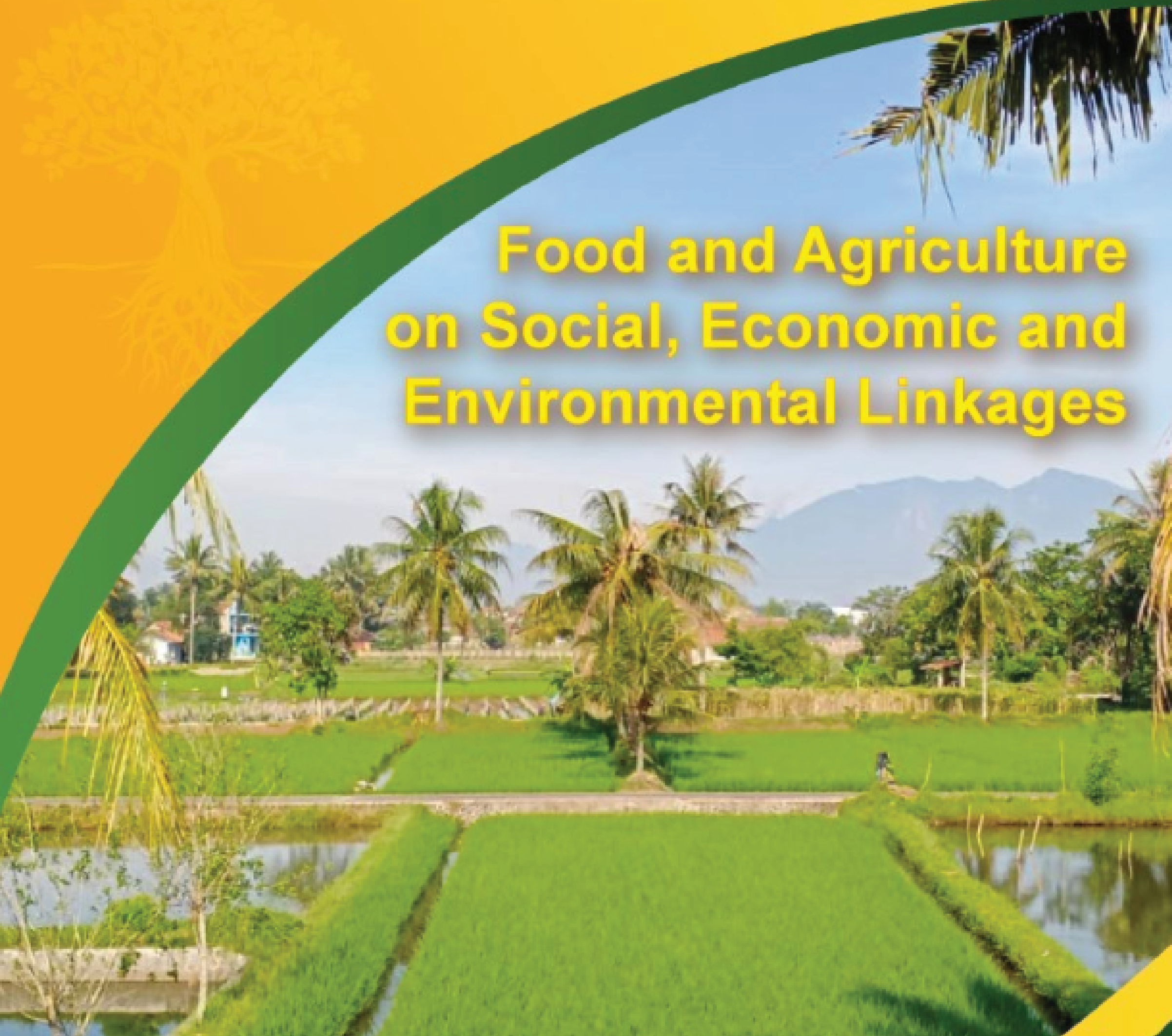
Food and Agriculture on Social, Economic and Environmental Linkages



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PREFACE

Food and agriculture are fundamental to ensuring that people can live and survive. Nothing artificial food can replace its functionalities. Food and agriculture play an essential key role in all are critical to improving food security and nutrition as well as in poverty alleviation. However, recently food and agricultural system have changed and degraded the environment. How it will be in the future is our challenge to save the planet and people but keep giving a profit.

The world faces unprecedented challenges, especially in the post-COVID-19 pandemic, countries' conflicts, floods, earthquakes, and climate change. The food and agriculture system must ensure the population has access to the nutrition it needs to flourish, especially as the climate change re-shapes agricultural production. Hunger and nutrient deficiencies need to be tackled at the same time. In the presence of climate change, increasingly challenging land-use conversion, rising health, and social costs from both individual and societal, geographic and demographic, and a growing global population, the problems arising from food and agriculture will likely become more severe. The absence of linkage and implications in social, economic, and environmental need responsibility from governance, policymakers, farmers, and consumers to do their part in combating hunger and nourishment. Nature has gracefully provided the necessary inputs to feed us, and we have, on many occasions, taken these precious gifts for granted. Working toward a sustainable food and agriculture production supply is crucial, affecting everything from the nutrient value of crops and food products to the health of livestock, the environment, society, and even the economy.

This book, "Food and Agriculture on Social, Economic and Environmental Linkages," contains materials that will enable the readers to identify the action, interactions, and linkages among social, economic, and environmental as well as the opportunities for providing food through agricultural production.

Editors:
Ristina Siti SUNDARİ
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Table Content

CHAPTER 1

NATURAL GOMUTI SWEETENER (*Arenga pinnata*) IN CONSUMER PERSPECTIVE AND BEHAVIOR

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1.1. Introduction

One of the plantation crops that have the potential to be developed is Gomuti sugar palm (Nurdasanti, Rochdiani, and Setia 2021). Many types of sugar other than gomuti Sweetener can be used as the main sweetening ingredient, including granulated sugar, rock sugar, corn sugar. One of the gomuti Sweetener-producing provinces is West Java province with a total production of gomuti Sweetener reaching 62940 tons in 2020 (Dinas Perkebunan, 2020). Gomuti Sweetener production in West Java from 2016 – 2020 can be seen in Figure 1.

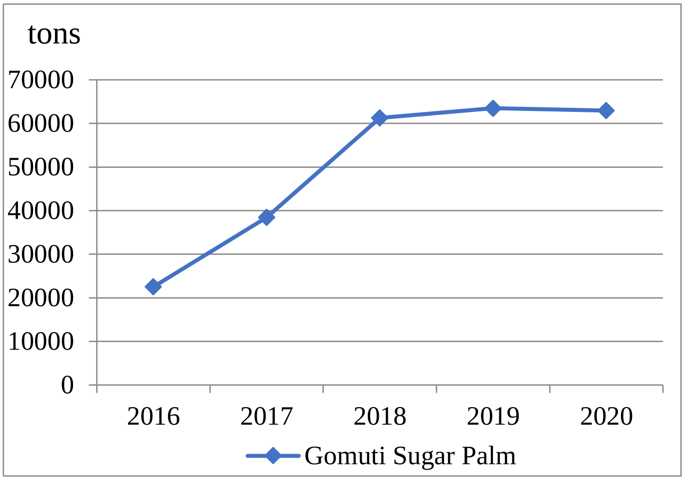

Figure 1. West Java Gomuti Gomuti Sweetener production in 2016 – 2020. (Dinas Perkebunan, 2020)

Based on Figure 1, the production of gomuti Sweetener in West Java Province in 2016 reached 22526 tons, in 2017 it reached 38468 tons, in 2018 it reached 61264 tons, in 2019 it reached 63497 tons, and in 2020 it reached 62940 tons. West Java gomuti Sweetener production tends to increase from 2016 – 2019 while production decreases in 2020. One of the gomuti Sweetener production centers in West Java province is in Pangandaran district with a palm plantation area of 189 ha and gomuti Sweetener production reaching 972 tons in 2020 (Dinas Perkebunan, 2020).

