed, and it's reported that 63% of the globally produced fish meal is utilized as feed sources in aquaculture. However, the decrease in natural stocks and the resulting price increases in acquiring fishmeal have directed producers towards seeking environmentally friendly and ecologically sustainable alternative sources instead of the protein sources currently used in fish production feeds. In this quest for alternative sources in fish feeds, producers and researchers have demonstrated that insects possess the qualities to meet this need while minimizing the impact on fish growth performance, food safety, and the environment.

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Chapter 6

PARASITE BIODIVERSITY OF FISHES IN TÜRKİYE – IV. MONOGENEA

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1. INTRODUCTION

Monogenean parasites (Platyhelminthes) are highly diverse with about 6000 – 7000 species and mostly ectoparasitic groups infesting mostly marine, brackish, and freshwater fishes around the world. A number of species have been reported to parasitize cephalopods, amphibians, reptiles, and mammals. Monogeneans fish parasites are known to be relatively high host specificity and it is generally assumed that many fish hosts (agnathans, cartilaginous and bony fish) harbour at least one unique monogenean species (Buchmann and Bresciani, 2006). Monogeneans are composed of two major groups, the monopisthocotyleans and the polyopisthocotyleans (Özer, 2019). These worms have two main structures; (a) the prohaptor, an adhesive part with attachment capacities through adhesive pads, cephalic openings located in the fore part of the worm, (b) the opisthaptor, an adhesive apparatus located in the hind part of the worm, equipped with sclerotized structures of hooks, clamps, and suckers (Buchmann and Bresciani, 2006). Members of Gyrodactylidae and Dactylogyridae are among the most reported parasites in wild and cultured fish.

Their life cycle involves only one host and they mostly spread by way of egg-releasing and free-swimming infective larvae (Öztürk and Özer, 2014). However, members of the family Gyrodactylidae are viviparous which allows transmission through host-to-host contact. Their simple and direct life cycle i.e. without intermediate hosts allow them rapidly multiply in suitable environments such as culture environments which provide a higher density of host fishes. This is important because, under intensive culture conditions, they have harmful impacts on the health of status of their hosts. The majority of the monogeneans are on external surfaces of fish (skin, fins, gills, mouth cavity, nostrils) but a few species have adopted an endoparasitic life (Buchmann and Bresciani, 2006).

A total of 401 and 561 fish species were registered in freshwater and marine environments in Türkiye, respectively (Faroese & Pauly, 2022). Fish are regarded as valuable food for human consumption and due to constant decreases in capture values in natural sources, some species, such as rainbow trout *Oncorhynchus mykiss*, European seabass *Dicentrarchus labrax*, and gilthead sea bream *Sparus aurata,* are cultured in either land-based culture facilities and/or net cages in lakes and seas to meet the increasing demand. Ornamental fish trade is another fast-growing industry in Turkey and either cultured individuals or imported ones are capturing more and more of the attention of hobbyists (Özer, 2022).

Monogenean parasites of fishes are subjected to many investigations in Türkiye in the last decades, and thus the very extensive amount of papers as well as several checklists reported these parasites on their respective hosts in freshwater and marine environments have been published by Öktener (2003, 2005, 2014), Özer (2019, 2020), Özer & Öztürk (2017), Öztürk & Özer (2014). Moreover, Özer (2021) published a very comprehensive host-parasite, as well as parasite-host checklist book based on all previous reports in Türkiye, and this chapter on the monogenean parasites of fishes in Türkiye has been created based on the data presented in this recent book which all the individual publications on each monogenean parasite species can be found.

2. MONOGENEAN PARASITE DIVERSITY OF FISHES IN TURKEY

According to Özer (2021), a total of 175 monogenean species were reported from all fish species from different environments in Türkiye with the highest number from wild freshwater fishes (89), followed by wild marine fishes, cultured marine, cultured freshwater, and aquarium fishes (Figure 1). On the other hand, the highest number of wild freshwater fish species (63) hosted the monogenean parasites, followed by wild marine, cultured marine, cultured freshwater, and aquarium fishes (Figure 2).

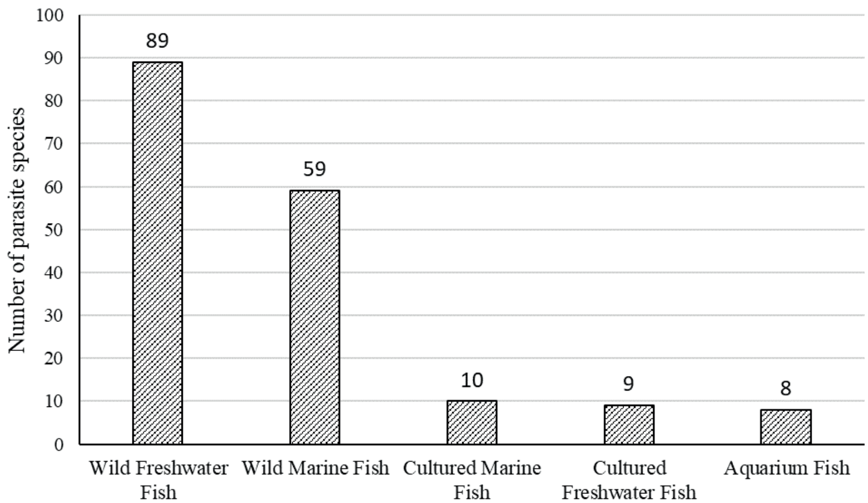

Figure 1. *The total number of monogenean parasite species reported from marine, freshwater, and aquarium fishes in Türkiye.*

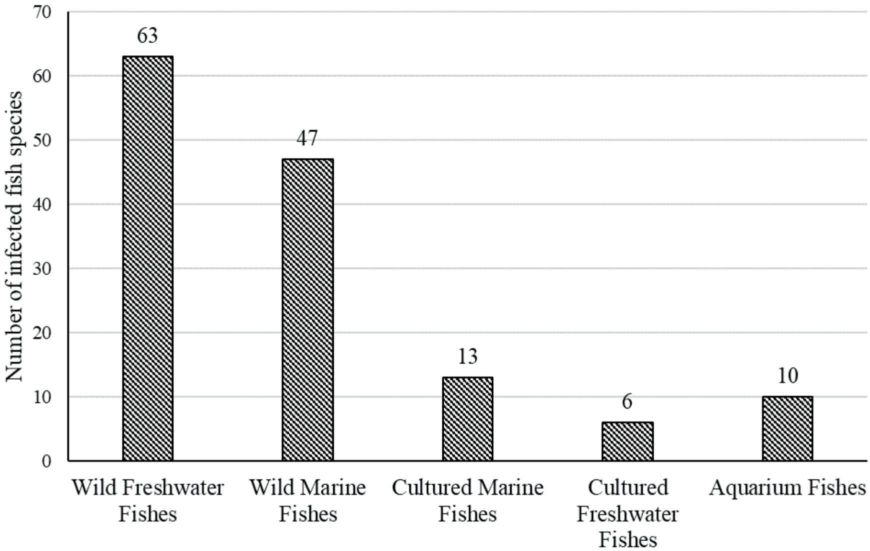

Figure 2. *The number of fish species infested by monogenean parasites in marine, freshwater, and aquarium environments in Türkiye.*

3. MONOGENEAN PARASITE DIVERSITY OF FRESHWATER FISHES

3.1. Wild freshwater fish

Monogenean parasite species reported from 4 and more wild freshwater fish host species in Türkiye is presented in Figure 3 and the lesser numbers can be seen in Özer (2021). Members of the two monogenean genera *Gyrodactylus* and *Dactylogyrus*, which were not determined to a species level, were the most commonly reported parasites from 23 and 14 different host species, respectively, and followed by *Dactylogyrus sphyrna* and *Paradiplozoon homoion*. The rest of the parasite species reported from 4 and more host species are also provided in Figure 3.

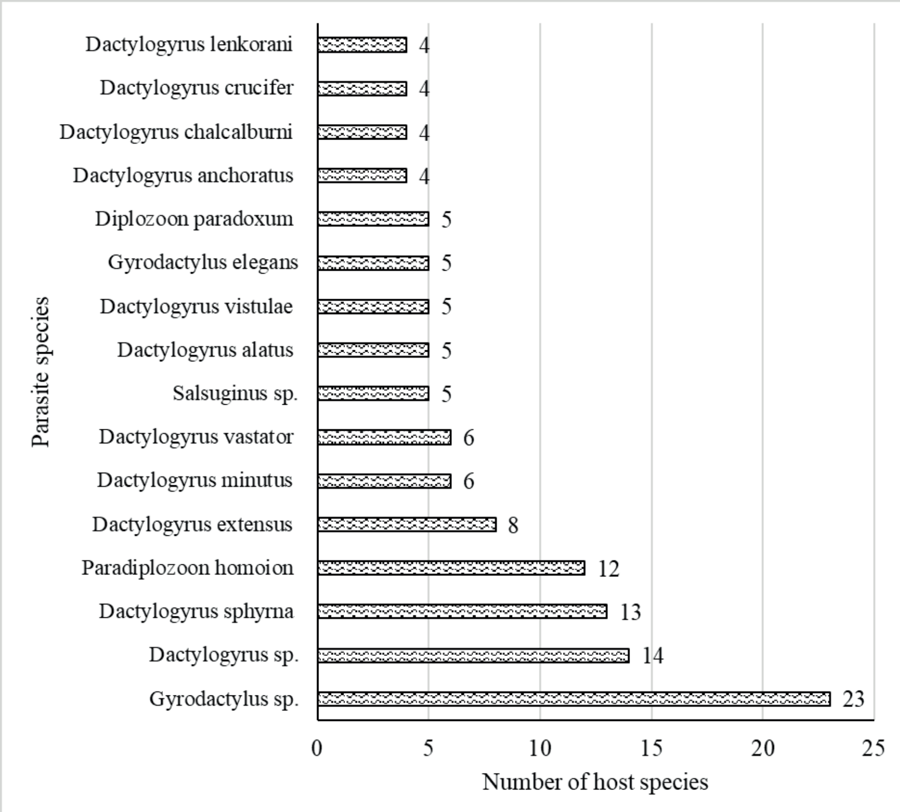

Figure 3. *The number of monogenean parasite species infesting wild freshwater fish species in Türkiye.*

When the number of different monogenean species from wild freshwater host species is considered, the common carp *Cyprinus carpio* was reported to host the maximum number of monogenean parasite species (16), followed by other cyprinid species of *Blicka bjoerkna, Squalius cephalus* and *Vimba vimba* with 11 different monogenean species and the rest of the fish species had lesser number of monogenean parasites (Figure 4).

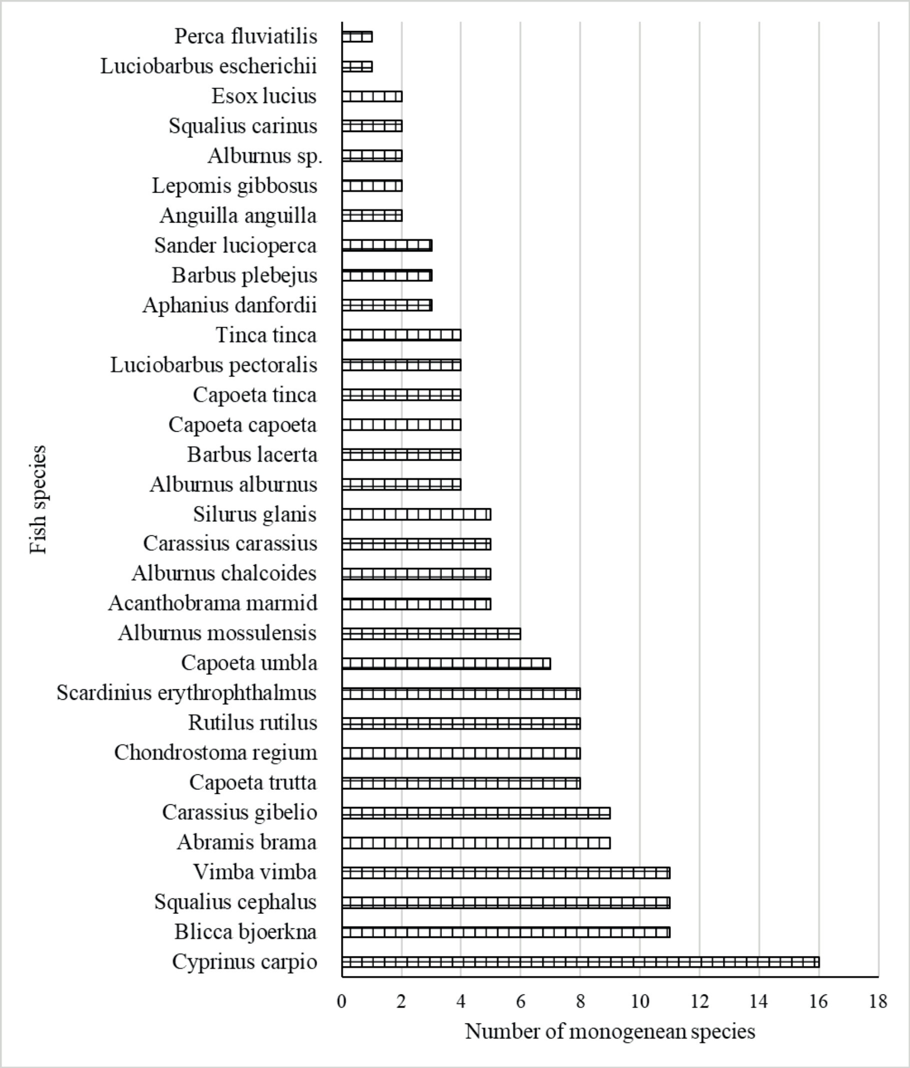

Figure 4. *The number of monogenean parasite species infesting the wild freshwater host fishes in Türkiye.*

3.2. Cultured freshwater fish

Among the cultured freshwater fish infesting monogenean parasites, *Gyrodactylus* sp was reported from 3 different host fish species, and the rest were very low in numbers (Figure 5). Number of cultured fish species is low in Türkiye and, not surprisingly, the numbers of monogenean parasites reported these host fishes are also low (Figure 5).

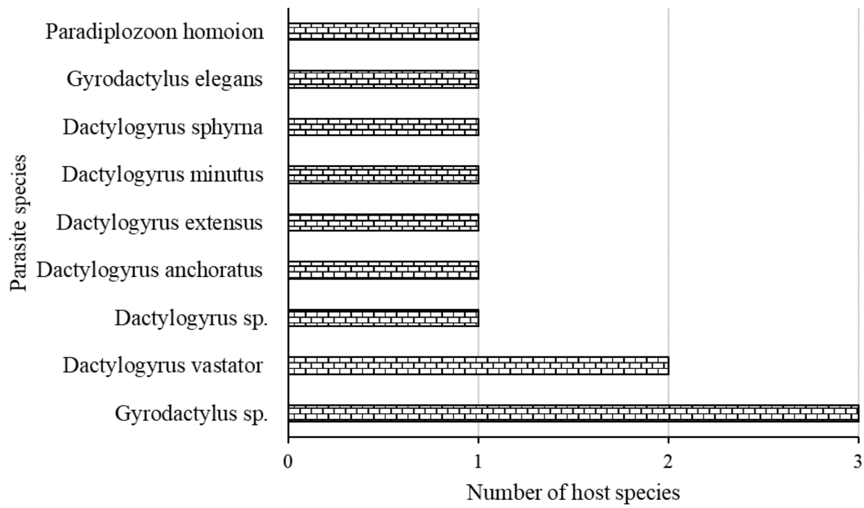

Figure 5. *The number of cultured freshwater fish host species infested by monogenean parasites in Türkiye.*

The common carp *Cyprinus carpio* and the rainbow trout *Oncorhynchus mykiss* are the most commonly cultured species in extensive and intensive facilities in Türkiye. When the number of monogenean parasite species infesting cultured freshwater fishes is considered, not surprisingly, the common carp is the most infested cultured fish species with 7 different monogenean species and the rest of the fishes had a lower number of monogeneans (Figure 6).