Gomuti Sweetener produced in Padaherang District is marketed directly to consumers without going through markets or middlemen. Gomuti Sweetener is packaged directly using dry palm leaves. Packaging can help reduce the risk of product damage, protect the goods inside from friction or collision and function as an attraction for buyers (Rahayu & Widajati, 2007). The gomuti Sweetener agro-industry has good opportunities and is expected to be able to increase the household income of the gomuti Sweetener producers themselves (Budiarto, 2010).

Gomuti Sweetener tends to be used more often in cooking seasoning than coconut sugar or granulated sugar. Of course, there are personal considerations for consumers in consuming gomuti Sweetener that is not yet known to the public, making it difficult to replace it with other sugars. Consumer preferences and consumer behavior are certainly attached to every consumption pattern, especially the consumption of gomuti Sweetener. Preferences and consumer behavior emerge when consumers are faced with the choice of a product to consume. Padaherang is one of the districts in Pangandaran Regency which contributes to gomuti Sweetener production. In 2020 production reached 5.04 tons.

Gomuti Sweetener is processed palm sap taken from the tapping process and then cooked until it turns solid. Processing of gomuti Sweetener still uses traditional techniques and the business is hereditary. Judging from its use, it is suspected that the demand for gomuti Sweetener will continue to increase, in line with the increase in population and increase in income (Manurung and Nataatmadja 2018). Housewives in Padaherang District tend to use gomuti Sweetener more often as an ingredient or seasoning in cooking. The economic growth of a region supported by good utilization of natural resources can accelerate the achievement of regional goals (Abidin et al. 2018) .

Consumer behavior is all a person's activities that involve buying and using products including the process of making decisions and determining these actions from experience about products or other sources (Yulianti et al., 2019) . Consumer characteristics include attitudes and behavior which are dynamic and developing, so that consumers will have new perceptions, new experiences in their lives as consumers (Sundari et al., 2020) . There are four indicators of consumer behavior such as income, lifestyle, product needs and preferences for products (Karina, Sundari, and Hidayati 2021). Consumer behavior is attached to consumers (Sundari, et. al 2017 dan 2020) In this case, especially in consuming gomuti Sweetener. Consuming gomuti Sweetener certainly considers inherent attributes such as taste, color, texture, water content, and price. Due to the lack of information about gomuti Sweetener, it is necessary to conduct research in terms of consumer preferences and behavior toward gomuti Sweetener consumption. With this research, producers are expected to be able to improve the quality of gomuti

Sweetener to meet consumer needs and satisfaction based on consumer behavior and their perspective.

1.2. Methods

The research was conducted in Padaherang District, Pangandaran Regency. Place determination is done intentionally or purposively according to sales data from gomuti Sweetener producers. This study used a survey method with the target population, namely housewives as consumers of gomuti Sweetener who had consumed gomuti Sweetener in the last month, with a total sample of 75 people. The measurement scale used is a Likert scale of 1-5 with criteria from strongly disagree to strongly agree. The data type uses cross-section data. The data sources used are primary data and secondary data. Primary data were obtained through interviews and questionnaires, which were given directly to the respondents. Secondary data were obtained from related agencies or institutions such as SMEs, farmer groups, and the Padaherang District Government, as well as from literature related to this research.

Data analysis used univariate Fishbein multi-attribute analysis, and Conjoint analysis. Fishbein multi-attribute analysis was conducted to determine the most considered attributes in consuming gomuti Sweetener. The attribute measurement scale used is a Likert scale of 1 – 5 with criteria from strongly disagree to strongly agree. Fishbein multi-attribute analysis model is as follows:

$$Ao = \sum_{1=1}^{n} ei.bi \qquad (1)$$

Notification:

Ao : Consumer behavior on gomuti sweetener
Bi : Consumer Level of confidence that gomuti gomuti Sweetener has certain attribute
Ei : Consumer evaluative dimension on the first variable that gomuti Sweetener has.
n : Amount of Gomuti gomuti Sweetener attribute

1.3. Result and Discussion

1.3.1 Characteristic of Respondent

Consumer characteristics are known based on gender, age, education and occupation. It is hoped that this will provide an overview of consumer conditions related to the problem and research objectives (Sugihastuti, 2020). Following are the characteristics of respondents based on gender, age, education and occupation.

Table 1. Characteristics of Respondents

No	Items	Respondents	Proportion
1	Gender		
	Man	0	0%
	Woman	75	100%
2	Consumer Age (Years)		
	0 – 14	0	0%
	15 – 64	75	100%
	> 64	0	0 %
3	Education		
	Elementary Scholl	40	53%
	Junior High School	27	36%
	Senior High School	7	9%
	S1	1	1%
	S2	0	0%
	S3	0	0%
4	Profession		
	civil servant	0	0%
	Private employees	1	1%
	Self-employed	11	15%
	Farmer	8	11%
	IRT	55	73%
	Other	0	0%

Source: Primary Data Processed (2022)

Based on Table 1, the research respondents were all female. This is in accordance with the needs of the sample in the study, housewives as consumers of gomuti Sweetener. The ages of all respondents were between 15 – 64 years. According to Said Rusli (1984) that the age of 15-64 years is a productive age where a person's age can affect openness to innovation, ages 15-64 years show a greater response to everything they face compared to ages > 64 years or <15 years

Furthermore, the characteristics of respondents based on their level of education were 40 people (53%) graduated from elementary school, 27 people (36%) graduated from junior high school, 7 people (9%) graduated from high school and 1 person (1%) graduated from bachelor degree. Respondents who did not take education would of course give a different response from those who did, because the higher the level of education, the higher the level of knowledge they get. This is in accordance with

Andrie's research, (2013) that the level of education that has been taken affects a person's perspective in responding to technology and innovation.

Respondents' occupations consisted of 1 person (1%) private employee, 11 people (15%) entrepreneur, 8 people (11%) farmers, and 55 people (73%) as housewives. In general, the respondent's work can affect his activities including food consumption patterns (Wadhani and Ratnaningsih 2021).

1.3.2 Gomuti Sweetener Consumer Behavior

consumer behavior of gomuti Sweetener, a survey was conducted of 75 respondents as consumers of gomuti Sweetener through four variable indicators of consumer behavior that had been prepared previously, namely, lifestyle, needs, preferences and traditions.

Table 2. Gomuti Sweetener Consumer Behavior Classification

No	Statement Items	Ideal Score	Actual score	Category
1	Lifestyle	375	367	Very good
2	Need	375	306	Very good
3	Favorite	375	322	Very good
4	Traditions/customs	375	351	Very good
Total			336.5	Very good

Source: Primary Data Processed (2022)

Consumer behavior is included in the very good category, successively considering the consumption of gomuti Sweetener consumption based on indicators of consumer behavior, namely lifestyle, traditions/customs, preferences, and needs. Consumers are more likely to consume gomuti Sweetener because of the healthy lifestyle they adopt, because consumers think that consuming gomuti Sweetener is able to maintain their health. This is in line with research (Sufa et al., 2017) that a healthy lifestyle is a physiological need and a basic human need to sustain life. Then in food processing for the sake of tradition, try to use gomuti Sweetener as a food seasoning so that it produces a good aroma and taste image.

Fulfillment of sugar for food ingredients or seasonings predominantly uses gomuti Sweetener because consumers really like this product. According to Sadeli & Utami, (2013) consumers look for products that match their characteristics and desires. Variants of types of sugar appear to meet consumer needs, for example coconut sugar or granulated sugar, thus fulfilling the need for gomuti Sweetener for food ingredients or seasonings can be replaced with gomuti sugar.

1.3.3 Gomuti Sweetener Consumption Level in Padaherang District

The average sugar consumption is 328 grams/per month. Referring to sugar consumption reference, according to the Ministry of Health of the Republic of Indonesia that the amount of consumption is in a low category.

Table 3. Gomuti Sweetener Consumption Levels in Padaherang

No	Statement Items	Use of Gomuti Sweetener	Total Monthly Consumption	Monthly Consumption Reference	Category
1	Consumption of Gomuti	Every day	328 grams	< 900 grams	Low

Source: Primary Data Processed (2022)

1.3.4 Consumer Perspective

The most considered attribute in consuming gomuti Sweetener in Padaherang District was carried out using Fishbein multi-attribute analysis. Consumer attitude is an important factor in product marketing strategy. Consumer attitudes are closely related to the concept of belief and evaluation of the level of importance. The results of the analysis can be seen in Table 4.

Tabel 4. Consumer Perspective on Gomuti

No	Atribut	Ei	Bi	Ao (ei.bi)	Perspective
1	Taste	4,4	4,02	17,69	Very Positive
2	Color	3,84	3,88	14,90	Positive
3	Texture	3,89	3,89	15,13	Positive
4	Water Content	3,97	4,00	15,88	Positive
5	Price	3,44	3,42	11,76	Negative

Source: Primary Data Processed (2022)

Table 4 explained the taste attribute is in the first place, including a very positive perspective with an Ao value of 17.69. This means that the taste attribute is the most important attribute in considering gomuti Sweetener consumption. This is in line with the research (Sundari & Umbara, 2019 and Sundari et. al., 2021) where consumers are more concerned with taste than other attributes in consuming the product, the color attribute is included in the positive category with an Ao value of 14.90, which ranks fourth among the other attributes. Gomuti Sweetener consumers in Padaherang District think that color is not so important in considering gomuti Sweetener consumption. This is not in accordance with the research of Nurhadi et al., (2019) that the color attribute was first in consideration of gomuti Sweetener consumption.

The texture attribute is included in the positive category with an Ao value of 15.13 which is in third place among the other attributes. The texture of the gomuti Sweetener certainly affects the smelting time. The softer the texture of the gomuti Sweetener, the faster the smelting process. This invention is in line with the research Subaktilah, (2018) Where texture is one of the attributes considered in consuming gomuti Sweetener, the water content attribute is included in the positive category with an Ao value of 15.88 which ranks second from the other attributes. Gomuti Sweetener consumers assume that the drier the gomuti Sweetener is, the easier it is to slice.

The price attribute is in the last order of the other attributes with an Ao value of 11.76, including the negative category. The price of gomuti Sweetener is not a consideration in consuming gomuti Sweetener in Padaherang District. It is the same with research Sundari & Umbara, (2019) that the price is not a reference for individuals to consume the product.

Tabel 5. Utility Estimate Perception

Utilities			
		Utility Estimate	Std. Error
Taste	Sweet	0,482	0,107
	Sweet-sour	-0,251	0,125
	Sweet-plain	-0,231	0,125
Color	Golden brown	0,253	0,107
	Brown	0,062	0,125
	Dark Brown	-0,315	0,125
Texture	Smooth	0,231	0,107
	Intermediate	-0,387	0,125
	Hoarsh	0,156	0,125
Water Content	Dried	0,336	0,107
	Intermediate	0,079	0,125
	Wet	-0,414	0,125
Price	< 1 USD	0,267	0,107
	1 – 2 USD	-0,178	0,125
	> 2 USD	-0,088	0,125
(Constant)		3,096	0,100

Source: Primary Data Processed (2022)

Based on Table 5, consumers prefer sweet-tasting gomuti Sweetener to sour-sweet and sweet-sour gomuti Sweetener, with a utility estimate value of 0.482. This invention is in line with the research (Nasution 2020) that the sweet taste is more favored by consumers. Consumers prefer gomuti with a yellowish brown color over brown and dark brown, with a utility estimate value of 0.253. This invention is in line with the research (Musita 2019) The color of golden-brown sugar is more popular with consumers because the color of gomuti is brighter, resulting from a clean production process.

The texture gomuti Sweetener consumers like the most is a soft texture with a utility estimate value of 0.231. In contrast, the texture of medium and coarse gomuti Sweetener could be more attractive to consumers. This invention is in line with the research (Nasution 2020) That gomuti Sweetener with a soft texture is believed to be better quality and easier to melt.The texture gomuti Sweetener consumers like the most is a soft texture with a utility estimate value of 0.231. In contrast, the texture of medium and coarse gomuti Sweetener could be more attractive to consumers. This invention is in line with the research (Nasution 2020) That gomuti Sweetener with a soft texture is believed to be better quality and easier to melt.

Gomuti Sweetener with little water content or dry is preferred by consumers over moist or wet gomuti Sweetener, with a utility estimate value of 0.336. The water content in gomuti Sweetener can affect the use of sugar. For example, moist sugar is difficult to slice. The price of gomuti Sweetener < 1 USD is preferred by consumers over other prices, with a utility estimate of 0.267. This invention is in line with the research (Ayu and Wati 2020) The price of brown sugar ranges from <20,000, and it is not uncommon for consumers to want cheap products of good quality.

The characteristics of gomuti Sweetener that consumers like are expected to be a reference for gomuti Sweetener producers to make the maximum possible product to achieve the desires and satisfaction of the consumers themselves. The quality of a product can also be determined based on inherent attributes and is a benchmark for consumers in meeting their needs and life satisfaction. (Sadeli and Utami, 2013). Gomuti Sweetener has good prospects for development, seen from the level of demand that continues to exist and needs that still need to be met, either domestically or in export (Evalia, 2004; Karina, 2021)

1.4. Conclusion

Consumer behavior in consuming gomuti in Padaherang District mainly considers the healthy lifestyle consumers adopt. Gomuti Sweetener consumers in Padaherang District consume gomuti Sweetener daily with a total consumption of 328 grams/month, including the low category. Partially, consumer behavior influences the level of consumption of gomuti Sweetener in the Padaherang District The attributes of gomuti Sweetener are based on their order of importance, namely taste, water content, texture, color, and price. Consumers like gomuti Sweetener with a sweet taste, dry water content, soft texture, yellowish brown color, and price < 1.00 USD/Kg

1.5. Suggestion

Consuming gomuti must be by consumption guidelines according to the Ministry of Health of the Republic of Indonesia to prevent illness due to excess sugar use. Gomuti Sweetener producers must strive to make gomuti Sweetener products consumer desires to meet their needs and life satisfaction.

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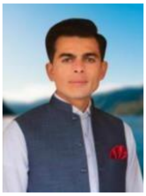

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CHAPTER 2

SUSTAINABLE PRODUCTION INSTITUTIONAL DESIGN TOWARD THE ENVIRONMENTAL SERVICES DEVELOPMENT

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2.1. Introduction

The sustainability of the agriculture system has a main part in contributing sustainable production and consumption of food and fibre in the world. How the agriculture production system is held will determine the environmental services availability. Sustainable agricultural development is mandatory in Indonesia Law No. 12, 1992. It is an agricultural practice that uses the basic principles of ecology as well as the science of the relationship between organisms and their environment. It has sustainable economic, ecological and social activities as its basic principles. It also the goals and targets of the SDGs 2015-2030 grouped pillars, i.e. social, economic, environmental, and legal development and governance, with sustainability concern.

Some of cash-crop agriculture production plants such as coffee or pepper need conditions to grow in the highlands. Most of the highland areas are water catchment or watersheds area. Topographically, cash-crop commodities such as coffee, pepper, banana, etc farming in Lampung laid upstream of the watershed area. It was the Sekampung watersheds in Tanggamus and Way Besai watersheds in West Sumatera. Sekampung watersheds cover seven districts with an area coverage amount 4,774.39 km^2. Land use of upstream Sekampung was dominantly by dryland farming, as the main source of the plantation (43.73%), rice field (16.19%), moorland (21.43%), and settlement (10.94%) (Sekampung-Mesuji Watersheds Agency, 2013). The land use change affected the environmental carrying capacity. Furthermore, agricultural production system in upstream watersheds is necessary to carry out on the sustainable production establishment. (Banuwa et al., 2008; Fitriani et al., 2020; Fitriani et al., 2022; Fitriani et al., 2018; Somura et al., 2018; Supriyadi et al., 2018).