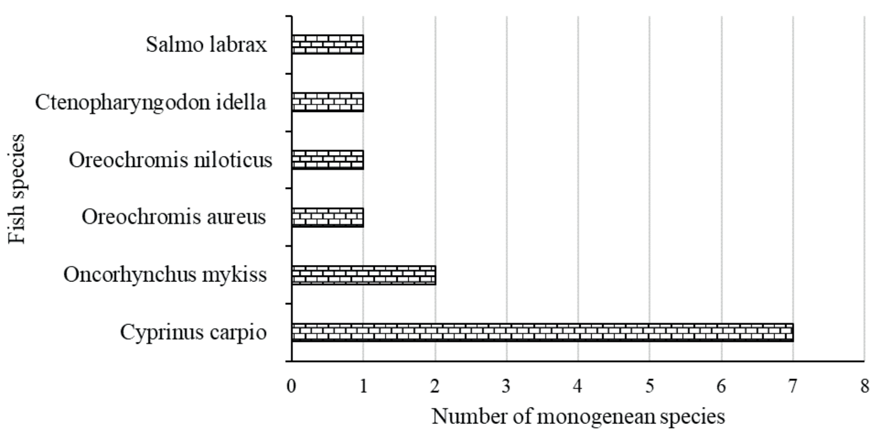

Figure 6. *The number of monogenean parasite species infesting cultured freshwater fishes in Türkiye.*

4. MONOGENEAN PARASITE DIVERSITY OF MARINE FISHES

4.1. Wild marine fishes

Monogenean parasite biodiversity from wild marine fishes inhabiting the surrounding seas of Türkiye was very high and mostly came from the Aegean Sea (42) in parallel to the higher number of fish species diversity, followed by the Black Sea, Sea of Marmara, and the Mediterranean Sea (Figure 7).

Monogenean parasites reported from ≥3 wild marine fishes were dominated by *Microcotyle erythrini* by being reported from 7 host fish species. This parasite was followed by an unidentified *Gyrodactylus* sp., *Solostamenides mugilis, Lamellodiscus* sp., *Gyrodactylus proterorhini* and *Choricotyle chrysophri* (Figure 8). Other monogenean species were also reported from 2 and a lesser number of fish species (see Özer, 2021 for details).

A very diverse wild marine fishes were reported to be the host for monogenean parasites from the surrounding seas of Türkiye (Figure 9). Mugilid species had more numbers of parasites among others by flathead grey mullet *Mugil cephalus* having 8 different monogenean species, followed by gilthead seabream *Sparus aurata* (7), golden grey mullet *Chelon auratus* (6), thinlip grey mullet *Chelon ramada* (5) and leaping mullet *C. saliens* (5), and the rest of fish species had lesser number of monogenean parasites (Figure 9).

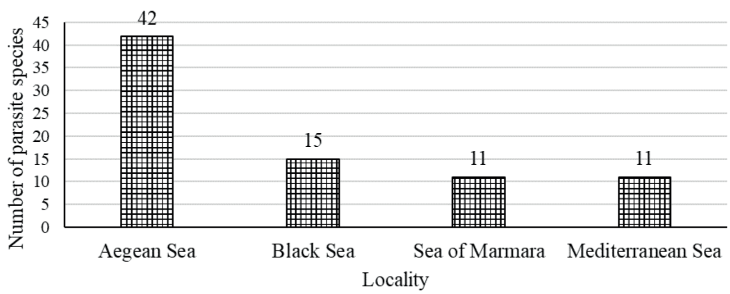

Figure 7. *The number of monogenean parasite species reported from wild marine fish species inhabited the surrounding seas of Türkiye.*

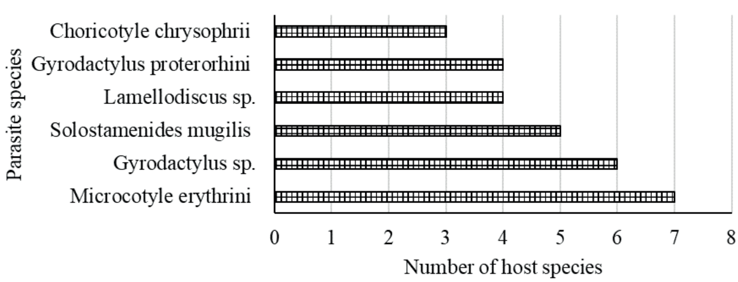

Figure 8. *The number of monogenean parasite species infesting ≥3 wild marine fish species in Türkiye.*

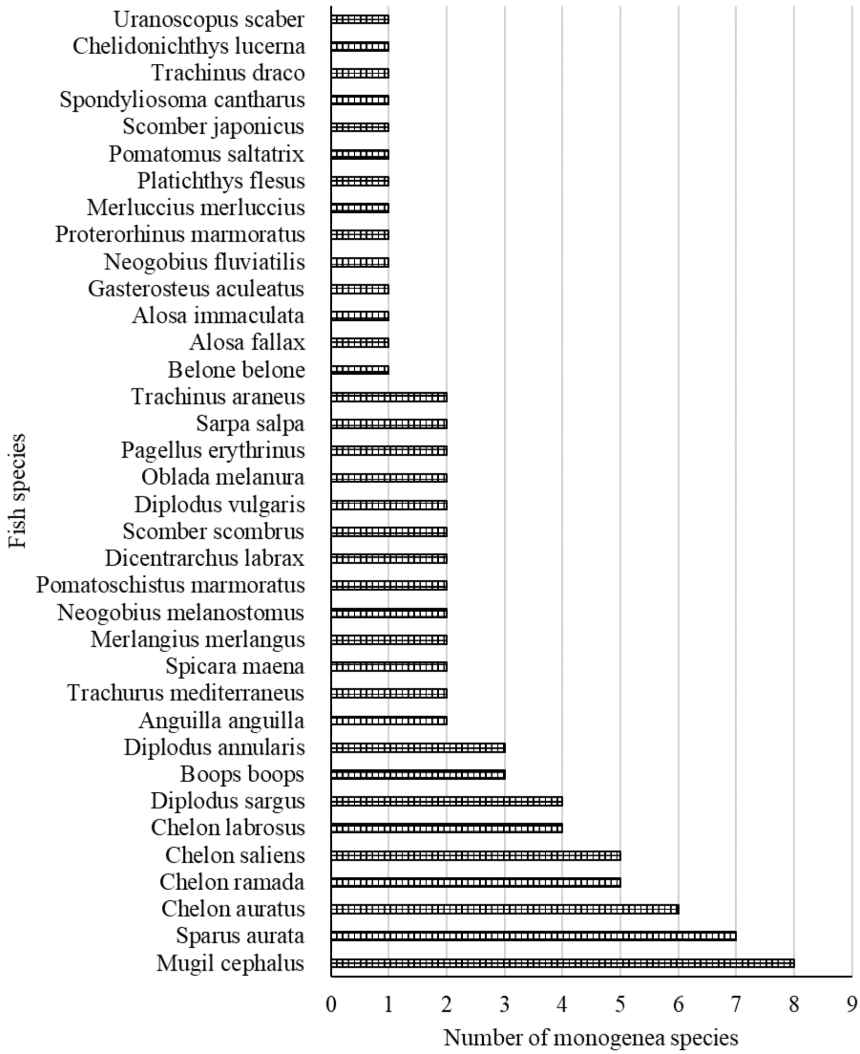

Figure 9. *The number of monogenean parasite species infesting the wild marine host fishes in Türkiye.*

4.2. Cultured marine fishes

Marine fish culture in the surrounding seas of Türkiye has been constantly growing over a couple of decades in the culture of seabass *Dicentrarchus labrax* and gilt-head sea bream *Sparus aurata*. In recent years, some other alternative marine fish species as well as rainbow trout *Oncorhynchus mykiss* production in the Black Sea are also have been subjected to cultural activities. Thus, more parasite species have been reported from these hosts in recent years and parasitological investigation on monogeneans yielded a wide range of parasite species infesting cultured marine fish hosts (Figure 10). *Microcotyle erythrini* was the most reported monogenean species from 8 different host species, followed by *Diplectanum aequans*, *Lamellodiscus echeneis,* and *Sparicotyle chrysophrii* from lesser number of host species (Figure 10).

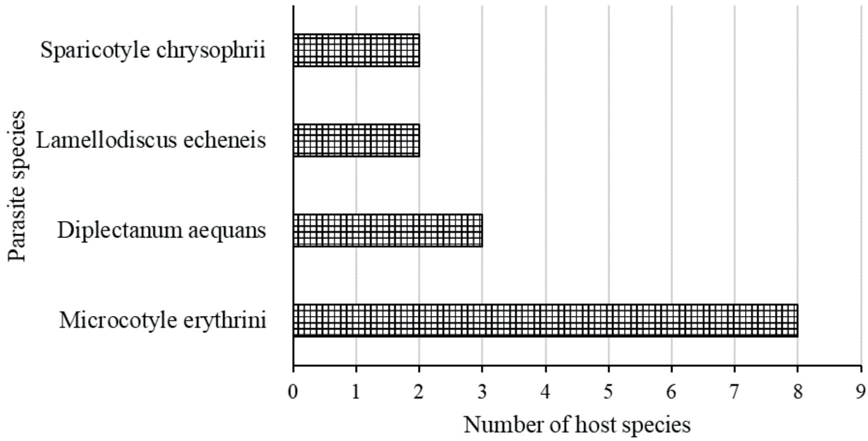

Figure 10. *The number of cultured marine fish host species infested by monogenean parasites in Türkiye.*

The intensive cultural activities on marine fishes are conducted on the most on gilt-head sea bream *S. aurata*, and seabass *D. labrax*, and some other alternative fish species are also cultured which can be seen in Figure 11. These cultured fish species have also been subjected to parasitological investigations and the number of reported parasite species was the highest (n=3) on the most cultured above-mentioned fish species. Some of the other fish species (*Boops boops, Dentex dentex, Pagellus erythrinus*) were found to be infected by two and the rest 9 fish species had only one parasite species (Figure 11).

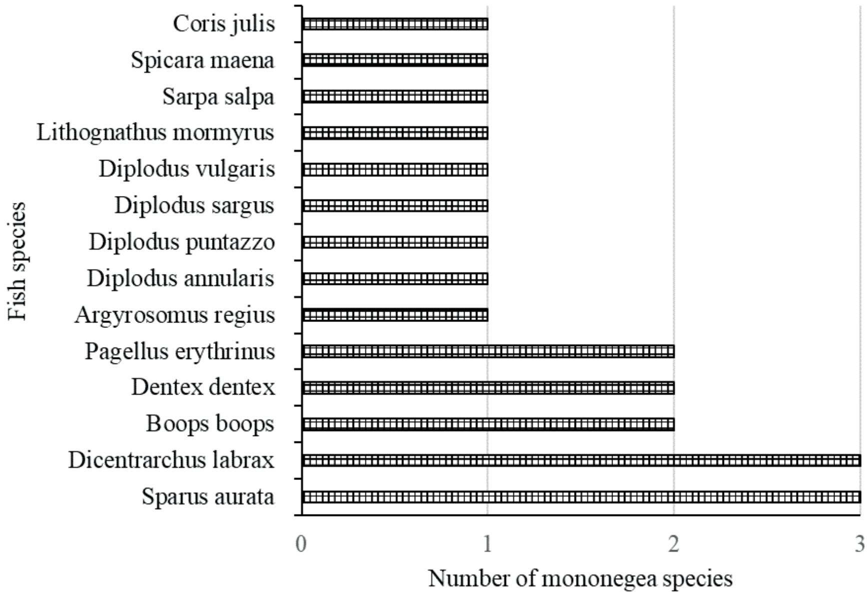

Figure 11. *The number of monogenean parasite species infesting the cultured marine fishes in Türkiye.*

5. MONOGENEAN PARASITE DIVERSITY OF AQUARIUM FISHES

Ornamental fishes and aquarium fisheries are popular sectors and are attractive to hobbyists worldwide. Of the 32 ornamental fish species in Türkiye, a total of 7 nominal species and 2 species identified only at the genus level have been reported to be infested with at least one monogenean parasite. Among them, members of 2 genera *Dactylogyrus* sp. and *Gyrodactylus* sp. were the most reported species reported from ornamental fish species, 5 and 3, respectively, followed by *G. bullatarudis* from 2 host species (Figure 12). The rest of the monogeneans belonging to 4 genera were reported from only one fish host species (Figure 12).

Of the infested ornamental fish species, goldfish *Carassius auratus* has been reported to be the host for 5 different monogenean species in Türkiye (Figure 13). Sailfin molly *Poecilia latipinna* and green swordfish *Xiphophorus hellerii* were reported to be infested by species and the rest of the ornamental fish species belonging to five different genera were reported to be the host for only one monogenean parasite species (Figure 13).