The maintained watersheds territory will provide the environmental services in the future. Therefore, agricultural activities surround watershed areas are necessary ensured to apply conservation aspects. The previous research reveals that the development of coffee production in the upstream area of Sekampung watersheds can be continued by applying conservation principals (Banuwa et al., 2008). Practically, coffee farming in an upper Sekampung plant with shade trees as a coffee agroforestry system (Arifin et al., 2014). Cash crops with agroforestry system well known as multi-strata or complex agroforestry and simple ones (Hairiah, 2010; Suprayogo et al., 2010).

Cash crop with an agroforestry system provides environmental services revealed by several studies. Agroforestry ensures the continued provision of multiple ecosystem services (Cerdaa et al., 2016), providing carbon stock and the most wildlife biodiversity (Wibawa, et al., 2010); (Megantara & Parikesit, 2015). Agroforestry has the highest diversity of indigenous trees from productive systems (Noponen et al., 2013), (Mendoza & Vosti, 2007); (Haggar et al., 2015). Multi-strata coffee provides better availability of environmental services through water and soil (Suyamto & Noordwijk, 2004); (K. Hairiah, 1995).

The establishment of the environmental provision of upstream Sekampung watershed is a crucial part to ensure the sustainable practices. However, the management of the watershed system faces a complicated problem, ranging from the high cost of externalities, natural resources subtraction, and also the common pool resources right management (Fitrian et al., 2018b; Fitriani & Kuswadi, 2021; Kerr, 2007; Kuswadi & Fitriani, 2021). Integrated agroforestry scheme in the collective design and its implementation need considered by farmers, scientists, agricultural extensions agents, and policymakers (Sharma, & Singh, 2016). The principle of sustainable production is related to rights and responsibilities, transaction costs, perceptions, preferences and motivations (Fitriani et al., 2022; Fitriani & Kuswadi, 2021). The strong motivation of farmers to carry out sustainable production is the cornerstone of the sustainability of the watershed services (Fitriani, 2022). There is no adequate interconnection linked information among stakeholders in upstream Sekampung. How the institutional interconnection among all actors designed? What the main driving power element that runs the institutional setting? Then, this study focuses on identifying all actors in the Sekampung watershed, tracing the existing conditions of agro-ecosystems by coffee farmer, and institutional settings to fulfill the requirements for the provision of environmental services in the PES scheme perspective.

2.2. Methods

2.2.1. Survey design

Research location is on the Upstream Sekampung watersheds site. It located in Air Naningan sub-district, Tanggamus Region, Lampung, Indonesia. Two villages selected Datar Lebuay and Sinar Jawa village. The coverage of the upstream Sekampung watersheds area is under jurisdiction of

Batutegi Forest Management Office (FMO). The respondent selected amount of 400 farmers randomly. Figure-1 described the site location.

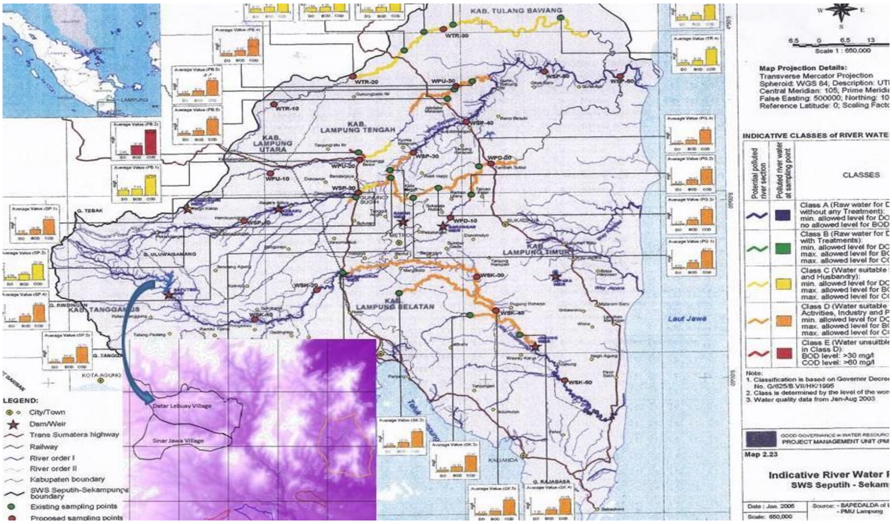

Figure1. Research site location in Datar Lebuay and Sinar Jawa Upstream Sekampung Watersheds, Air Naningan sub-district, Tanggamus, Lampung, Indonesia (BP-DAS Way Seputih-Way Sekampung, 2012)

1.2.2. Data analysis

Data exploration was trough by a closed questionnaire set. A questionnaire designed to investigates the watersheds stake holder involved, institutional, the element need, and interconnection between. Interconnection between element in system run with Interpretive Structural Modeling (ISM). ISM approach is well-known to describe interrelation among various elements that stakeholders in institution set involved. Then depth analysis in synthesizing the kind of opportunity of PES development in upstream Sekampung watershed developed. ISM is deriving the driver-power ranks of the sub-elements from the reachability matrix as an improvement in studying the hierarchy of sub-elements (Saxena, et al., 1992). ISM step start from a structural self-interaction matrix (SSIM) built on pairwise comparison of variables based. SSIM converted into a reachability matrix (RM) and its transitivity is checked (Attri, Dev, & Sharma, 2013; Sukwika, 2018; Surya & Sapei, 2018). The element list at Table 1.

Table1. The element based on PES scheme perspective

Code	Need Element
A1	Realistic Effectively mitigates, reduce or avoids threats to ES for all parties involved (Scoping stage)
A2	Voluntary (stakeholders analysis) Engagement involves choice rather than being the object of regulation
A3	Conditional (Negotiation & implementation) Services and rewards or compensation are dynamically linked
A4	Pro-poor (All stage) Mechanisms selected are positively biased towards disadvantage stakeholders
A5	Quantity and quality performance of ecological services
A6	Dealing activities (Negotiation & implementation)
A7	Similarity goal, criteria, and the plan
A8	Farmer's income generating
A9	Skilled Forest Officer
A10	DAS stakeholders participation
A11	Legal jurisdiction (land and institution)
A12	Intermediary (University, NGO, Government)

Sources: compilation based PES requirement (Leimona, et al., 2018; Meine et al., 2004; B. M. Swallow et al., 2009; B. M. B. Swallow, et al., 2007; Villamor & van Noordwijk, 2011 Wunder 2008)

Table 2. A structural self-interaction matrix (SSIM)

Code	Element	12	11	10	9	8	7	6	5	4	3	2	1
A1	Realistic	A	A	A	A	V	A	V	X	A	X	X	
A2	Voluntary	A	A	A	A	V	A	V	X	A	X		
A3	Conditional	A	A	A	A	V	A	V	X	X			
A4	Pro-poor	A	A	A	A	V	A	A	X				
A5	Performance of ES	A	A	A	A	A	A	X					
A6	Negotiation implementation	A	A	A	A	A	X						
A7	Similarity goal and the plan	A	A	A	A	X							
A8	Farmers' income generating	O	A	A	O								
A9	Skilled Forest Officer	O	O	O									
A10	Stakeholders participation	A	O										
A11	Legal jurisdiction	V											
A12	Intermediary (Univ, NGO, Gov)												

V indicates i variable that influence j variable

A indicates j variable that influence i variable

X indicates i variable that influence j variable in vise versa

O indicates i variable and j variable not related

2.3. Result and Discussion

2.3.1. Land Right Management

Farmer in upstream Sekampung gets used to with the term of environmental services. They realized that the agricultural production activity at upstream Sekampung must aware toward the preventive and rehabilitative action to secure the land ability. The willingness to environmental services provision by coffee farmers at upstream Sekampung watersheds was displayed at (Table3). Almost all respondent at difference land tenure were well-willingness to approve agroforestry program and so the commodities certification. Most of the respondent (74.75%) was well-willingness in supporting the Sekampung environmental service program. Farmer’s holding forest management right (Community Based Forest Manajemen or locally called HKm (Hutan Kemasyarakatan)) and private both indicate the interesting to approve the program.

The respondent’s willingness to provide the environmental services was attainted to 67.75%. Although the private showed lower rate compare with others. Tt could be explained as consequences for institutional land tenure establishment still need to be accomplished. But overall, it could be concluded that this fact revealed the well-awareness of a farmer in supporting the sustainable production in upstream watersheds. This finding relevant with the previous research carried out by Prasmatiwi et.al (2011) in West Lampung which identified the willingness to pay (WTP) for ecological service concluded that the coffee farmers accept the obligation to minimize forest destruction. They will adopt Good Agro-forestry Practices (GAP) to conserve land, add the shade trees, environment tax, and replant plant woods. This fact will be important to set the next stage in PES development.

2.3.2. PES (payment for environemental services) institutional set-up

The identification of the opportunity of PES (payment for environemental services) was developed based on conditional level as one of the principals of PES scheme implementation displayed at Table4. The basis way to meet four principles developed by (Wunder, 2008): Realistic, Conditional, Voluntary and Pro-poor. The principals are a focus on ‘assets’ (natural + human + social capital) that can be expected to provide future flows of environmental services. The effects of PES from some ex ante judgments reveal that there is a good reason to continue experimental PES implementation for purposes of consolidating our knowledge (Wunder, 2006). The three ‘paradigms’ distinguish analysis the compensation and rewards (including payments) for environmental services. There is CES (commoditized environmental services), COS (compensating for opportunities skipped) and CIS (co-investment in (landscape) stewardship) paradigm (M Van Noordwijk & Leimona, 2010).

The primary difference between three paradigm of PES: CES, COS, and CIS is the way in which conditionality is achieved and the scale (individual, household, or community) in which the voluntary principle takes shape. CIS has the biggest opportunity to be ‘pro-poor’, as both CES and COS presuppose property rights that the rural poor often don’t have (Meine van Noordwijk & Leimona, 2010). CES, equivalent to a strict definition of PES, may represent an abstraction rather than a current reality. COS is a challenge when the legality of opportunities to reduce environmental services is contested. The willingness of environmental services provision by farmer digging by collecting the farmre’s respons on their willingness to support, join, and implement the environmental services provision. Table 3 displayed the farmer’s acknowledgment on participation in environmental services provision.

Table 3. The willingness of environmental services provision by farmer

		Land_Tenure			
		Private	HKm	non-HKm	Total
AF program willingness	Yes	17.5	51	30.25	98.75
	No	0.25	0	1	1.25
Certification commodities willingness	Yes	17.5	48.5	29.25	95.25
	No	0.25	2.5	2	4.75
Environmental Services willingness to Watersheds	Yes	14.5	39.75	20.5	74.75
	No	3.25	11.25	10.75	25.25
Environmental Services Provider willingness	Yes	13	37	17.75	67.75
	No	4.75	14	13.5	32.25

HKm (Hutan Kemasyarakatan=Community Based Forest Management)

Most of the farmers (>90%) are positive about joining the agroforestry and commodity certification programs. Meanwhile, farmers who are ready to participate in the Environmental Services and Become Environmental Services Provider were in the range of 64-74%. Some farmers (26-35%) are still not interested in joining. This shows that there are still farmer members who have different views and have not communally agreed in providing environmental sustainability services. Various efforts to build farmer institutions can ensure close interpersonal relationships within groups enabling intense information inclusion and realizing agreed institutional goals.

Based on this term the scheme of paradigms PES scheme of environmental services in upstream Sekampung watersheds set Table4 and Table5. Table4 informed the opportunity to develop PES scheme based on conditional level fulfillment. The strongest opportunity to developed was CIS first, the next COS, and then CES (Table5). CIS is the first step in PES development (Swallow, et.al., 2010), (Pasha, et.al., 2010), (B. M. Swallow et al., 2009). CIS was more flexible to improve the upstream Sekampung watersheds with trust bond within stakeholders. The arrangement has been setting by Batutegi FMO and the HKm (CBFM) or farmer group association. It performed as good manageable and well established on recovery the vegetation diversity due to minimized critical land and deforestation. FMO as the government presented is a regulator in pushing the sustainability fulfillment of cash crop cultivation on the state land (protection forest). The delivery of authority on forest land from state to society to manage the sustainable cultivation is important legalization. PES and conservation arrangements are an exchange of property rights (Zhang, 2017). The inclusion of indigenous peoples' capabilities and socio-cultural values are critical for ES assessments. Approach integration is essential for appropriately informing local, regional and global development policies (Kaur & Russell-smith, 2017) (Faosiy & Daud, 2015).

Development of COS scheme on upstream Sekampung has the open opportunity as next step after the CIS well established. COS as compensation and reward for environmental services has mechanisms: (1) localized scarcity for particular environmental services, (2) influence from international environmental agreements and international organizations, (3) government policies and public attitudes favoring a mixture of regulatory and market-based instruments, and (4) security of individual and group property rights (B. M. Swallow et al., 2010).

Currently, the situation on upstream Sekampung described that the vegetation coverage of coffee agroforestry system becomes an environmental service. The second condition could be fulfilled by coffee certification scheme which is promoting intensively on site location, especially for private and CBFM land tenure. Some of the coffee certification as global private regulation has presented at site location, such as 4C, Rainforest Alliance, and Organic (Ibnu, Glasbergen, Offermans, & Arifin, 2015).

Table4. Development the Environmental Services (ES) Prototype at Upper Sekampung Watersheds based the ES principles

Principles	Upstream Sekampung Watersheds Environmental Services (ES) Prototype					
	Carbon stock: Protecting soil and tree stocks	Water consumption1: Total water yield for irrigated paddy farm	Water consumption2: Total water yield for hydro power	Water rehabilitation: General watersheds rehabilitation and erosion control	Eco-label: (eco-certification) Guaranteeing production landscape meet environmental standard	Ecotourism: Providing guided access to landscapes of beauty/recreational value/heritage
Realistic Effectively mitigates, reduce or avoids threats to ES for all parties involved (Scoping stage)	Road construction (accessibility) is the main determinant of 'opportunity' for non-conservation **Fact:** Possibilities of substantial international payments for results achieved.	Sedimentation on reservoir impacts to total water yield. Lateral flows affecting the irrigated area of paddy farm **Fact:** 9 million m^3 debit capacity of Batutegi DAM Debit outflow 2-2.5 thousand $lt.sec^{-1}$ Irrigated paddy farmer (66 thousand ha)	Sedimentation on reservoir impacts to total water yield. Lateral flows affecting the hydro power operation **Fact:** Erosion rate 67,5 $ton.ha^{-1}.year^{-1}$ > 38,7 $ton.ha^{-1}.year^{-1}$ (Nippon Koei, 2003 in Banuwa, et.al., (2008) Batu Tegi Dam supplies 22 the electricity power with the capacity 28 MW Argoguruh station capacity 125.2 $gigawatt.year^{-1}$	CAF is a kind of promoting tree cover and permanence of litter layer protecting the soil as a good precaution. **Fact:** Well-practiced Coffee Agroforestry (CAF) (>90% CAF form)	Coffee certification as non-state regulation is come up from the consumer side. **Fact:** Coffee certification awareness. Some coffee farmer groups accomplished coffee certification. 4C, Rain Forest Alliance, Organic, Utz certified, and also a local certification scheme (Inofice)	The local and international appreciation of landscapes beauty depends on culture and time. **Fact:** Beautiful scenery of Batu Tegi Dam, Best-practiced CAF and coffee certification in beautiful hill landscape also the local wisdom be valuable ecotourism destination. Easier access to the site (1.5 hours from Bandar Lampung).
Voluntary	Demand is for	Enhancement	Hydro power plant	"Holistic"	Consumers awareness	The appreciation