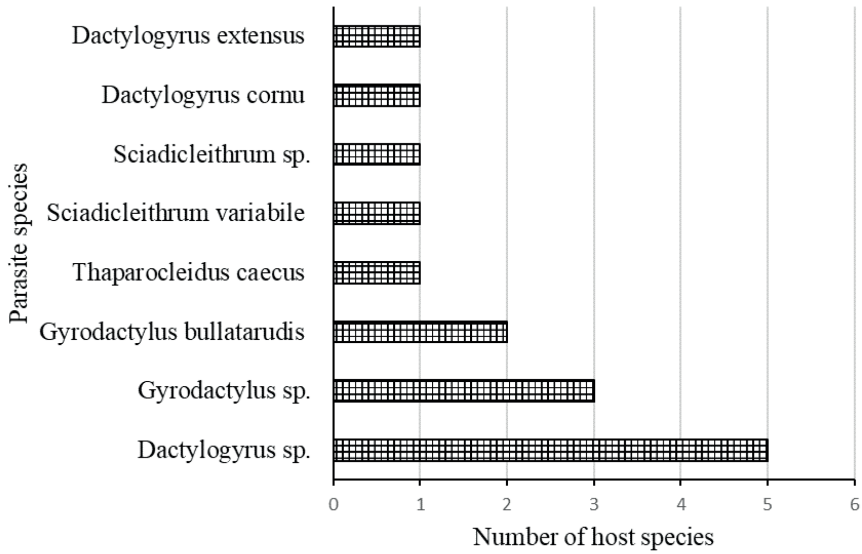

Figure 12. *The number of ornamental fish host species infested by monogenean parasites in Türkiye.*

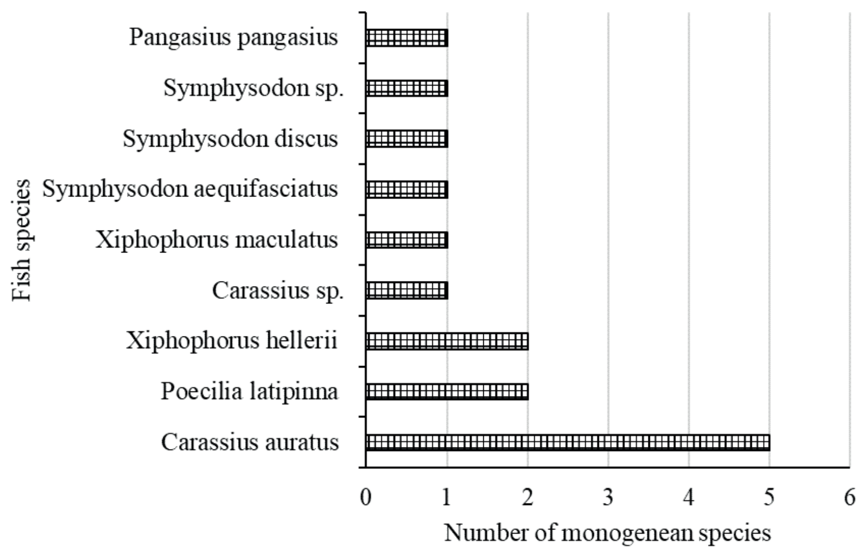

Figure 13. *The number of monogenean parasite species infesting the ornamental fishes in Türkiye.*

6. PARASITIC MONOGENEAN INVESTIGATIONS ON FISHES IN TÜRKİYE AND RECOMMENDATIONS

This chapter provided comprehensive data on the previously reported monogenean parasites and their wild and cultured host fishes in marine, freshwater, and aquariums in Türkiye. It is clear from the above-provided data constituted from the comprehensive work by Özer (2021), that monogeneans are one of the most specious parasites infesting wild freshwater, wild marine, cultured marine, cultured freshwater, and ornamental fishes represented by 89, 59, 10, 9, and 8 species, respectively and by those values, monogenean parasites were either the most or second most specious parasitic group among all others. The total of monogenean parasite-reported wild freshwater, wild marine, cultured marine, cultured freshwater, and ornamental host species are 63, 47, 13, 6, and 10, respectively, very low when considering the reported 561 marine and 401 freshwater fish species in Türkiye by Froese & Pauly (2022). Currently, we do not know the actual number of monogenean species infesting their host fishes as the result of several factors; i) the investigations focused only on the target parasite groups of relatively larger-sized ones such as Nematoda, Cestoda, etc, and the neglection of small-sized members of Monogenea taxon ii) the limited number of professionals working on monogenean parasites of fishes, iii) limitations on the financial sources as well as facilities providing more advanced technological work environments, such as molecular identification, SEM, etc., enabling actual species identifications and so on. Thus, we believe that more studies will yield more monogenean reports from different hosts inhabiting different localities and this will help to overcome this deficiency.

7. CONCLUSION

Monogeneans are among the most diverse groups of fish parasites in Türkiye and worldwide. Türkiye has great fish diversity sources inhabiting both freshwater and marine environments suitable also for fish culture. The ornamental fish trade is also another source of fish diversity in Türkiye. Based on previous reports and a common belief, we can assume that all fish species in all these sources have at least one parasite species in their lifespan, and monogeneans will find most likely a high place in the diversity of parasites of fishes in Türkiye.

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Chapter 7

SOUTHEASTERN ANATOLIA REGION INSECT FAUNA III (ORDER LEPIDOPTERA II: SUPERFAMILIES Papilionoidea, Pyraloidea, Tineoidea, Yponomeutoidea, Tortricoidea, Zygaenoidea) OF TURKEY

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Introduction

Insects (Insecta) are the most numerous group of animals in the world, with over one million species that have been described (Price, 1997). Insects are difficult to study because they represent the most species-rich, yet one of the least known, of all taxa of living organisms, a problem that is compounded by a dearth of skilled entomologists. Although the number of described insect species is uncertain due to synonyms and the lack of a global list, most authorities recognize 900000-1000000 named morpho-species, representing 56% of all species known on Earth (Groombridge, 1992; Anonymous, 2003). Sensible estimates of the number of insects yet to be discovered range from another 1 million to 30 million species (Erwin, 1982-1991), although most predict around 2-8 million more species (May, 1990; Gaston, 1991; Stork, 1997; Ødegaard, 2000). Conservative estimates suggest that 50-90% of the existing insect species on Earth have still to be discovered, yet the named insects alone comprise more than half of all known species of organism.

Insects constitute the most diverse form of animal life in terrestrial ecosystems. Most species are innocuous and essential components of natural ecosystems. Because they are cold-blooded, the rates of key physiological processes in their life cycles are determined by environmental conditions, especially temperature and precipitation. In general, they have short generation times, high fecundity and high mobility (Moore & Allard 2008).

About 150,000 species of living Lepidoptera have been described in approximately 124 families. At the species level, this is about 17% of the world's known insect fauna. However, estimates suggest that there may be two or three times this number of species in the order.

The order Lepidoptera is divided into two as diurnal butterflies (Rhopalocera) and noctiurnal butterflies (Moths) (Heterocera). The antennae of the former are of the knob type; frenulum (bristle or bristles located at the bottom of the anterior edge of the second wing) is absent; the body is thin; they fly during the day. In the latter, the antenna is of different shapes; there is a frenulum; the body is thickly built; they fly at night. However, many systematists find it correct to divide Lepidoptera into 2 suborders, called Frenatae and Jugatae. In the Jugatae, the veining of both pairs of wings is similar and the wings are joined to each other by a small protrusion (Jugum). In Frenatae, the hind wings are smaller and less veined, and the two wings are joined to each other only by the frenulum, or they are attached to each other by the enlarged bottom of the hindwing.

Lepidoptera species utilize all parts of plants roots, trunk, bark, branches, twigs, leaves, buds, flowers, fruits, seeds, galls and fallen material. Larvae feeding in concealed situations wood borers, leaf and bark miners, casebearers, leaf tiers and leaf rollers usually belong to more primitive families; exposed feeders, especially those that feed by day, are from more recent lineages.

Butterflies and moths play an important role in the natural ecosystem as pollinators and as food in the food chain; conversely, their larvae are considered very problematic to vegetation in agriculture, as their main source of food is often live plant matter.

Turkey in fact seems to be like a small continent in terms of biological diversity. Despite the Anatolia is not a continent alone, it contains all properties of a continent that should have an ecosystem and habitat. Each of seven geographical regions in Turkey has a distinguishable climate, flora and fauna.

This study aims to determine insect species found in various ecologies on Southeastern Anatolia Region of Turkey.

Material and Methods

Entomology studies on insect species of Southeastern Anatolia Region (Adıyaman, Batman, Gaziantep, Diyarbakır, Mardin, Siirt, Şanlıurfa, Şırnak) in different ecological provinces were made between the years 1948-2020 (Figure 1).

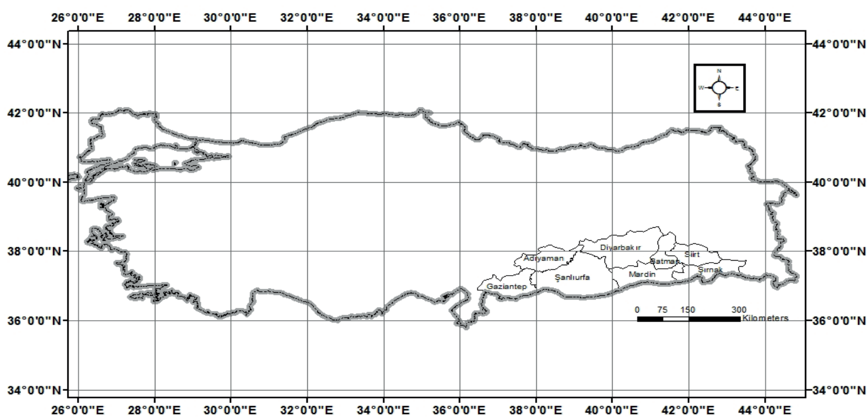

Figure 1. *Sampling localities in the Southeastern Anatolia Region of Turkey.*

In this study, I prepared for the inventory has reached the major advantage of the waterways:

-Currently in Turkey, published or unpublished entomology journals related to scanning,

-Giving more weight to faunistic studies, and in the meantime, the insect fauna of our country foreign scientific journals that publishes articles about scanning,

-Faculty of Agriculture, Faculty of Science and Regional Plant Protection Research Institute in the library of books on insect fauna and the screening of the booklet,

-The doctorate (PhD) and the master's thesis of entomology in the region on the scanning,

-Review of other studies on the insect fauna in the area.

In this study, I evaluated the information as described above were obtained.

It is also the addition of my current research and observations.

Results and Discussion

Surveys on insect species in various ecologies have been conducted in the provinces (Adıyaman, Batman, Gaziantep, Diyarbakır, Mardin, Siirt, Şanlıurfa, Şırnak) of Southeastern Anatolia region between the years 1948-2020. Almost 2600 species and subspecies almost 180 families belonging to 13 insect orders are defined owing to these studies. In this study: 34 species belonging to 4 superfamilies in the order Lepidoptera were determined. Species are given in systematic order. In addition, information was given about the distribution of Lepidoptera species in the Southeastern Anatolia Region and their host plants.

ORDER Lepidoptera

SUPERFAMILY Papilionoidea Latreille, 1802

FAMILY Hesperiidae Latreille, 1809

***Carcharodus alceae* (Esper, 1780)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Aydın, 2012; Recorded by Halil Bolu).

Figure 2. *Dorsal (a), ventral (b), and lateral (c) view of the adult stage of Carcharodus alceae.*

FAMILY Lycaenidae Leach, 1815

***Lampides boeticus* (Linnaeus, 1767)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Aydın, 2012; Recorded by Halil Bolu).

Figure 3. *Dorsal (a), and ventral (b) view of the adult stage of Lampides boeticus.*

Lycaena phlaeas **(Linnaeus, 1761)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Aydın, 2012; Recorded by Halil Bolu).

Figure 4. *Dorsal (a), and ventral (b) view of the adult (female) stage of Lycaena phlaeas.*

Nordmannia acaciae **(Fabricius)**

Distribution of the studies area: Diyarbakır, Southeastern Anatolian Region, **Host plant:** Almond (Maçan, 1986; Bolu et al., 2005a-b; Bolu & Çınar, 2005; Bolu et al., 2011).

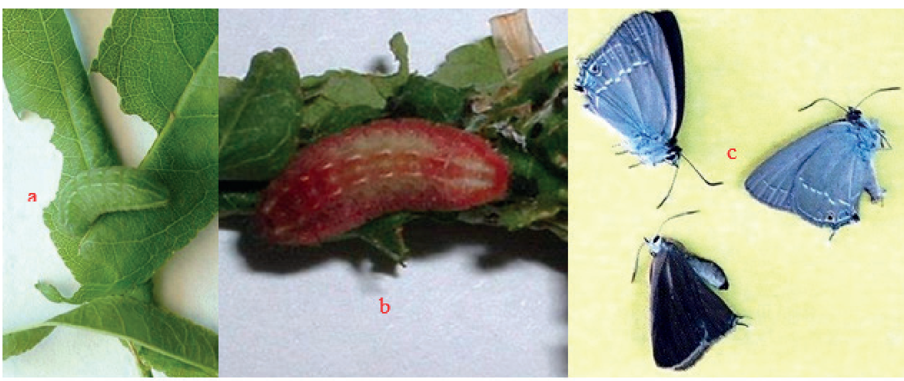

Figure 5. *Larva (a), prepupae (b) and the adult stage (c) (lateral view) of Nordmannia acaciae.*

Figure 6. *Adult stage (dorsal (a) and ventral (b) view) of Nordmannia acaciae.*

***Polyommatus coridon* (Poda, 1761)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

Figure 7. *Dorsal (a) and ventral (b) view of the adult stage of Polyommatus coridon.*

***Polyommatus agestis* (Denis & Schiffermüller, 1775)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Aydın, 2012; Recorded by Halil Bolu).

Figure 8. *Dorsal (a) and ventral (b) view of the adult stage (male) of Polyommatus agestis.*

Figure 9. *Dorsal (a) and ventral (b) view of the adult stage (female) of Polyommatus agestis.*

FAMILY Nymphalidae Rafinesque, 1815

***Argynnis pandora* (Denis & Schiffermüller, 1775)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Aydın, 2012; Recorded by Halil Bolu).

Figure 10. *Dorsal (a) and ventral (b) view of the adult stage of Argynnis pandora.*

***Chazara briseis* Linnaeus, 1764**

Distribution of the studies area: Mardin, **Host plant:** Almond (Recorded by Halil Bolu).

Figure 11. *Dorsal (a) and ventral (a) view of the adult stage (male) of Chazara briseis.*

***Hipparchia (Neohipparchia) parisatis* (Kollar, [1849])**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

Figure 12. *Dorsal (a) and ventral (b) view of the adult stage (male) of Hipparchia parisatis.*

***Hipparchia statilinus* Hufnagel, 1766**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

Figure 13. *Dorsal (a) and ventral (b) view of the adult stage (male) of Hipparchia statilinus.*

Hyponephele lycaon **(Rottemburg, 1775)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

Figure 14. *Dorsal (a) and ventral (b) view of male individual of Hyponephele lycaon.*

Figure 15. *Dorsal (a) and ventral (b) view of female individual of Hyponephele lycaon.*

***Coenonympha tullia* (Müller, 1764)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

Figure 16. *Dorsal (a) and ventral (b) view of the adult stage (male) of Coenonympha tullia.*

***Issoria lathonia* (Linnaeus, 1758)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Aydın, 2012; Recorded by Halil Bolu).

Figure 17. *Dorsal (top) and ventral (bottom) view of male (a) and female (b) individuals of Issoria lathonia.*

***Kirinia roxelana* (Cramer, 1777)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Aydın, 2012; Recorded by Halil Bolu).

Figure 18. *Dorsal (a) and ventral (b) view of the adult stage (Male) of Kirinia roxelana.*

***Melanargia galathea* (Linnaeus, 1758) larissa**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

Figure 19. *Dorsal (a) and ventral (b) view of the adult stage of Melanargia galathea.*

Polygonia egea **(Cramer, 1775)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Aydın, 2012; Recorded by Halil Bolu).

Figure 20. *Dorsal (a) and ventral (b) view of the adult stage (Male) of Polygonia egea.*

Vanessa atalanta **(Linnaeus, 1758)**

Distribution of the studies area: Diyarbakır, **Host plant:** Plum (Recorded by Halil Bolu).

Figure 21. *The adult stage of Vanessa atalanta on the plum tree.*

Vanessa cardui **(Linnaeus, 1758)**

Distribution of the studies area: Diyarbakır, Southeastern Anatolian Region, **Host plant:** Weeds (Karaat et al., 1986; Aydın, 2012; Recorded by Halil Bolu).