(stakeholders analysis) Engagement involves choice rather than being the object of reglation	certified emission reduction (CER) rather than carbon **Fact:** Stakeholders linked: Land tenure holders Batu Tegi FMO Local government Intermediary institution	irrigated area for paddy farm is important to food security **Fact:** Stakeholders linked: Coffee farmer groups Land tenure holders Batu Tegi FMO Farmer group in downstream Local government Intermediary institution	needs to accomplish consumer satisfaction. **Fact:** Stakeholders linked: Coffee farmer groups Land tenure holders Batu Tegi Power Electricity Consumers of Power Electricity Intermediary institution Local government	perception of watersheds function **Fact:** Stakeholders linked: Coffee farmer groups Batu Tegi FMO Farmer group Batu Tegi Power Electricity and Consumers Intermediary Local Government	of sustainable coffee production **Fact:** Stakeholders linked: Coffee farmer groups Land tenure holders Batu Tegi FMO NGO-certification roles Coffee exporter Intermediary institution Local government	of landscapes beauty and cultural traditions to provide potential tourists. **Fact:** Stakeholders linked: Coffee farmer groups Land tenure holders Batu Tegi FMO NGO-certification roles Coffee exporter, Intermediary
Conditional (Negotiation & implementation) Services and rewards or compensation are dynamically linked	Forest definition and additionally issues in A/R-CDM; high transaction cost REDD debate focus on partial C accounting	Sedimentation caused by the geological and geomorphological. Irrigation facilities maintenance Collective action in rehabilitation & sedimentation reduction	Intercepting sediment flows is generally easier to accomplish. Sedimentation process. Conducting collective action in rehabilitation & sedimentation reduction	Communication gap with a scientist who tries to enhance clarity Planting and maintaining a specified number of trees with the certain competition of species.	The relevance of global standard met the local condition. Need transparency and compliance monitoring. Certification as a tool to promote sustainability. All farmers prefer certification schemes as tangible economic benefits.	Global ecotourism is a highly volatile market where security and political concern can interfere
Fact:	The government	Minister of Public	Minister of Public	Governor of	The arrangement has	Valuations

Institutional setting policy	policy 7 principles REDD+ Safeguards (Cancun Agreement-COP 16, Decision 1/CP16) Valuations Guidance Government Regulation Nu. 46 The year 2017 about Environmental Economic Instruments	Works Decree o. 592 / KPTS / M / 2010 on the Water Resources Management Pattern of the Seputih-Sekampung River Region Minister of Environmental Regulation Nu. 15 2012 about Forest Ecosystem Economic Valuations Guidance Government Regulation Number 46 the Year 2017	Works Decree o. 592 / KPTS / M / 2010 on the Water Resources Management Pattern of the Seputih-Sekampung River Region Minister of Environmental Regulation Number 15 the Year 2012 about Forest Ecosystem Economic Valuations Guidance Government Regulation Number 46 the Year 2017 about Environmental Economic Instruments	Lampung decree No 52 of 2016 as a guideline for utilizing of production on forest area Valuations Guidance Government Regulation Number 46 the Year 2017 about Environmental Economic Instruments The arrangement has been setting by Batutegi FMO and the land tenure holders.	been setting by certification's vendor with farmer groups. Monitored and assessment by international sustainable standard	Guidance Government Regulation Number 46 the Year 2017 about Environmental Economic Instruments Regional Regulation Of Tanggamus District Number: 16 Plan of Space Region Tanggamus District Year 2011-2031 Governor of Lampung decree No 52 of 2016 as a guideline for utilizing of production on forest area with partnership and cooperation.
Pro-poor (All stage) Mechanisms		Rural poor may have appropriate 'in kind' reward to	Rural poor may have not accessed to electricity and 'in	Enhanced local environmental services may be a	Enhanced local environmental services may be a major 'co-	Enhancement of skills needed for rural poor to have

selected are positively biased towards disadvantage stakeholders		practice sustainable CAF **Fact:** 2.705 households in the pre prosperous family categories Air Naningan sub district	kind' reward may be appropriate **Fact:** 2.705 households in the pre prosperous family categories in Air Naningan sub district	major 'co-benefit' of specific relevance to rural poor **Fact:** 2.705 households in the pre prosperous family categories	benefit' of specific relevance to rural poor **Fact:** 2.705 households in the pre prosperous family categories in Air Naningan sub district	a chance to benefit **Fact:** 2.705 households in the pre prosperous family categories in Air Naningan sub district

Table5. The scheme of paradigms PES development at the upper Sekampung watershed

Conditional level	CES (*Commoditized Environmental Services)*	COS *(Compensating for Opportunities Skipped)*	CIS (*Co-investment in landscape stewardship*)	Principals
	I, IV	III (or less often at level 2, 4)	II dan III	
I. Quantity and quality performance of ecological services	Commoditized ES procurement with conditionality at the level I based on actual service delivery and direct marketability. The price level recurrent monetary payment may be fully negotiable and provides news sources of income. There is no explicit poverty target. Services and rewards are dynamically linked	COS is focused on relations 2 and 3, within current "right to pollute; it adds human capital (opportunity to reduce/enhance ES Minimum debit of water Water storage management Sedimentation Minimum erosion	CIS generally has conditionality at level 3 (or less often at level 2 or 4). Mostly on collectively own or state-owned land can include negotiated tenure conditional on ES maintenance. The conditionality level 4 (entrust local resources management	**Realistic:** Water supply availability **Voluntary:** (stakeholders analysis) Engagement involves choice rather than being the object of regulation Parties mandatory
II.Agro ecosystem condition	CES is focused on interaction 4, or 1+5, that directly links providers and beneficiaries of ES beneficiary. Conducting collective action in	Planting and maintaining a specified number of trees with the certain competition of species Planting and maintaining coffee with minimum complex agroforestry trees (200-400)	Planting and maintaining a specified number of trees with the certain competition of species (vegetation coverage) Setting up a management	Realistic CAF provides ES in upper Sekampung watersheds Coffee certification applied an

Conditional level	CES (*Commoditized Environmental Services)*	COS *(Compensating for Opportunities Skipped)*	CIS (*Co-investment in landscape stewardship*)	Principals
	I, IV	III (or less often at level 2, 4)	II dan III	
	rehabilitation and sedimentation reduction to achieve a specified percentage (above 30%) of erosion reduction	Setting up a management plan to rehab watersheds	plan to watersheds rehabilitation Well-Coffee Agroforestry practiced Conservation principals	Institutional set of stakeholders Parties Voluntary Pro-poor
III.Dealing activities (Negotiation & implementation)	ES Provider ES Beneficiary Clearly agreement between provider and beneficiary of ES with the strong governance of institutional set Role of the transaction (transaction set) Mandatory ES policy	Agroforestry accomplishment Coffee certification applied an Institutional set of stakeholders Transaction set Hydroelectric Power (HEP) company royalty agreements signed for River Care groups along the river	CAF provides ES in upstream Coffee certification scheme Beneficiary: Hydroelectric Power (HEP) company royalty agreements Local water company Farmer groups in downstream	Realistic: CAF provides ES in upper Sekampung watersheds Parties Voluntary Pro-poor
IV. Similarity goal, criteria, and the plan	ES rewards agreement strike balance between outcome-based reward, activity-centered incentive, support for community-scale resource management and the establishment of trust. Management plant of CAF in general, including specified agricultural technic Institutional setting (regulation)	Clearly agreement between provider and beneficiary WTA in upper stream vs WTP in down stream Transaction set (TC of implementing the rewards is US$ 55 per household (Arifin, Swallow, Suyanto, & Coe, 2009)). Institutional setting (regulation)	Clearly agreement between provider and beneficiary WTA in upper stream vs WTP in down stream Transaction set (TC the rewards is US$ 55 per household (Arifin et al., 2009)). Institutional setting (regulation)	Realistic: CAF provides ES in upper Sekampung watersheds Parties voluntary or mandatory
Prototype upper	Carbon stock: Protecting soil	Water consumption1 to paddy farm	Water rehabilitation	

Conditional level	CES (*Commoditized Environmental Services)*	COS *(Compensating for Opportunities Skipped)*	CIS (*Co-investment in landscape stewardship*)	Principals
	I, IV	III (or less often at level 2, 4)	II dan III	
Sekampung ES	and tree stocks Carbon market initial agreement	Water consumption to hydro power Ecotourism	Eco-label: (eco-certification)	

Sources: adopted of paradigms PES by (M Van Noordwijk & Leimona, 2010)

The commoditazed environmental issues become mainstream on the agricultural global market (Musa, et.al., 2010). The government policies and regulatory market-based instruments represented by Regulation of the State Minister of Environment Nu. 15 of 2012 and Governor of Lampung decree No 52 of 2016 as a guideline for utilizing of production on forest area with partnership and cooperation. COS development also promising as PES scheme initiation at upstream Sekampung.

While to develop the CES scheme it will require more condition and transparency within provider and beneficiary. There must be clearance and certainty on the supply of environmental services which is providing by the provider. The demand side also has set the ability of the beneficiary to consume the environmental services. The marketable of environmental services need the clearance and countable environmental services. It needs more comprehension and deeply analyzes and synthesized to explore the opportunity in CES development on site location. Current information about this information does not ready yet. The future stage of research related these issues will be important. Based the PES opportunity set at Table 5, can be identify the stakeholders in upstream Sekampung watersheds linked with beneficiary in the middle and downstream. The stakeholders linked between coffee farmer groups, land tenure holders, Batu Tegi FMO, NGO-certification in upstream and beneficiary in downstream it could be Hydroelectric Power (HEP) company, local water company, farmer groups in downstream farmers group, and intermediary involved university, local government, NGO global corporation/exporter.

2.3.3. Interpretive Structural Modeling (ISM) the driver-power ranks of PES

Interpretive Structural Modeling (ISM) used as tool to derive the driver-power ranks of the sub-elements of the basic requirement of PES scheme. It also derives the dependence level between elements. It involved twelve elements, i.e. (A1) Realistic Effectively mitigates, reduce or avoids threats to ES for all parties involved (Scoping stage); (A2) Voluntary (stakeholders analysis) Engagement involves choice rather than being the object of regulation; (A3) Conditional (Negotiation & implementation) Services and rewards or compensation are dynamically linked; (A4) Pro-poor (All stage) Mechanisms selected are positively biased towards disadvantage stakeholders; (A5) Quantity and quality performance of ecological services; (A6) Dealing activities (Negotiation &

implementation); (A7) Similarity goal, criteria, and the plan; (A8) Farmer's income generating; (A9) Skilled Forest Officer; (A10) DAS stakeholders participation; (A11) Legal jurisdiction (land and institution) and (A12) Intermediary (University, NGO, Government).

First step in ISM is arrangement a structural self-interaction matrix (SSIM) on pairwise comparison of variables based, then converted into a reachability matrix (RM), after that checked its transitivity. A structural self-interaction matrix (SSIM) of PES element was list at Table 6. The correction of a structural self-interaction matrix (SSIM) of PES element was list at Table 7.

Table 6. Structural self-interaction matrix (SSIM) converted to reachability matrix (RM)

Code	Elemen kebutuhan	12	11	10	9	8	7	6	5	4	3	2	1	Driving Power
A1	Realistic	1	1	1	1	0	1	0	1	1	1	1		9
A2	Voluntary	1	1	1	1	0	1	0	1	1	1			8
A3	Conditional	1	1	1	1	0	1	0	1	1				7
A4	Pro-poor	1	1	1	1	0	1	1	1					7
A5	Performance of ES	1	1	1	1	1	1	1						7
A6	Negotiation implementation	1	1	1	1	1	1							9
A7	Similarity goal and the plan	1	1	1	1	1								5
A8	Farmers' income generating	0	1	1	0									6
A9	Skilled Forest Officer	0	0	0										1
A10	Stakeholders' participation	1	0											3
A11	Legal jurisdiction	0												3
A12	Intermediary (Univ, NGO, Gov)													3
	Dependence Level	8	8	8	7	3	6	2	4	3	2	1	0	

Table 7. Converted to reachability matrix (RM) correction

	12	11	10	9	8	7	6	5	4	3	2	1	DP	R
A1	1	1	1	1	0	1	0	1	1	1	1		9	1
A2	1	1	1	1	0	1	0	1	1	1		0	8	2
A3	1	1	1	1	0	1	0	1	1		0	0	7	3
A4	1	1	1	1	0	1	1	1		0	0	0	7	3
A5	1	1	1	1	1	1	1		0	0	0	0	7	3
A6	1	1	1	1	1	1		0	0	1	1	1	9	1
A7	1	1	1	1	1		0	0	0	0	0	0	5	5
A8	0	1	1	0		0	0	0	1	1	1	1	6	4
A9	0	0	0		1	0	0	0	0	0	0	0	1	7
A10	1	0		1	1	0	0	0	0	0	0	0	3	6
A11	0		1	1	0	0	1	0	0	0	0	0	3	6
A12		1	0	1	1	0	0	0	0	0	0	0	3	6
D	8	9	9	10	6	6	3	4	4	4	3	2		
L	3	2	2	1	4	4	6	5	5	5	6	7		

Table 8. Rank of driving power and dependence level

Rank	Driver Power	Level	Dependence Level
1	Realistic	1	Skilled Forest Officer
1	Negotiation & implementation	2	Legal jurisdiction (land and institution)
2	Voluntary	2	Stakeholders’ participation
3	Pro-poor	3	Intermediary (University, NGO, Gov)
3	Performance of ES	4	Farmers’ income generating
4	Farmers’ income generating	4	Similarity goal, and the plan
5	Similarity goal, and the plan	5	Performance of ES
6	Stakeholders’ participation	5	Pro-poor
6	Legal jurisdiction (land and institution)	5	Negotiation & implementation
6	Intermediary (Univ, NGO, Government)	6	Voluntary
7	Skilled Forest Officer	6	Negotiation & implementation

Based on the Table 8, the results show that the driver power element of PES requirement was (A1) Realistic effectively mitigates, reduce or avoids threats to ES for all parties involved (Scoping stage) and (A3) Conditional (Negotiation & implementation). In other side, the high level dependence element was skilled forest officer (A9) land jurisdiction (A10), and Stakeholders participation (A11), then intermediary presence (A12). Services and rewards or compensation are dynamically linked stakeholders in upstream Sekampung watersheds. The main driving power element that runs the institutional setting of the provision of environmental services is the realization of a program that effectively mitigates, reduces or avoids scoping stages; Dealing activities (negotiation & implementation); and Voluntary (stakeholders analysis); The dependence element that needs to be prepared is the improvement of human resource skills, legal jurisdiction (land and institution), participation of stakeholders, and the presence of intermediaries (universities, NGOs, government).

The awareness of coffee farmers in providing the environmental services was sufficient as an initial set to build the opportunities on PES scheme. This finding becomes primary information to set the long term participation of coffee society in providing upper Sekampung environmental services. Base on the identification the opportunities on PES development revealed that the strongest opportunity to developed PES was CIS scheme, the next was COS, and then CES scheme. Meanwhile the most suitable scheme to become the start of Sekampung watershed service by coffee farmers is the CIS (Co-investment in landscape stewardship) scheme.

The CIS scheme requires certainty of the agro ecosystem condition of coffee farming with agroforestry with contract preparation guaranteeing the ability to meet the environmental service prerequisites

2.3. Conclusion

The main driving power element that runs the institutional setting of the provision of environmental services is the realization of a program that effectively mitigates, reduces or avoids scoping stages; Dealing activities (negotiation & implementation); and Voluntary (stakeholders analysis); The dependence element that needs to be prepared is the improvement of human resource skills, legal jurisdiction (land and institution), participation of stakeholders, and the presence of intermediaries (universities, NGOs, government).

Meanwhile the most suitable scheme to become the start of Sekampung watershed service by coffee farmers is the CIS (Co-investment in landscape stewardship) scheme. The CIS scheme requires certainty of the agro ecosystem condition of coffee farming with agroforestry with contract preparation guaranteeing the ability to meet the environmental service prerequisites.

2.4. Recommendation

However, this study has a limited scope of analysis, which is only focused on the activities of coffee producer farmers as a service provider of the Sekampung watershed. In other words, this research information only describes the supply side (supply side) of environmental services by coffee farmers as producers and providers of environmental services (providers). Testing the work of the environmental services market scheme requires an analysis of the demand side (beneficiary) of the Sekampung watershed service users.