Figure 22. *Dorsal (a) and ventral (b) view of the adult stage of Vanessa cardui.*

FAMILY Papilionidae Latreille, 1802

***Archon apollinus* (Herbst, 1789)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

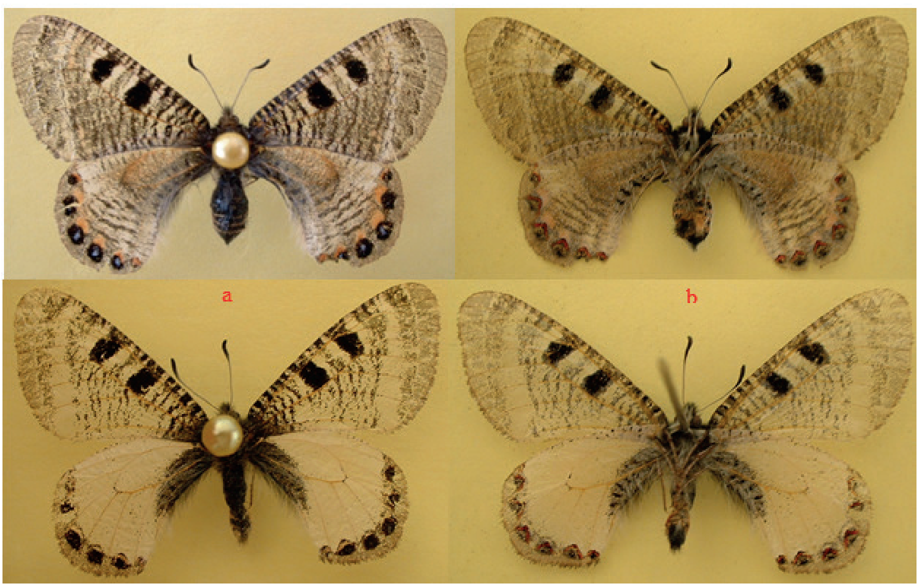

Figure 23. *Dorsal (a) and ventral (b) view of female (top) and male (bottom) individuals of Archon apollinus.*

Iphiclides podalirius **Linnaeus, 1758**

Distribution of the studies area: Diyarbakır, **Host plant:** Almond (Recorded by Halil Bolu).

Figure 24. *Ventral (a) and Dorsal (b) view of male individual of Iphiclides podalirius.*

Figure 25. *Dorsal view of the adult stage and larval stage of Iphiclides podalirius.*

Papilio machaon **Linnaeus, 1758**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

Figure 26. *Dorsal view of the adult stage (female) of Papilio machaon.*

Zerynthia cerisy **(Godart, 1824)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

Figure 27. *Dorsal (a), and ventral view of the adult stage of Zerynthia cerisy.*

Zerynthia polyxena **(Denis & Schiffermüller, 1775)**

Distribution of the studies area: Diyarbakır, **Host plant:** *Aristolochia rotunda* (Polaszek et al., 2022).

Figure 28. *Adult [dorsal (a), ventral (b)], larval (c) and pupal (d) stage of Zerynthia polyxena.*

FAMILY Pieridae Swainson, 1820

***Aporia crataegi* (Linnaeus, 1758)**

Distribution of the studies area: Diyarbakır, **Host plant:** Almond (Bolu et al., 2005a-b; Bolu & Çınar, 2005; Aydın, 2012).

Figure 29. *Male (top-bottom) and female (middle) individuals of Aporia crataegi.*

Figure 30. *Larva (a), prepupa (b), and pupa (c) stage of Aporia crataegi.*

***Colias croceus* (Geoffroy, 1785)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

Figure 31. *Dorsal (a) and ventral (b) view of the adult stage of Colias croceus [male (top) and female (m./b.)]. Polymorphism of C. croceus (C.c.f. croceus (1,2), C.c.f. helice (3)).*

Euchloe ausonides **(Lucas, 1852)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

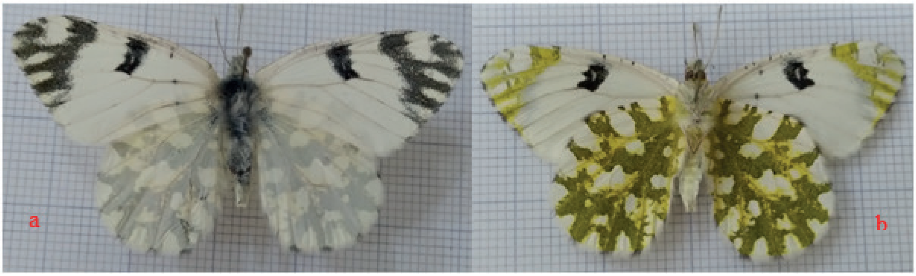

Figure 32. *Dorsal (a) and ventral (b) view of the adult stage of Euchloe ausonides.*

Pieris brassicae **Linnaeus, 1758**

Distribution of the studies area: Diyarbakır, **Host plant:** Cabbage (Aydın, 2012; Recorded by Halil Bolu).

Figure 33. *Dorsal (a) and ventral (b) view of the adult stage (female) of Pieris brassicae.*

Pieris rapae **(Linnaeus, 1758)**

Distribution of the studies area: Diyarbakır, **Host plant:** Cabbage (Aydın, 2012; Recorded by Halil Bolu).

Figure 34. *Larva stage (a); lateral (b) and dorsal (c) view of the adult stage of Pieris rapae.*

Pontia edusa **Fabricius, 1777**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

Figure 35. *Dorsal (a) and ventral (b) view of male (top) and female (bottom) individuals of Pontia edusa.*

SUPERFAMILY Pyraloidea Latreille, 1809

FAMILY Pyralidae Latreille, 1809

***Anagasta kuehniella* (Zeller, 1879)**

Distribution of the studies area: Diyarbakır, Siirt, Şanlıurfa, **Host plant:** Determined in warehouses and factories (Ergül et al., 1972).

***Ancylolomia tentaculella* (Hübner, 1796)**

Distribution of the studies area: Şanlıurfa, **Host plant:** Gramineae, (Ünlü et al., 1995).

***Cynaeda dentalis* (Denis & Schiffermüller, 1775)**

Distribution of the studies area: Şanlıurfa, **Host plant:**Unknown (Ünlü et al., 1995).

***Ectomyelois ceratoniae* (Zeller, 1839)**

Distribution of the studies area: Şanlıurfa, **Host plant:** Pomegranate (Mart & Kılınçer, 1993).

***Nymphula nymphaeata* Linnaeus, 1758**

Distribution of the studies area: Şanlıurfa, **Host plant:** *Potamogeton* sp., *Hydrocharis morsus-ranae* (Ünlü et al., 1995).

***Ostrinia nubilalis* (Hübner, 1796)**

Distribution of the studies area: Diyarbakır, Mardin, Şanlıurfa, **Host plant:** Maize (Gözüaçık & Mart, 2005).

***Plodia interpunctella* (Hübner, [1813])**

Distribution of the studies area: Adıyaman, Diyarbakır, Siirt, Şanlıurfa, **Host plant:** Determined in warehouses and factories (Ergül et al., 1972).

SUPERFAMILY Tineoidea Latreille, 1810

FAMILY Psychidae Boisduval, 1829

***Amicta oberthuri* Hey.**

Distribution of the studies area: Diyarbakır, Şanlıurfa, **Host plant:** Barley, Chickpeas, Lentils, Melon, Watermelon, Wheat, (Türkmen, 1987).

FAMILY Tineidae Latreille, 1810

***Kermania pistaciella* Amsel, 1964 (Oinophilidae)**

Distribution of the studies area: Adıyaman, Batman, Diyarbakır, Gaziantep, Mardin, Siirt, Şanlıurfa, **Host plant:** Pistachio (Küçükarslan, 1966; Günaydın, 1978; Bolu, 2002; Bolu et al., 2005b; Şimşek & Bolu, 2017; Bolu, 2020).

SUPERFAMILY Tortricoidea Latreille, 1802

FAMILY Tortricidae Latreille, 1802

***Archips rosana* (Linnaeus, 1758)**

Distribution of the studies area: Mardin, **Host plant:** Cherry (Çınar et al., 2004; Bolu et al., 2005a-b).

***Cydia pomonella* (Linnaeus, 1758)**

Distribution of the studies area: Şanlıurfa, **Host plant:** Apple, Pomegranate (Mart & Altın, 1992; Bolu et al., 2005b).

***Grapholita janthinana* (Duponchel, 1843)**

Distribution of the studies area: Diyarbakır, **Host plant:** Almond, Apple (Maçan & Maçan, 1987; Bolu et al., 2005a-b; Bolu & Çınar, 2005).

***Hedya nubiferana* Haworth, 1811**

Distribution of the studies area: Diyarbakır, **Host plant:** Almond (Bolu et al., 2005a-b; Bolu & Çınar, 2005).

***Lobesia botrana* (Denis & Schiffermüller, 1775)**

Distribution of the studies area: Adıyaman, Diyarbakır, **Host plant:** Vineyard (Maçan, 1984).

***Polychrosis botrana* Schiff**

Distribution of the studies area: Gaziantep, **Host plant:** Vineyard (Sipahi, 1957).

SUPERFAMILY Yponomeutoidea Stephens, 1829

FAMILY Yponomeutidae Stephens, 1829

***Prays oleae* Bernard, 1788**

Distribution of the studies area: Mardin, **Host plant:** Olive (Kaplan et al., 2011).

***Ypsolopha persicella* (Fabricius, 1787)**

Distribution of the studies area: Diyarbakır, **Host plant:** Almond (Bolu et al., 2005b; Bolu & Çınar, 2005).

SUPERFAMILY Zygaenoidea Latreille, 1809

FAMILY Zygaenidae Latreille, 1809

***Adscita statices* (Linnaeus, 1758)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

Figure 36. *Dorsal (a) and ventral (b) view of the adult stage of Adscita statices.*

***Theresimima ampelophaga* (Bayle-Barelle, 1809)**

Distribution of the studies area: Diyarbakır, **Host plant:** Vineyard (Maçan, 1984).

***Zygaena loti* (Denis & Schiffermüller, 1775)**

Distribution of the studies area: Diyarbakır, **Host plant:** Weeds (Recorded by Halil Bolu).

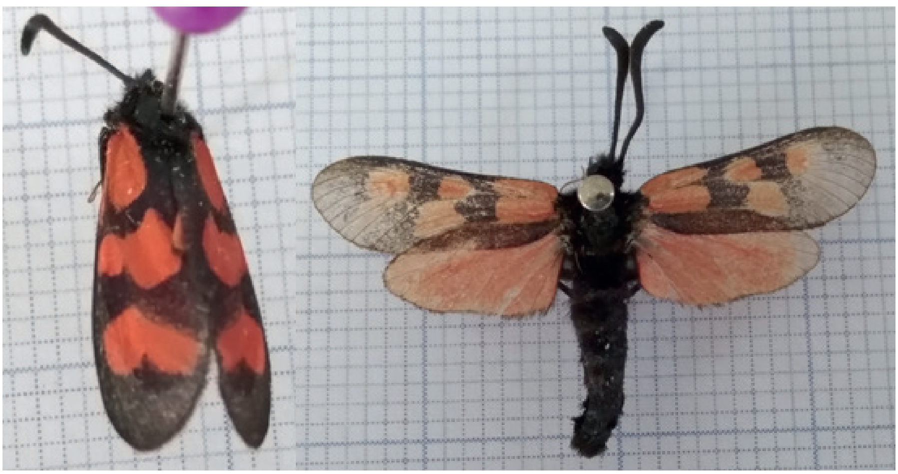

Figure 37. *The adult stage of Zygaena loti.*

As a result, Southeastern Anatolia Region is a region bordering with neighboring countries. Therefore, it is a region rich in flora and fauna. It is necessary to protect and record this biodiversity. However, the random and uncontrolled entry of plant production materials from neighboring countries into the region creates negative effects in terms of "Plant Protection". In order to preserve the natural diversity and balance, quarantine rules must be carefully followed when planting materials are brought into the country by citizens or by import.

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Chapter 8

MANAGEMENT OF WEEDS IN CORN BY APPLYING OF PRE- AND POST-EMERGENCE HERBICIDES

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Introduction

Corn is the most cultivated crop in world, with an area of 205 million ha harvested for grain in 2021. According to 2021 FAO data, corn produced 1210235135.14 tons is the most produced grain in the world (FAOSTAT, 2023). Among the top five corn-producing countries in the world, the USA accounts for 31.72%, China for 22.5%, Brazil for 7.30%, and Argentina for 5% (FAOSTAT, 2023).

It is possible to eliminate the increasing food deficit in the world is possible by increasing crop yields. Therefore, one of the most important factors limiting amount of yield is weeds. A report by Oerke and Dehne (2004) indicates that weed pressure resulted in a 37% reduction in maize production.

The management of weeds is an essential component of crop production. It is estimated that weeds cause 12% of crop losses in the United States (Pimentel, 2005), and about 34% of crop losses worldwide. However, actual estimated losses can be reduced to 8.5% with manual or mechanical weeding and herbicides, and are likely to be lower in developed nations (Oerke, 2006). In this regard, weed management plays a critical role in crop production, especially in grain crops, as twice as much energy is derived from these three crops as from any other. (FAO, 1995). Estimated to account for 42 percent of world food calories and 37 percent of protein consumption (FAOSTAT, 2021).

Managing weeds is one of the most challenging aspects of corn production. Herbicides and tillage are the most commonly used weed control methods among corn farmers (Dong et al. 2017; Grint et al. 2022). Herbicides are the most effective and common method of controlling weeds. It is important to use the correct herbicide active ingredient at the appropriate time and in the proper dosage in order to achieve the desired results from herbicide application. It is crucial to know the weed vegetation and weed resistance events before choosing herbicides.

Due to the widespread use of chemical weed control, herbicide resistance has been widespread, especially for postemergence herbicides (Jha et al. 2017; Heap, 2023,). It is possible to minimize over-reliance on post-emergent herbicide applications and prevent resistance development by applying pre-emergent herbicides early in the season (Knezevic et al. 2019).

Pre-application application of herbicides with soil residual activity provides a longer period of effective control

Controlling weeds in the growing season so that crops are protected from weed interference during their most vulnerable stages (Grint et al. 2022b; Oliveira et al. 2017a). Moreover, it is important to classify herbicides based on various factors, such as chemical families, site of action, mode of action, translocation, time of application, selectivity, etc. (Heap and Duke, 1990; Varshney et al., 2012).

Pre herbicides can reduce the weed density and delay the time to POST applications, thus lowering the selection pressure for further resistance to POST herbicides (Faleco et al. 2022a; Oliveira et al. 2017b). Therefore, it is necessary to control weeds again in the case of secondary weed infestation. Thus, post-emergence herbicides should be used. Pre-emergence and post-emergence herbicides were more effective when used in combination (Imran and Al Al Tawaha, 2021; Biplab et al., 2022). But before emergence (preemergence), and after crop emergence (postemergence). The choice of herbicide application timing depends on many factors and varies from grower to grower and field to field. Many corn growers use more than one herbicide applications that may provide a season-long weed control (Jhala et al., 2014).

Despite this amount, new resistances are being developed by weeds against herbicides every day. In addition to agricultural measures, newly developed herbicides are of great importance in reducing this worldwide concern. In order to control weeds in all crops and to control weeds that have developed resistance, herbicides are becoming more important.

The problem of herbicide resistance poses challenges to weed management in corn and many other crops. Amaranthus species that are resistant to glyphosate affect more than 1.2 million acres of cropland in the US (Heap, 2014). It has also been documented that weeds are resistant to herbicides that inhibit photosystem II, such as atrazine, and HPPD-inhibiting herbicides (Heap, 2014). It has been documented that seven monocots and 17 dicots are resistant to PSII inhibitors in corn-producing regions in the US (Stephenson et al., 2015). As a result of the overuse of atrazine, including the detection in surface and groundwater, crop rotation injury, and the development of triazine-resistant weeds, and the increase in glyphosate-resistant weed acreage, growers have asked about the use of PRE herbicides for early-season and possibly season-long weed control in corn. While several relatively recently developed soil-applied herbicides have been available for several years, there is a scarcity of field-based information about weeds commonly found in corn-growing regions.

Currently, herbicide-resistant weeds are one of the biggest challenges for extensive agriculture (Heap, 2014, Heap and Duke, 2018, Scursoni et al., 2019). Today, synthetic herbicides continue to be the main method of controlling weeds in agroecosystems 70 years after they were introduced (Heap, 2014, Heap and Duke, 2018, Vila-Aiub, 2019). Dixon et al., 2021, Heap, 2014, Hicks et al., 2018 indicate herbicide resistance emerges as a predictable result of repeated and intensive herbicide application (Dixon et al., 2021). Agricultural landscapes have been dominated by large-scale monocultures, which have replaced more diverse farming systems and are relying on high amounts of herbicides (Gage et al., 2019, Ramankutty et al., 2018).

There are a number of alternatives to herbicides that farmers can use to reduce herbicide-resistant weed spread (Beckie, 2006, Heap, 2014, Scursoni et al., 2019). There is barely any research on landscape-scale solutions (Seppelt et al., 2020), but they are a promising field (Dauer et al., 2009). Herbicide resistance may spread more readily in agricultural landscapes where crops are larger and less diverse, compared to landscapes with a greater diversity and complexity. There are multiple hypotheses to explain this. A more diverse and complex landscape, for example, could facilitate the outcross of weeds inside and outside crop fields, reducing the spread of herbicide-resistant traits since resistance-causing mutations are often associated with fitness costs in herbicide-untreated conditions (e.g., diverting resources from reproduction to defense; Vila-Aiub, 2019). A smaller field adjacent to a large natural and semi-natural habitat can also act as a barrier to herbicide-resistant traits since the composition of weed communities changes with distance from the field edge (Bourgeois et al., 2020). In recent years, glyphosate-resistant corn has been quickly adopted and used extensively in corn-growing areas across the state (Wiggins et. al., 2015). A modified 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) gene conferred resistance to glyphosate on nearly 61 million ha of soybeans (Glycinemax L.) Merr., corns, and cotton (Gossypium hirsutum L.) in 2009 (Monsanto, 2009). A shift in weed populations has been caused by glyphosate-resistant crops, a reduction in traditional herbicide use, and the intense use of glyphosate for weed control (Culpepper, 2006; Owen, 2008). Glyphosate-resistant weeds gained a selective advantage as a result. Amaranthus species, which are glyphosate-resistant weeds, have become a problem in corn-producing areas in the United States (Culpepper and York, 1998; Klingaman and Oliver, 1994). Atrazine and HPPD inhibitor herbicides are commonly used for weed control in corn, and are effective against glyphosate-resistant weeds, such as *A. palmeri* (Sutton et. al., 2002).

It can be applied alone or in tank-mixtures with other herbicides (Walsh et. al., 2012). As a result of their broad-spectrum weed control, flexibility of application timing, tank-mix compatibility, and crop safety (Walsh et. al., 2012; Stephenson and Bond, 2012), HPPD-inhibiting herbicides have become popular among corn growers.

Due to the increased occurrence of glyphosate-resistant weeds, growers have been using pre-emergence herbicides and overlapping soil residual herbicide programs (Beckie et al., 2019). The use of pre-plant and pre-emergence herbicides has increased from 25% to 70% between 2000 and 2015 (Peterson et al., 2018).

Pre-emergence herbicides are an important part of an IWM program because they provide early control of weeds and can delay the evolution to post-emergence products.

Thus, it is possible to control weeds for a longer period of time during the vegetation period.

The evolution of resistance to pre-emergence herbicides has been slower than resistance to post-emergence herbicides (Somerville et al., 2017), and soil-applied herbicide mixtures could further slow resistance evolution (Busi et al., 2020).

In soil-applied herbicides, simplified rotations or a lack of rotation can lead to resistance evolution (Busi et al., 2019); as the rate of pre-emergence herbicide dissipates in the soil over time, decreasing concentrations of single applications may allow herbicide-resistant weeds to emerge (Wuerffel, et al., 2017).

Therefore, resistance management should include other tactics in addition to pre- and postemergence herbicides. According to historical experience in selecting herbicide-resistant weeds, herbicide resistance is inevitable when herbicides provide the only weed control option (Shaner, 2017). Through natural or mechanical means, herbicide resistance may develop, and it may impact management beyond cropping systems. The following tables present the most recent pre-emergence and post-emergence herbicides developed (Table 1-2).

Pre-Emergence Herbıcıdes Recently Included In Integrated Weed Management In Corn

Table 1. Herbicides, action group, and. Composition

Herbicides	Mode of Action	Site Action	Active Ingredient
AAtrex	Photo-synthesis	Photosystem II Inhibitors	Atrazine
Dual Magnum	Growth Regulator	Fatty acid Inhibitors	*S*-Metolachlor
Bicep II Magnum	Photo-synthesis, Growth Regulator	Photosystem II, Fatty acid Inhibitors	*S*-Metolachlor + Atrazine
Callisto	Pigment	HPPD Inhibitors	Mesotrione
Acuron	Photo-synthesis, Growth Regulator, Pigment	Photosystem II, Fatty acid, HPPD inhibitors	Atrazine + *S*-Metolachlor + Mesotrione + bicyclopyrone
Anthem	Cell Membrane Disrupters, Growth Regulator	PPO, Fatty Acid Inhibitors	Fluthiacet-methyl + pyroxasulfone
Anthem ATZ	Cell Membrane Disrupters, Growth Regulator	PPO, Fatty Acid, Photosystem II Inhibitors	Fluthiacet-methyl + pyroxasulfone + Atrazine
Balance Flexx	Pigment	HPPD Inhibitor	Isoxaflutole
Bullet	Photo-synthesis, Growth Regulator	Photosystem II, Fatty Acid Inhibitors	Alachlor + Atrazine
Corvus	Amino acid synthesis, Pigment	ALS, HPPD Inhibitors	Thiencarbazone-methyl + isoxaflutole
Degree Xtra	Growth Regulator, Photo-synthesis	Fatty Acid, Photosystem II Inhibitors	Acetochlor + Atrazine
Guardsman Max	Growth Regulator, Photo-synthesis	Fatty Acid, Photosystem II Inhibitors	Dimethenamid-P + Atrazine
Harness	Photo-synthesis, Growth Regulator	Photosystem II, Fatty Acid Inhibitors	Acetochlor + Atrazine
Instigate	Amino acid synthesis, Pigments	ALS, HPPD Inhibitors	Rimsulfuron + Mesotrione
Leadoff	Amino acid synthesis	ALS Inhibitors	Rimsulfuron + thifensulfuron-methyl
Lexar	Growth Regulator, Photo-synthesis, Pigments	Fatty Acid, Photosystem II, HPPD Inhibitors	*S*-Metolachlor + Atrazine + Mesotrione
Outlook	Growth Regulator	Fatty Acid Inhibitor	Dimethenamid-P

Prowl H_2O	Seedling Root Growth Inhibitors	Microtubule Inhibitors	Pendimethalin
Sharpen	Cell Membrane Disrupters	PPO Inhibitors	Saflufenacil
Verdict	Cell Membrane Disrupters, Growth Regulator	PPO Inhibitors, Fatty Acid Inhibitor	Saflufenacil + dimethenamid-P
Warrant	Growth Regulator	Fatty Acid Inhibitor	Acetochlor
Zemax	Growth Regulator, Pigment	Fatty acid, HPPD Inhibitors	*S*-Metolachlor + Mesotrione
Zidua	Growth Regulator	Fatty Acid Inhibitor	Pyroxasulfone

POST-EMERGENCE HERBICIDES RECENTLY INCLUDED IN INTEGRATED WEED MANAGEMENT IN CORN

Table 2. Herbicides, action group, and. Composition

Herbicides	Mode of Action	Site of Action	Active Ingredient
2,4-D Amine	Growth Regulator	Sipecific Site	2,4-D
Aim	Cell Membrane Disrupters	PPO Inhibitors	Carfentrazone-ethyl
Armezon	HPPD Carotene synthesis	HPPD inhibitor	Topramezone
Basis Blend	Amino acid Synthesis	ALS Inhibitors	Rimsulfuron, Thifensulfuron-methyl (10%)
Beacon	Amino acid Synthesis	ALS Inhibitors	Primisulfuron-methyl
Buctril	Photo-synthesis	Photosystem II Inhibitors	Bromoxylnil
Cadet	Cell Membrane Disrupters	PPO Inhibitors	Fluthiacet-methyl
Callisto	Pigment	HPPD Inhibitors	Mesotrione
Callisto GT	Pigment, Amino acid Synthesis	HPPD, EPSP Inhibitors	Mesotrione, Glyphosate,
Clarity	Growth Regulator	Synthetic auxins	Dicamba (Diglycolamine)

Dicamba	Growth Regulator	Synthetic auxins	Dicamba (Diglycolamine)
DiFlexx	Growth Regulator	Synthetic auxins	Diglycoamine (4 lbs ae/gal)
Expert	Growth Regulator, Amino acid, Photo-synthesis	Fatty acid, EPSP, Photosystem II İnhibitors	S-metachlor + Glyphosate + Atrazine
Glyphosate	Amino acid Synthesis	EPSP Inhibitors	Glyphosate
Halex GT	Growth Regulator, Amino acid, Pigment	Fatty acid, EPSP, HPPD İnhibitors	S-metachlor + Glyphosate + Mesotrione
Harmony SG	Amino acid Synthesis	ALS Inhibitors	Thifensulfuron
Impact	Pigment	HPPD Inhibitors	Topramezone
Liberty	Nitrogen Metabolism	Glutamine Synthesis Inhibitor	Glufosinate-ammonium
Permit	Amino acid Synthesis	ALS Inhibitors	Halosulfuron
Resolve	Amino acid Synthesis	ALS Inhibitors	Rimsulfuron
Resolve Q	Amino acid Synthesis	ALS Inhibitors	Rimsulfuron + thifensulfuron
Resource	Cell Membrane Disrupters	PPO Inhibitors	Flumiclorac
Reviton	Cell Membrane Disrupters	PPO Inhibitors	Tiafenacil
Solida	Amino acid Synthesis	ALS Inhibitors	Rimsulfuron
Solstice	Cell Membrane Disrupters, Pigment	PPO, HPPD Inhibitors	Fluthiacet methyl + mesotrione
Spirit	Amino acid Synthesis	ALS Inhibitors	Prosulfuron + primisulfuron
Status	Growth Regulator	Auxin Transport, Synthetic auxins	Diflufenzopyr + dicamba
Warrant	Growth Regulator	Fatty acid inhibitors	Acetochlor
Yukon	Growth Regulator	ALS Inhibitors	Halosulfuron-methyl + dicamba

Discussion

The use of genetically modified corn cultivars resistant to additional herbicides, such as dicamba and 2,4-D in corn, may pose inherent challenges to those seeking to control glyphosate-resistant weeds (Mortensen, et al., 2012), but these new crop trait technologies may present some inherent challenges. It may be possible to manage glyphosate-resistant strains effectively with a combination of mesotrione, isoxaflutole, glufosinate, dicamba and 2,4-D in cropping systems with high glyphosate resistance (Wright, 2010; Meyer, 2015). It is possible, however, that off-target movement could cause damage to nearby, sensitive broadleaf plants. Many crops have been damaged by low or simulated drift rates of several herbicides, but dicamba and 2,4-D drift are particularly concerning due to their high potential for crop injury (Everitt and Keeling, 2009; Wiedau et al., 2019). Symptoms of PGR herbicides (plant growth regulators) injury include leaf cupping, crinkling, and/or epinasty, which may occur at very low rates in susceptible plants (Sciumbato et al., 2004).

Agronomic crops that are susceptible to pesticides are not the only crops grown near herbicide-treated fields, as are vegetable and fruit crops, orchards, vineyards, and homeowner gardens/landscapes, all of which have been shown to be highly sensitive to 2,4-D and dicamba (Dittmar et al., 2016), and therefore pose a concern for off-target movement.

The movement of herbicide particles and vapors from adjacent crops can cause injury to adjacent agronomic and horticultural crops when environmental conditions are favorable. An herbicide's risk to sensitive plants depends on a variety of factors, including its formulation, tank additives, herbicide rate, nozzle type, droplet size, spray pressure, sprayer type (shielded/unshielded), boom height, timing of application, and prevailing environmental conditions (Ellis and Griffin, 2002; Carlsen et al., 2006). These factors include wind speed, stability and turbulence, temperature, and humidity. However, by reducing the doses of selected herbicide mixtures and introducing different new generation herbicides into rotation, drift and damage events can be prevented.

Conclusion

In general, many treatments with two or three herbicides provided better weed control than one herbicide alone and the chance of corn injury appears to be minimal with any herbicide combinations under normal growing conditions. Our results indicate that in a year with little or no rainfall within 7 to 14 d after PRE herbicide application any combination of PRE herbicides may need to be followed by POST herbicides for control of escaped weeds.

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Chapter 9

POSSIBILITIES OF USING PLANT-BASED MEASUREMENT TECHNIQUES IN IRRIGATION TIME PLANNING.

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INTRODUCTION

The rapid increase in the world population poses people's food needs as the most important problem in the near future. The main reason for this problem is the increasing population, decreasing agricultural areas due to industrialization and urbanization, and increasing drought due to global climate change. The sector with the highest global water consumption is the agricultural sector. Therefore, the effects of drought are generally first seen in agriculture and gradually spread to other water-dependent sectors. The meaning of drought in the agricultural sector is different from other sectors , because the amount of moisture in the plant root zone during growth periods is more important for plants than the total precipitation during the year. As a result, the lack of water in the soil that plants need during the germination and development period is called agricultural drought (Kapluhan, 2013).

The most important effects of agricultural drought on production can be listed as decreases in productivity in terms of quantity and quality, increase in diseases and pests, increase in product losses, change in the reproductive cycle in animal husbandry, and decrease in the conversion rate of feed to product. In order to reduce these effects of drought, we need to develop methods that will provide maximum benefit from rainfall-related moisture and irrigation water in the agricultural systems we apply (Gürbüz, 2011). In the development of water resources, irrigation is an element of crop production that increases the effectiveness of other agricultural inputs, ensures stability in crop production and is an integral part of modern agriculture (Korukçu and Yıldırım, 1981). Since Turkey is in the arid and semi-arid climate zone, rainfall cannot meet the water needs of plants and irrigation is needed (Güngör and Yıldırım, 1989). Irrigation is defined as the way in which the part of the water that plants need in their root areas, which cannot be met by natural means, is given to the soil at the appropriate time and amount in order to continue their normal development and produce products. In recent years, with the use of new technologies in agricultural production, efforts are being made to maximize the yield obtained per unit area and thus the income.One of the new technologies used in agriculture is techniques that allow the plant water stress level to be obtained quickly and with high sensitivity The use of the plant water stress index (CWSI) allows the critical water stress threshold value of plants to be taken into account. Thus, productivity losses due to water stress or water losses due to untimely irrigation can be prevented (Gençoğlan, 2005). In addition, these methods allow the evaluation of the factors that restrict the plant's ability to benefit from water in the soil and the planning of irrigation time in larger areas in a shorter time and with high sensitivity levels. Thus, by increasing water use efficiency and irrigating more areas with existing water resources, the quality and efficiency in plant production can be increased.

Since the plant responds to its environment in determining when to apply irrigation water and is located between the soil and the atmosphere, which is the water source, irrigation scheduling requires monitoring the plant to reveal its internal water status. In determining the amount of irrigation water to be applied, plant parameters must be correlated with the amount of moisture in the soil. Various methods and indicators can be used to determine the water content of plants. In this context, leaf water potential, photosynthesis rate, leaf temperature, stomatal resistance, chlorophyll content and leaf area index measurements come to the fore among plant-based measurement techniques. Today, there is a need to test and develop the methods, models and indices developed in studies conducted for this purpose through field trials for regions with different climate and soil characteristics.

Plant-Based Measurement Techniques and their use in agricultural Irrigation Time Planning

Leaf Surface Temperature: Plants combine the effects of soil and atmosphere within themselves. For this reason, the use of plant-based measurements in irrigation programming has gained increasing importance in recent years (Ödemiş and Baştuğ, 1999). Additionally, if the water intake of the plant is limited during the growth period, pore resistance increases, transpiration decreases and leaf temperature increases. Using this feature and psychrometric measurements, plant water stress index (CWSI) is determined.

FİGURE 1. Leaf Surface Temperature measuring instrument

Leaf Water Potential: Leaf water potential (LWP) is an effective indicator of plant water coverage. Some devices developed in recent years have made it easier to measure LWP in the field. In this respect, LWP has the potential to be used in determining irrigation timing for many plants both in research and practice. As water evaporates, a tension is created that draws water from the roots. As the soil dries out, moisture, wind or heat load increases, it becomes increasingly difficult for the roots to keep up with evaporation from the leaves. This causes tension to increase. Under these conditions, the plant begins to experience "hypertension". Pump-Up Chamber or Pressure Chamber is used to measure the leaf water potential of the plant. The method used in both measuring devices is the same, but the working styles of the devices are different.

figure 2. Pump-Up Chamber.(Leaf Water Potentıal Measurıng Instrument).

Leaf Area Index: Transpiration in plants is the transport of water taken from the soil by the roots to the leaves through the xylem tissue and releasing it to the atmosphere in the form of vapor through the pores covering the leaf epidermal surface. Therefore, increasing the leaf surface width will increase the amount of water lost through transpiration. Therefore, leaf surface width is seen as one of the most important factors affecting transpiration. The most important criterion used in expressing leaf surface width is leaf area index (LAI), which is defined as the ratio of the sum of single surface areas of unit plant leaves to unit plant area (Korukçu and Evsahibioğlu, 1987). Leaf area index measurements are carried out with portable leaf area index measuring devices and plant growth periods should be taken into account during measurements.

figure 3. Leaf area index (YAI) measuring device.

Stoma Resistance: Stomata, formed by the differentiation of epidermis cells, are living structures that control transpiration and gas exchange in plants with their opening and closing properties. Stomata are microscopic pores that plants use for breathing and play an important role in photosynthesis and transpiration (Akman, 1985). Therefore, it indicates that the plant needs to be watered. Stoma resistance is measured with a device called porometer.

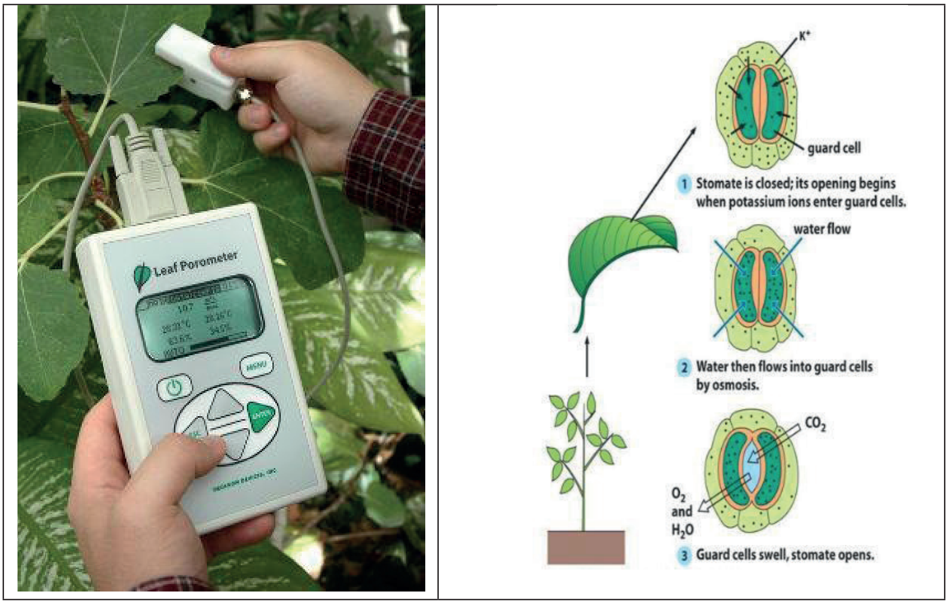

figure 4. Stoma resistance measuring device (porometer).

Chlorophyll Amount: The most important duty of plants is to form the basis of the food chain. Almost all living life depends on green plants that perform photosynthesis. The pigment that gives plants their green color is chlorophyll. Chlorophyll enables photosynthesis, where oxygen and nutrients necessary for the survival of all other living things are produced. However, determining the factors that cause changes in the amount of chlorophyll is important in terms of providing the basis for many studies, from plant health to stress factors. The chlorophyll content of the plant is measured using a chlorophyll meter. The plant leaf is placed between the radiation source and the radiation sensor. Leaf chlorophyll content is determined by using the relationship between the amount of radiation passing to the other side of the leaf and the amount of chlorophyll in the leaf. The device must be calibrated before taking measurements.

figure 5. Klorofilmetre

Photosynthesis Rate: Photosynthesis rate is determined by measuring the amount of CO_2 used or O_2 released during photosynthesis. Water, one of the environmental factors affecting the rate of photosynthesis, is absolutely necessary for photosynthesis to occur. The rate of photosynthesis increases at water concentrations above the 15% water value required for enzymes to work however, after a certain point, the increase in water content does not increase the rate of photosynthesis. Taking these changes into consideration, the photosynthesis rate is measured. A photosynthesis rate measuring device that provides accurate results in a short time is used for measurements. Since the sensor head is where the leaf is placed, the CO_2 and H_2O concentration is controlled from the leaf surface in the measurements.

figure 6 Portable Photosynthesis Meter.

Plant-Based Measurement Techniques in Irrigation Time Planning (Orta et al. 2002), in their research conducted under Tekirdağ conditions, examined the relationships between plant water stress index (CWSI), leaf area index (LAI) and stomatal resistance of sunflower plants irrigated with furrow irrigation method. In the research, the trial subjects where irrigation water was applied when 50% of the available water holding capacity was consumed (100%), as well as the trial subjects where 75, 50, 25 and 0% of this amount was applied were taken into consideration. As a result of the research, LAI values varied between 0.38 and 3.00 m2/m2 depending on the growth periods of the plant, while the highest LAI values were obtained at 100%. As a result of the research, statistically significant relationships were obtained between plant water stress index (CWSI), leaf area index (LAI) and stomatal resistance.

As a result of studies conducted by many researchers in Turkey and around the world on various plants in different climatic and regional conditions, it has been stated that CWSI can be used in the preparation of irrigation programs (Nielsen and Gardner 1987; Gençoğlan and Author 1999; Author et al. 1999; Irmak et al. 2000; Alderfasi and Nielsen 2001; Orta et al. 2002; Colaizzi et al. 2003; Orta et al. 2003; Gonza´lez-Dugo et al. 2005; Erdem et al. 2010). The same researchers explained that irrigation time can be determined with CWSI, but this method does not give an idea about the irrigation water to be applied. Studies were carried out to determine the plant water stress index (CWSI) for sunflower, watermelon, wheat, potato and bean plants, which have been grown intensively in recent years in the regions located in the west of Turkey, and to investigate the possibilities of using them in irrigation time planning (Orta et al. 2002; Orta et al. et al. 2003; Orta et al. 2004; Erdem et al. 2006a; Erdem et al. 2006b; Erdem et al. 2010) determined the lower and upper baselines used in calculating the plant water stress index (CWSI) with the infrared thermometer technique and determined the yield The relationships between seasonal average CWSI and yields, which can be used in forecasting, are revealed.

(Malone et al. 1993) stated that stomatal density is directly proportional to water constraint and that plants respond to water stress by increasing the number of stomata. (Yang and Wang, 2001) and (Zhang et al. 2006) in wheat; (Laajimi et al. 2011) in apricot; (Ennajeh et al. 2010) and (Aktepe Tangu, 2012) on olive; (Fu et al. 2013) obtained similar results in eggplant and determined that stomatal density increased as water stress increased. (Andrieu et al. 1997), leaf area index is an important variable characterizing growth in corn plants. In the study conducted to determine the leaf area index in Grignon, it was observed that the mentioned value varied between 0 and 4 (Pamuk, 2003).

In a study conducted on grapevine, photosynthesis measurements were made on mature leaves that were fully sunbathed between 10-12 hours, and according to the results obtained, it was understood that the photosynthesis values in 2011 varied between 9.77 and 14.32 µmlCO_2/m^2/s. Photosynthesis values obtained in 2012 vary between 6.02 and 14.99 µmlCO_2/m^2 /s. Although the photosynthesis results obtained from a leaf vary depending on the species, it can reach up to 18µmlCO_2/m^2/s under normal conditions. If this value falls below 8 µmlCO_2/m^2/s, it is accepted that the vine is stressed (Bahar, 2011). In their research on Chardonnay and Cabernet sauvignon grape varieties, (Williams and Araujo, 2002) examined the relationships between leaf water potential measurement at dawn, leaf water potential measurement at noon and stem water content measurement methods using a pressure chamber. Additionally, these methods were compared with soil and plant-based measurement methods. As a result of the results obtained, they determined a linear relationship between the leaf water potential and stem water content measurement results at noon and the leaf water potential measurement results at dawn. A linear relationship was determined between the photosynthesis rate and stomatal resistance measurements made at noon and the three methods used.

Researchers stated that 3 methods can be used to determine irrigation time in the vineyard. As a result of their evaluation considering the practical applications of the methods (dawn measurements need to be completed before sunrise and stem water content measurements require wrapping the leaves to be measured with aluminum foil 90 minutes before measurement), they explained that leaf water potential measurements at noon are more appropriate. (Demirtaş and Kırnak ,2006) in their research conducted in Malatya in 2001-2002, irrigated apricot trees with mini sprinkler and bowl irrigation methods at 15, 20 and 25 day intervals. In the research, leaf water potential (LWP) measurements were made before and after each irrigation. The change in LWP values measured before irrigation was found to be statistically significant at 5% between irrigation intervals, but no statistical difference was found after irrigation. The lowest average seasonal LWP value measured before irrigation was obtained from the 25-day sprinkler irrigation application with -32.65 bar, and the highest was obtained from the sprinkler irrigation 15-day application with -30.93 bar. It was also explained that different irrigation methods had no statistical effect on leaf water potential. (Maya ,2007) examined the time-dimensional change of leaf water potential (LWP) in cotton plants under different irrigation programs and nitrogen contents. In the study, irrigation applications were carried out at 100, 70 and 50% of the approximately one-week cumulative evaporation values obtained from the open water surface evaporation pan (Class A pan). According to the research results, 493, 316 and 163 mm of irrigation water was applied to the trial subjects, respectively. Before irrigation, for full irrigation (100%) LWP = -15.5 bar ±2.7, for light stress (70%) LWP = -17.8 bar ±3, for medium stress (50%) LWP = -20.1 bar measured as ±3.3. Considering the mentioned issues, it has been stated that LWP = -17.8 bar value can be used in cotton irrigation time planning.

(Bozkurt Çolak, 2010) carried out a two-year study in the Mediterranean Region of Turkey, under the conditions of Adana province, in order to create the optimum irrigation program that would provide the highest yield and quality, based on the leaf water potential values of table grape varieties irrigated by the drip method. In the study, four different issues were discussed: These were irrigation issues created according to three different threshold values of midday leaf water potential (I1: Ψl = -1.0 MPa; I2: Ψl = -1.3 MPa; I3: Ψl = -1, 6MPa); the undiluted witness is the subject (I4). As a result of the research, the effects of irrigation issues on vine yield differed according to varieties and years. Great differences have been detected in the effect of irrigation on yield, vine development and must quality. It was determined that the differences emerged as a result of the environmental conditions and the effect of the applied irrigation program. Midday leaf water potential of Flame Seedless variety is between Ψl = -1.0 and -1.3 MPa (-10 bar); The highest yield was obtained by irrigating the Italia variety at Ψl = -1.3 MPa (-13 bar). It has been explained that the missing moisture in the root zone should be brought to field capacity during irrigation.

(Köksal, et al. 2010) investigated the possibilities of using leaf water potential (LWP) and plant water stress index (CWSI) values in determining the irrigation time of green beans grown under drip irrigation method in their research conducted under Ankara, Turkey conditions. The trial subjects in the research were created by applying 120, 90, 60, 30, 10 and 0 times the open water surface evaporation amounts during a 7-day irrigation interval. In the study, LWP values varied among trial subjects and increased as the irrigation water level increased. In addition, soil water content, CWSI and YSP values determined for the same day in the trial subjects were evaluated statistically.

A linear relationship was obtained between soil moisture content -CWSI and soil moisture content -LWP. LWP values varied between -10.0 and -18.0 bar for the trial subjects, and the average was measured as -14.4 bar. As a result, it was explained that LWP values measured between -14.0 and -18.0 bar can be used in irrigation time planning of dwarf green beans. (Özer ,2012) It was aimed to use evaporation amounts and plant-based measurement techniques to determine yield and yield elements, plant water consumption and develop appropriate irrigation programs in the pumpkin (cucurbita pepo L.) plant irrigated with drip irrigation method in Tekirdağ conditions. The research was composed of trial subjects where irrigation water was applied at 0, 50, 75, 100 and 125% of the evaporation from a Class A container. In general, it has been observed that different irrigation practices have statistically significant effects on yield and yield elements. Additionally, as the moisture deficiency in the soil increased, CWSI values increased. The leaf area index calculated for the trial subjects generally increased with the increase in irrigation rates. Leaf area index (LAI) values varied between 0.81-1.56 m^2/m^2 in the first year and 0.68-1.66 m^2/m^2 in the second year. As a result, it was determined that plant water stress index values can be used to determine irrigation time and estimate the yield of squash. Additionally, significant relationships were obtained between plant water stress index and leaf area index. In their research conducted in Hungary, Pepo and (Novak, 2016) examined the effects of early, late and normal planting dates on the leaf area index (LAI), chlorophyll content (SPAD) and yield of sunflower plants. The research was conducted on two different sunflower varieties in 2012, 2013 and 2014. As a result of the research, LAI values were calculated as 5.1-5.3 m^2 /m^2 in early sowing dates, 4.5-5.2 m^2 /m^2 in normal sowing dates and 4.4-5.2 m^2 /m^2 in late sowing dates. Statistically significant relationships were obtained between LAI values and sunflower yields. Additionally, it has been explained that chlorophyll content (SPAD) is not affected by planting date and sunflower varieties. (Gönen, Bozkurt Çolak, Yazar, Tanrıverdi and Sesveren, 2018) conducted a study on leaf water potential (YPS) and plant water stress index (CWSI) measurements in eggplant plants and evaluation of the most appropriate irrigation time during the day using surface and subsoil drip irrigation systems. They determined different irrigation levels (100, 75, 50%). Plant crown temperature (Tc) and air temperature (Ta) were measured with a pressure chamber for LWP measurements, and with an infrared thermometer for CWSI measurements. According to the results of the study, when subsoil and surface drip irrigation were compared, it was determined that CWSI values were lower and LWP values were higher in the subsoil drip irrigation method. It was seen through CWSI and LWP measurements that plants were most stressed in the middle of the day.

In their research conducted in Kahramanmaraş province of Turkey in 2016, (Yazıdıç and Değirmenci, 2018) examined the changes in leaf water potential and chlorophyll values of cotton plants under different irrigation water amount applications. In the research, the trial subjects were planned to be 100, 75, 50 and 0% of the cumulative evaporation amounts measured from the Class A evaporation vessel. Leaf water potential and chlorophyll measurements were carried out between 12:00 and 13:00, before and after irrigation. At the end of the research, leaf water potential (LWP) values before irrigation were -23.4 to -26.91 bar for 100%, -22.74 to -26.1 bar for 75%, -26.6 to -31 for 50%. For .08 bar and 0%, it was measured as -33.08 to -41.24 bar. Leaf water potential measurements after irrigation were -19.32 to -24.6 bar at 100%; -19.6 to -22.12 bars on 75%; -24.65 to -29.12 bars on 50%; At 0% it is between -30.9 and -33.08 bars. Chlorophyll measurement values before irrigation are 31.8-43.5 at 100%, depending on the irrigation subjects; 35.4-41.6 on 75%; 40-47 on 50%; At 0%, it was measured between 45.5-53.1. Chlorophyll values after irrigation are 35.2-43.9 at 100%; 36.1-41 on 75%; 40.6-44.3 on 50%; At 0%, it was measured between 48.2-51.2. Considering irrigation issues, it has been stated that leaf water potential and chlorophyll values can be used to determine water stress and irrigation scheduling.

CONCLUSION

Limited water resources and the rapid and unplanned development of industry in recent years threaten these existing resources to a greater extent day by day in terms of quality and quantity, restricting the amount of water to be used for agricultural irrigation. Considering the rapidly increasing population, it is necessary to maximize the efficiency obtained from unit area. The way to further increase the achieved production values is to implement conscious and economical irrigation practices. Since the plant responds to its environment in determining when to apply irrigation water and is located between the soil and the atmosphere, which is the water source, the plant must be monitored to reveal the plant's internal water status in order to schedule irrigation.

Studies show that it is very important to use plant-based measurement techniques in irrigation time planning. Unfortunately, while the available irrigation resources in the world are decreasing rapidly by becoming polluted, irrigation water is becoming very valuable. Therefore, using plant-based measurement techniques when determining irrigation time is effective and efficient. irrigation can be done.

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Chapter 10

DEEP LEARNING APPLICATIONS ON MARINE ENVIRONMENT AND PRODUCTS

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INTRODUCTION

In recent years, numerous studies have focused on the recent advances in packaging materials and technologies of fishery products, optimization of the processing conditions of fishery products, the usages of advanced technologies combined with sophisticated statistical methods for evaluating freshness and quality of seafood products, predictive models used for determining the shelf-life and bacterial growth of marine food products. The usage of these statistical models is preferred due to the many advantages it provide in the fields of food and seafood, as in every field. The preference and usage of these statistical models would be also developed day by day (Kılınç et al., 2021; Kılınç and Kılınç, 2022; Kılınç et al., 2022a; Kılınç et al., 2022b; Kılınç et al., 2022c; Li et al., 2023; Kılınç et al., 2023). In recent years, Artificial intelligence (AI) is one of these developing technologies that has been not only used with different data sources but also has become a technology that can provide fast solutions in evaluating the safety and quality of food products (O'Shea et al., 2023). The correlation between AI, deep learning (DL), and machine learning (ML) has been explained as follows. The field of AI forms the outermost cluster. The ML cluster domain is located inside the AI cluster domain. There is also a subset of DL within the ML set. The fields of AI include the fields of DL and ML (Zhu et al., 2021). ML methods, together with sensing devices for quality assessment, have become useful tools that allow the quality of food products to be evaluated quickly and effectively based on empirical data (Nturambirwe and Opara, 2020). In other words, experimental and numerical data have great potential for training ML models (Loisel et al., 2021). But as machine learning strategies advance, the scale and complexity of data processing increase, traditional ML methods have generally become not applicable. End of the finding as this situation, DL methods have been accessed, due to their more advanced architectures and data analytic capabilities (Zhu et al., 2021). In addition to this, DL has received significant attention due to its feature learning capacity based on multilayer artificial neural networks. The combination of genome characterization and molecular analysis using advanced techniques such as DL, spectroscopy, electrophoresis, and chromatography, would create a new approach for investigating the quality dynamics of foodstuffs (Jeevanandam et al., 2022). In addition to this, a BC-guided IoT-based food quality traceability system can not be only established for food products using the DL model (Manisha and Jagadeeshwar, 2023), but also DL applications can be made for image-based market food nutrient forecast (Ma et al., 2022). Some of the studies have been summarized about the usages of DL on aquatic products and their environment as follows. By integrating DL and statistical methods, the proposed method effectively addressed the problems of sea conditions in traditional methods, ensuring unsupervised quality control, and offering important details for the analysis of marine time series observation data (Xie et al., 2023). Additionally, DL outperformed ML for fish quality rating using images (Jayasundara et al., 2023). Another study showed that DL models could use time series phenotypes and hyperspectral data to estimate the quality characteristics of lettuce and water stress in a non-destructive way (Yu et al., 2023). A lot of studies have been conducted using DL applications, and the studies conducted are briefly indicated below. DL habitat modeling for organisms moving in rapidly changing estuarine environments was applied (Guenard et al, 2020). Additionally, various ocean noise classifications were made using DL (Mishachandar and Vairamuthu, 2021). Later in the year, harmful algal blooms were determined by integrated explainable DL prediction (Lee et al., 2022). Furthermore, fish otolith identification was performed using the deep hierarchical classification model (Stock et al., 2021). Moreover, DL models were also used for monitoring food processing and packaging (Zhu et al., 2021). In accordance with the above-mentioned studies, intelligent and automatic technology has been used in many different industries thanks to its quick development. These smart and automatic technologies create new challenges and opportunities for smart fisheries fields (Wu et al., 2022). In this direction, recent developments in computational technologies have created an eagerness to use AI, especially DL, in marine environments and products. Therefore, in this review, DL applications in marine sciences have been examined, and the latest publications made on this subject are included. In other words, this review will give an extensive summary of the applications of DL in marine environments and products in recent years.

The Advantages and Disadvantages of Deep Learning Models

For many years, modeling has been used in the design of food processes. Modeling has grown in popularity for process optimization in the food sector since it is convenient and has high forecasting capabilities. Improving model's accuracy and dependability is a difficulty in modeling. Consequently, numerous modeling strategies have been created over time. (Therdthai, 2021). DL models are one of these modeling techniques that have recently been proposed in applications of incomplete data use (Sun et al., 2023). In contrast to this scarce and high-dimensional consumer shopping data are available, which makes it difficult for researchers to conduct reliable and time-saving analyses. Such data can be processed by DL models, but many of the conclusions drawn from them are difficult to understand. This limits their usefulness in applications meant to enhance administrative decision-making and comprehend multi-category purchase behavior. (Xia and Chatterjee, 2022). In contrast to, DL models can produce a result with greater precision compared to traditional ML algorithms. Additionallyit is very helpful in many different fields, previously in the field of image classification. In recent years, the hardware advancements and identification of novel DL network topologies have significantly increased the accuracy and dependability of the DL model used for image categorization (Yu et al., 2022). In addition to this, DL techniques have made it easier to train fish image classification models and identify different varieties of fish in light of advancements in the field of computer vision (Kaya et al., 2023). For example, this article presented the underwater sea cucumber automatic detection method based on DL, which provided effective technical support for the automatic breeding and harvesting of sea cucumbers (Peng et al., 2021). Computer vision applications such as DL are not only found in automated systems for the harvesting, classification, grading, and processing of fish and fishery products, but also they are used for understanding and optimization of applications related to fishing, fish farming, and fish processing (Mathiassen et al., 2012). Additionally, the quality of food products can be estimated using computer vision algorithms, however there is a plenty of research on the subject, and no android-based applications have yet been created for this particular use. Contrarily, user-friendly, affordable, and portable equipment with quality estimate capabilities will support quick, real-time quality measurement of food products (Meenu et al., 2021). Industry 5.0, which combines AI and robots with the human mind to promote human-centered solutions, is the focus now on digital technology. The global food chain is experiencing considerable operational benefits from these digital technologies, including increased production and efficiency as well as decreased contamination, waste and food fraud. (Rowan, 2023).

Deep Learning Methods and Formulations

The types of DL models were identified as, Bidirectional Gated Recurrent Units, Bidirectional Long Short-Term Memory, Long Short-Term Memory, and Gated Recurrent Units by (Wang et al., 2023).

Long Short-Term Memory (LSTM)

Long Short-Term Memory (LSTM) is a one kind of memory block for artificial neural networks. It was developed in 1997 by Jürgen Schmidhuber and Sepp Hochreiter (Hochreiter and Schmidhuber, 1997). LSTM is recognized for its capacity for learning long-term dependencies, especially when working with time-series data. An LSTM cell comprised in four main components: a memory cell, an input gate, an output gate, and a forget gate.

Memory Cell

The memory cell ensures that the information is stored over a long period. It contains information from the previous time step and the current time step.

Input Gate

The input gate controls whether information will be added to the memory cell. If the input gate is active, the information will be added to the memory cell.

Output Gate

The output gate controls whether information from the memory cell will be output. If the output gate is active, the information is passed to the next layer.

Forget Gate

The forget gate controls whether information in the memory cell will be forgotten. If the forget gate is active, the information will be removed from the memory cell. The working principles of the LSTM cell are expressed with the following formulas (Graves, 2012):

Forget Gate:

$$ft=\sigma(Wf\cdot[ht-1,xt]+bf)$$

Input Gate:

$$it=\sigma(Wi\cdot[ht-1,xt]+bi)$$

$$\tilde{C}t=\tanh(WC\cdot[ht-1,xt]+bC)$$

Memory Cell Update:

$Ct = ft * Ct - 1 + it * \tilde{C}t$

Output Gate:

$ot = \sigma(Wo \cdot [ht - 1, xt] + bo)$

$ht = ot * \tanh(Ct)$

Here, σ indicates the sigmoid activation function, and tanh represents the hyperbolic tangent activation function. W and b are the weights and bias terms, respectively ht and Ct are the hidden state and memory state at time t, respectively. LSTMs have been successful in various application areas owing to their capacity for learning long-term dependencies. Especially in fields such as speech recognition, natural language processing, and music generation, LSTMs have achieved impressive results (Sutskever et al., 2014). However, since the training of LSTMs is complex, sometimes simpler structures or more advanced structures may be preferred.

Bidirectional Long Short-Term Memory (BiLSTM)

Bidirectional Long Short-Term Memory (BiLSTM) is a variant of Long Short-Term Memory (LSTM) designed to improve the learning of sequential data by utilizing data from both past and future time steps. BiLSTM was introduced by Schuster and Paliwal in 1997 (Schuster and Paliwal 1997). A BiLSTM consists of two LSTMs: a forward LSTM and a backward LSTM. The forward LSTM processes the input sequence from start to end, while the backward LSTM processes it from end to start. The hidden states of these two LSTMs are then concatenated at each time step to form the final output.

The forward and backward LSTMs in BiLSTM use the same LSTM equations described in the LSTM model.

1. **Forget Gate (Forward and Backward)**:

$f_t^f = \sigma(W_f^f \cdot [h_{t-1}^f, xt] + b_f^f)$

$f_t^b = \sigma(W_f^b \cdot [h_{t-1}^b, xt] + b_f^b)$

2. **Input Gate (Forward and Backward)**:

$i_t^f = \sigma(W_i^f \cdot [h_{t-1}^f, xt] + b_i^f)$

$i_t^b = \sigma(W_i^b \cdot [h_{t-1}^b, xt] + b_i^b)$

$\tilde{C}_t^f = \tanh(W_c^f [h_{t-1}^f, xt] + b_c^f)$

$\tilde{C}_t^b = \tanh(W_c^b [h_{t-1}^b, xt] + b_c^b)$

3. **Memory Cell Update (Forward and Backward)**:

$\tilde{C}_t^f = f_t^f * C_{t-1}^f + i_t^f * \tilde{C}_t^f$

$\tilde{C}_t^b = f_t^b * C_{t-1}^b + i_t^b * \tilde{C}_t^b$

4. **Output Gate (Forward and Backward)**:

$o_t^f * W_o^f + [h_{t-1}^f, xt] * b_o^f$

$o_t^b * W_o^b + [h_{t-1}^b, xt] * b_o^b$

$h_t^f * o_t^f * \tanh (C_t^f)$

$h_t^b * o_t^b * \tanh (C_t^b)$

At each time step, the outputs of the forward and backward LSTMs are concatenated to form the final output:

$h_t = [h_t^f, h_t^b]$

Here, the superscripts *f* and *b* denote the forward and backward LSTMs, respectively. The primary advantage of BiLSTM is its ability to consider both past and future contexts in the sequence. This helps the model capture patterns and dependencies that a unidirectional LSTM might miss. BiLSTMs have been successful in a wide range of applications due to their ability to capture information from both directions in a sequence. They are especially useful in natural language processing tasks like text classification, sentiment analysis, and named entity recognition. BiLSTMs have also been used in speech recognition, bioinformatics, and other time-series data analysis tasks (Graves and Schmidhuber, 2005). BiLSTMs offer a powerful way to improve the learning of sequential data by utilizing information from both past and future time steps. They have been successfully applied in various domains, demonstrating their effectiveness in capturing complex patterns and dependencies in data.

Gated Recurrent Units (GRU)

Gated Recurrent Units (GRU) is a type of recurrent neural network (RNN) architecture introduced by Cho et al., (2014). It is designed to capture dependencies in sequential data more effectively than traditional RNNs, while being computationally more efficient than Long Short-Term Memory (LSTM) units. A GRU cell consists of two gates: an update gate and a reset gate, and a candidate activation which is used to compute the next hidden state. The working principles of the GRU cell are expressed with the following equations:

1. **Update Gate**:

$$z_t=\sigma(Wz\cdot[h_{t-1},x_t]+b_z)$$

2. **Reset Gate**:

$$r_t=\sigma(Wr\cdot[h_{t-1},x_t]+b_r)$$

3. **Candidate Activation**:

$$\tilde{h}_t=\tanh(Wh\cdot[r_t*h_{t-1},x_t]+b_h)$$

4. **Hidden State Update**:

$$h_t=(1-z_t)*h_{t-1}+z_t*\tilde{h}_t$$

Here, σ represents the sigmoid activation function, tanh represents the hyperbolic tangent activation function, W and b are the weights and bias terms, respectively. h_t is the hidden state at time t, z_t and r_t are the update gate and reset gate at time t, respectively.

The primary advantage of GRU is its ability to learn long-term dependencies in sequences, while being computationally more efficient than

LSTMs. GRUs use fewer parameters than LSTMs, which makes them faster to train and less prone to overfitting on small datasets. GRUs have been successful in various application areas, including natural language processing tasks like text classification, sentiment analysis, and machine translation. They are also used in speech recognition, bioinformatics, and other time-series data analysis tasks. GRUs offer a powerful and efficient way to capture temporal dependencies in sequential data. They have been successfully applied in various domains, demonstrating their effectiveness in capturing complex patterns and dependencies in data.

Bidirectional Gated Recurrent Units (BiGRU)

Bidirectional Gated Recurrent Units (BiGRU) is a variant of Gated Recurrent Units (GRU) designed to improve the learning of sequential data by utilizing information from both past and future time steps. Similar to Bidirectional Long Short-Term Memory (BiLSTM), BiGRU consists of a forward GRU and a backward GRU.

A BiGRU consists of two GRUs: a forward GRU and a backward GRU. The forward GRU processes the input sequence from start to end, while the backward GRU processes it from end to start. The hidden states of these two GRUs are then concatenated at each time step to form the final output. The forward and backward GRUs in BiGRU use the following GRU equations:

1. **Update Gate (Forward and Backward)**:

$$z_t^f = \sigma(W_z^f \cdot [h_{t-1}^f, x_t] + b_z^f)$$

$$z_t^b = \sigma(W_z^b \cdot [h_{t-1}^b, x_t] + b_z^b)$$

2. **Reset Gate (Forward and Backward)**:

$$r_t^f = \sigma(W_r^f \cdot [h_{t-1}^f, x_t] + b_r^f)$$

$$r_t^b = \sigma(W_r^b \cdot [h_{t-1}^b, x_t] + b_r^b)$$

3. **Candidate Activation (Forward and Backward)**:

$$\widetilde{h_t^f} = \tanh(W_h^f [r_t^f * h_{t-1}^f, x_t] + b_h^f)$$

$\widetilde{h_t^b}$=tanh(W_h^b[$r_t^b * h_{t-1}^b$,x_t]+b_h^b)

4. **Hidden State Update (Forward and Backward)**:

$\widetilde{h_t^f}$=(1-z_t^f) $* \, h_{t-1}^f$]+$z_t^f \, * \, \widetilde{h_t^f}$)
$\widetilde{h_t^b}$=(1-z_t^b) $* \, h_{t-1}^b$]+$z_t^b \, * \, \widetilde{h_t^b}$)

At each time step, the outputs of the forward and backward GRUs are concatenated to form the final output:

h_t=[h_t^f,h_t^b]

Here, the superscripts *f* and *b* denote the forward and backward GRUs, respectively. The primary advantage of BiGRU is its ability to consider both past and future context in the sequence. This helps the model capture patterns and dependencies that a unidirectional GRU might miss. BiGRUs have been successful in various application areas due to their ability to capture information from both directions in a sequence. They are commonly used in natural language processing tasks like text classification, sentiment analysis, and named entity recognition. BiGRUs are also useful in speech recognition, bioinformatics, and other time-series data analysis tasks (Cho et al., 2014). BiGRUs offer a powerful way to improve the learning of sequential data by utilizing information from both past and future time steps. They have been successfully applied in various domains, demonstrating their effectiveness in capturing complex patterns and dependencies in data.

The Applications of the Deep Learning on Classification of Marine Products and Environment

There are many areas of use of the DL method. Among the most important areas of use among these are the classification of fishing products and the areas of use related to the environment in which they live. The studies conducted on this subject are briefly summarized below. The DL neural network was improved and implemented as a non-destructive, intelligent, and real-time method to automate the identification of various economically most known carp species such as silver carp (*Hypophthalmichthys molitrix*), common carp (*Cyprinus carpio*), large-headed carp (*Hypophthalmichthys nobilis*), and grass carp (*Ctenopharingodon idella*) (Banan et al., 2020). Another study addressed the aspect of classifying and identifying food types applying AI through transfer learning techniques, computer vision, and DL.

The researchers used a dataset with huge amounts of images of food classified into different categories including seafood in this study. For each experiment, data magnification techniques were used to generate an additional number of images on average. The results of the trials with various Convolutional Neural Networks (CNN) demonstrated that transfer learning with the EfficientNetV2 model was able to classify various types of food from photographs with a substantial verification accuracy of 94.5%. Food classification with images was successfully done by DL methods (Suddul and Seguin, 2023). Another author provided a comprehensive survey on DL in food category recognition. The modern development of big data and the development of data-oriented fields such as DL have led to advances in the recognition of food categories. With developing computational power and increasingly large food datasets, the potential of this approach was reported yet to be performed (Zhang et al., 2023).

In terms of fish classification and real-time data monitoring, the Internet of Things (IoT), and DL each offered to be an efficient solution. In the end, the authors created a hybrid (CNN+Convolution LSTM) model with an accuracy of 97% and outperformed state-of-the-art techniques in every aspect (Dense Network 201, Dense Network 169, Dense Network 121). In addition, the research conducted some experiments with the IoT-based solution. Although the proposed solution exhibited some disadvantages, it was reported to be applied in real-time solutions (Ahmed et al., 2023). In one study, various algorithms based on DL were studied for the identification of fish species and length prediction. Additionally, for the sample partitioning task, the authors adopted the Mask R-CNN algorithm for the challenge of fish species identification, whereas a Mobile Net-V1 convolutional neural network was also used to estimate the length of every individual. The results showed that when the overlap between individuals was medium to low, both the identification and length prediction models determined that the catch was well-measured (Ovalle et al., 2022). In the other study, the DL capability allowed the automatic segmentation of shell areas from lobster images to calculate rating characteristics, including color, size, and weight. For the following research targeted at identifying specific lobsters, this discovery produced a high-quality input dataset. The effectiveness of the CNN method was evaluated in a mobile application environment and verified in a sizable image dataset gathered in a lobster processor. The results of this study played a significant role in the development of the comprehensive biometric system used to track Southern Rock Lobster (SRL) products (Vo et al., 2020).

The performance comparisons of some studies conducted using advanced modeling techniques are as follows. FishNET-S managed to achieve an accuracy of 84.1%, while FishNET-T achieved an accuracy of 68.3%. Comparison analysis conducted using general ML and state-of-the-art DL models showed that the performance of the proposed new learning technique was determined as dominant and uncontroversial very good (Jayasundara et al., 2023). The IsVoNet8 model was compared with the ResNet 50, ResNet 101, and VGG16 models in another study. The success accuracy obtained as a result of the comparison was determined as 98.62%, which was the highest in Isvonet8 (Kaya et al., 2023). Improved faster recurrent CNN was also used to identify three squid species from the North Pacific Ocean. This proposed method was reported to be shown to be a non-invasive, robust, and highly efficient system for squid classification. Additionally, this method was also highlighted to be able to be used for improving the other processes of marine food products (Hu et al., 2020). These models not only can be used for the classification of fishery products, but they can be also used for predicting fishing areas such as marine environmental variables. For example, they have been also used for forecasting water quality (WQ) parameters in various water resources, such as coastal areas, rivers, lakes, seas, oceans etc. (Wai et al., 2022). For this purpose, the construction of a mullet mackerel (*Scomber japonicus*) fishing area prediction model based on DL and marine environmental variables in the northwestern Pacific Ocean was examined. As a result of this study, the 3D CNN model was found to be better than the 2D CNN model. For the 3D CNN, this model performed learning information about the ocean remote sensing environmental variables that were most easily distinguishable in different classifications (Han et al., 2023). The DL-PPCE model was presented by the authors this new approach was shown to estimate 17 pigment concentrations and estimated pigment concentrations worldwide gave rise to many advantages for analyzing phytoplankton community dynamics on a large space-time scale (Li et al, 2023). Additionally, the integrated DL forecasting model predicted the (HABs) harmful algal blooms spread, identified variable impacts that helped decision-makers, and effectively implemented preventive responses, thereby protecting aquatic ecosystems, and reducing economic losses (Lee et al., 2022).

The Applications of the Deep Learning on Aquaculture

Some of the applications of DL models on aquaculture are summarized as follows. DL models such as long-short-term memory (LSTM), recurrent neural network (RNN), and gated recurrent unit (GRU) have been often used to predict the trend of time series, but it was unclear which one was more suitable for the prediction of dissolved oxygen in the fishery pond. It was concluded by the authors that GRU performed better overall and it was declared to be applied to practical applications (Li et al., 2021). A method of detecting the damage of the sea cage based on machine vision and DL was proposed, which could detect the structure of the sea cage in real time and accurately detect the damaged area of the cage. The MobileNet-SSD model was optimized in terms of model size as well and detection speed was compared to the SSD model. In the experiment, simulated damaged images of the sea cage were determined to be used for testing. Experimental results were shown that the plan improved the efficiency of sea cage inspection and accurately detected damaged areas in the cage in real-time (Liao et al.,2022). DL has received increasing attention in global aquaculture because it provides important information about fish behavior, productivity, and fish quality. In addition, compared with the faster region CNN, YOLO, YOLOv2, YOLOv3, and single-pulse multi-box detector, the performance of each evaluation metric of the proposed method was improved by 10% -20% (Hu et al., 2021). In one research, the DL model SO-YOLOv5 based on YOLOv5 was proposed for underwater small object recognition, which improved the algorithm's recognition ability for items of various sizes in a complicated setup. In addition, the proposed approach was reported to have practical application value to improve the level of intelligence in aquaculture (Xuan et al., 2023). In another research, the DL object detection algorithm based on YOLOv7 was used to design a new network called Underwater-YOLOv7 (U-YOLOv7) for underwater organism detection. This model met the requirements both in terms of accuracy and speed (Yu et al., 2023). Additionally, object detection based on DL was performed to detect certain characteristics. The authors focused on monitoring fish heads and eyes as a correct indicator of the position of the fish. Feature matching and then 3D reconstruction were performed to measure the 3D position of the fish, where the directions of the fish rotation were predicted (Nygard et al., 2022).

The Applications of the Deep Learning on Freshness of Marine Products

Freshness is an important indicator for evaluating the nutritional and safety properties of fish products (Wang et al., 2023). Evaluation and smart fish freshness monitoring is extremely important in the fishery product production and trading. Given the large volume of industrial production, it is difficult to quickly and precisely assess fish freshness using traditional methods (Taheri-Garavand et al., 2020). As a matter of this approach, the authors developed an easy detection platform based on a smartphone application (APP) with the inclusion of a DL model to monitor food freshness in real-time. Colorimetric indicator rods on a cellulose paper were first formed by gelatinization of synthesized gelatin methacryloyl (GleMA) by bromocresol green (BCG) encapsulation through UV-induced crosslinking. After the photo was taken, the DL model with the CNN was trained using 1735 images of labeled chopsticks and then predicted the freshness of meat well with an accuracy of 96.2% (Gong et al., 2023). One study aimed to apply the CNN to model Raman spectra data for rapid classification of freshness ratings of sea bass (*Lateolabrax japonicus*) fillets. This research provided an example of combining portable Raman spectrometry with DL for rapid and non-destructive analysis of food quality (Wang et al., 2023). Using the CNN long-term short-term memory model, the correct prediction of salmon freshness under temperature fluctuations was examined. When the temperature fluctuates, the model accurately predicts the total viable numbers (TVC) with a determination coefficient (R^2) greater than 0.95, under variable temperature conditions (Wu et al., 2022).

The Applications of the Deep Learning on Quality and Safety of Marine Products

Traditional fishery machine vision-based algorithms for recognizing products often use characteristics created by humans that are highly depends on human experience, which makes it potentially ineffective and erroneous (Liu et al., 2019). However, advanced data analytics techniques, including DL learning, ML, and natural language processing algorithms, help to analyze complex data efficiently and can be applied to these datasets for food safety prediction (Benefo et al., 2022). DL models have been developed not only to predict food safety but also to predict the safety and quality of water, as well as energy resources in the future (Raya-Tapia et al., 2023). Shrimp recognition based on DL algorithms was proposed for shrimp quality evaluations. The smart net model (Deep Shrimp Net) was observed to be not only efficient but also the idea of classifier combination integrated into the newly built CNN model ensured good performance (Liu, 2020). Because of the morphological differences of shrimp and, the LeNet-5 structure (Shrimp Net) was recreated for identification and matching efficiently. This model is also reported to show good performance not only for shrimp classification but also for shrimp quality measurement on the production lines (Liu et al., 2019). For safety and quality determination of shrimp and other seafood, hyperspectral imaging in combination with the DL method was successfully used to evaluate the TVB-N content during cold storage of the Pacific (*Litopenaeus vannamei*) white shrimp. The deep hyperspectral properties in HSI were used as spectral indices for nondestructive estimation of TVB-N value in shrimp, which would motivate further research efforts on the method of DL property extraction (Yu et al., 2019). In another study, batch sorting and rapid sensory analysis of mackerel products developed using YOLOv5s algorithm and CBAM: verification by means of TPA, colorimetry, and PLSR analysis were performed. The accuracy of the model was evaluated by sensory evaluation, tissue profile analysis, and colorimetry analysis (Huang et al., 2023). As the other usage of DL, CNN model was successfully improved and achieved a high accuracy rate of 99.7% in identifying six pathogenic *Vibrio* species within 15 minutes, offering a new technique for pathogenic bacteria identification (Yu et al., 2023).

The Applications of the Deep Learning on Processing of Marine Products

Food material science has developed to assistance the improvement of food products by combining food sensorial properties, structure, nutrition, food processing, and digestion with the impact on consumers. Nevertheless, food design has not advanced to cope with this increasing complexity of food systems. The ability to understand consumer demands, capture their attention, and turn it into the physical and chemical characteristics of the end product is still one of the most difficult problems in the food industry. As a result, new ways of supporting food design and processing have been required (Al-Sarayreh et al., 2023). Machine vision is mostly applied in all areas of food processing technology. Meanwhile, image processing is an significant component of machine vision. It can take advantage of machine learning (ML) and DL models to effectively determine the type and quality of food products. Then, the tracking create in the machine vision system can handle tasks such as detecting the locations of defective spots or foreign objects, food grading, and removing foreign substances (Zhu et al.,2021). Traditional ML algorithms based on handmade properties normally have poor performance because of their limited representational capacity of complex food properties. In recent years, The most often used structure of DL, extraction of features, has seen the development of CNN as an efficient and potentially useful tool. CNN is also being used for the identification and analysis of complicated food matrices (Liu et al.,2021). For example, the evaluation of moisture content (MC) in salted sea cucumbers by hyperspectral (HSI) and low field nuclear magnetic resonance (LF-NMR) based on the Fusion-net deep learning (FDL) network framework was studied in one study. The rapid non-destructive detection of MC in salted sea cucumbers was informed to be well-performed with HSI and LF-NMR data based on the DL framework. Additionally, the benefit of data fusion detection based on the FDL framework was also confirmed by (Zeng et al., 2022). Moreover, the DL approach was studied to estimate and optimize energy in fish processing industries. The results of the experiments showed that the ANN model performed with higher accuracy than the long-short-term memory (LSTM), peephole-LSTM, and gated recurrent unit (GRU) as an artificial recurrent neural network (RNN) architecture (Ghoroghi et al., 2023).

Conclusion

This review proceeds by demonstrating the current and potential usages of DL on marine environments and products. For this purpose, recent studies have been examined about this advanced methodology summarized. Some convenience and challenges have been found and highlighted in this advanced methodology. Although the DL method provides advantages such as being fast, intelligent, convenient, non-destructive, efficient, inexpensive, and accurate in prediction, it also brings some difficulties as follows; possible solutions for better integration of these advanced AI, and its subfields, ML and DL, developing data availability, and transferring data from the results of research parameters to parameters involved with industry. It is foreseen that solutions will be found to the problems encountered today in the future and the use of these approaches will be completely preferred. DL-based models will be used for assistance in forecasting personal demand in the fields of aquaculture, fisheries, seafood processing in the near future.

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