Therefore, the next important research stage is the search for the WTP demand side (willingness to pay) in the Sekampung watershed community in the middle and downstream. The work of payment for environmental services schemes can only take place if the parties who have services and service users meet to agree to exchange the prerequisites for developing an environmental services market mechanism.

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CHAPTER 3

FACTORS INFLUENCING THE DYNAMICS OF TOMATO CROP: A REVIEW

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3.1. Introduction

The vegetable crop known as the tomato (Lycopersicum esculentum Mill) is said to have its roots in the Andean area of South America. It is a member of the Solanaceae family. In terms of acreage, tomato is second only to potatoes among the major vegetable crops farmed worldwide, but it ranks first among crops used for processing. The current state of the world places a high priority on the adoption of organic agricultural methods for proper food production. (Pinho et al., 2011). Tomato farming has expanded significantly as a result of the crop's rise in popularity over the past 50 years. Its productivity has improved significantly over the past several years by roughly 10% as a result of the fact that it is an important source of vitamins and minerals for many countries. Additionally, it has just come to light that it is a significant source of lycopene, a carotenoid with antioxidant characteristics that may help prevent diseases like cancer and cardiovascular disease. (Bertin & Génard, 2018). In terms of output and planted area, tomatoes are the most important produce in Egypt (approximately 252 thousand hectares) (10.3 million tons). Due to its ease of cultivation and the genetic consistency that results from autogamy, tomatoes are good plant materials for physiological and cytological studies (Tomato, 2020).

A number of methods have been employed to examine how environmental factors affect the development of tomato crops. As land use changes, particularly the conversion of unproductive land to arable land, promote processes like the global carbon cycle that are linked to changes in climate conditions, and climate change influences the evolution of agricultural landscapes. It was discovered that there is a strong relationship between climate and the variability of biophysical processes in agricultural productivity (Ardabili et al., 2013).

The production of food for humans nowadays depends more and more on the greenhouse cultivation of vegetables. It now makes up a significant portion of the farming machinery used to produce the majority of the world's vegetables. Many modern greenhouses are now using intelligent control mechanisms to fully automate the regulation of ventilation, supplemental lighting, and sunshades in order to simultaneously boost greenhouse productivity and save energy. (Das et al., 2020). To determine how best to implement a management strategy, a sophisticated control system routinely collects data on the greenhouse environment and crop growth status. The former relies on live photos and real-time recordings of crops, while the latter transmits data from scattered sensors that measure temperature, light intensity, carbon dioxide concentration, and humidity (Guerreiro et al., 2016). The digitization and visualization of greenhouse plants has become a top priority in agricultural facilities as a result of the quick development of modern greenhouses. This work can be quite difficult given the complex surroundings and intricate structure that a crop often possesses, but research has been sparked by new technologies and sensors, making it an intriguing and promising issue among farmers, engineers, and botanists. Fresh foods like fruits and vegetables rich in vitamins and minerals are made possible by greenhouses and indoor growing techniques. The high crop yield per area and great water use efficiency per unit of production that greenhouses offer come at a high energy cost and expensive initial investment. Many nations are increasing their greenhouse output to ensure fresh food is produced locally when possible (Albert, Gricourt, et al., 2016).

The yield of vegetables cultivated in greenhouses and the quality of the fruit both benefit from irrigation and fertilizer. Two key elements influencing crop growth and yield are the management of water and nutrients applied in fertilizers. In fact, adequate water and nutrient levels in the plant root zone, which can increase the absorptive surface area and root capacity, have a significant impact on crop yield and quality (Albert, Segura, et al., 2016). The use of field management techniques that maintain better returns while increasing the efficiency of fertilizer and water consumption has made the sustainable use of water and fertilizer in agriculture a top issue. One of the most significant annual crops grown in solar greenhouses is the tomato, which also has a high water requirement and necessitates irrigation throughout the growing season. However, in regions with limited water supplies, like northwest China, increasing water conservation may be more advantageous than increasing crop productivity (Liu et al., 2018).

A significant environmental factor that severely reduces agricultural productivity is water logging. Heavy rainfall, inadequate irrigation, uneven topography, poor drainage, or a heavy soil texture can all contribute to this. According to estimates, 16% of tomato production regions globally and 13% of the world's land area are at risk of flooding and water depletion. Because it inhibits physiological function, waterlogging has a detrimental effect on the vegetative and reproductive growth of tomato plants. (Chu et al., 2009). Hypoxia in the roots, which is brought on by a lack of oxygen, causes yellowing and death of leaves from the base to the stem, epinasty in tomato leaves, and a decrease in nitrogen levels in the tomato plant's shoots. Seedlings can emerge quickly after waterlogging, avoid leaf chlorosis, and restrict shoot and root growth, dry matter accumulation, and final production (Tewolde et al., 2016).

3.2. Major Assessments

3.2.1 Soilless culture

Experience growing tomatoes without soil using a solid substrate, as is often practiced in the greenhouse, shows that water stress and salinity increase the concentration of sugars and acids in tomato fruits. Under such conditions, plant and fruit growth is reduced. Since the water content of tomato fruit can decrease with water stress, the sugar concentration can increase, resulting in higher fruit quality, but the yield of marketable fruit generally decreases. A slight reduction in water supply can improve fruit quality without reducing marketable fruit yield and consistent with the findings of nitrogen and potash deficiencies. In addition, secondary metabolites, i.e. aroma volatiles, may be increased (Martínez-Ruiz et al., 2019).

Agriculture suffers as a result of climate change. For the purpose of reducing the effect of climate change on crops, we need some alternative technology. Since there is a possibility to produce food close to consumers due to population development in all places, hydroponic technology has become more popular in the developing globe. This system provides the balanced nourishment required for plant growth and development to roots submerged in a nutrient solution, whether or not a dormant medium like mineral wool or coconut fibers is used. The use of hydroponics in agriculture is rising in popularity worldwide. For Bangladesh's coastal and frosty regions, hydroponics is appropriate. Despite the significant benefits of hydroponics, there are still several drawbacks that prevent soilless farming from spreading further in Bangladesh. A number of crops, including lettuce, cherry tomatoes, cucumbers, herbs, and many more kinds of vegetables, have been grown successfully using hydroponics. Faster growth, more yield, simpler handling, better water efficiency, and reduced fertilizer use are its advantages over traditional production systems. Many fruit and vegetable plant can be grown in soilless culture such as on the wall, pot, edge, isle, rooftop (Sundari et al., 2021). Compared to conventional systems, hydroponic crops enable the production of high-quality products. High crop quality and yield, reduced fertilizer costs, effective water use, decreased environmental contamination, and increased control and efficiency of the production process are all advantages of this system (Ali et al., 2021).

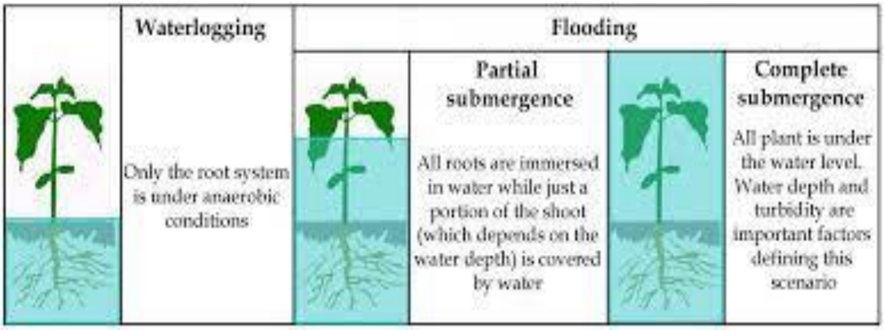
3.2.2. Water stress

To adapt physiologically to harsh settings, tomato plants can control water loss, tissue water potential, and growth in response to abiotic stimuli. Although stress adaptation often slows development and lowers yield, it can sometimes enhance tomato fruit quality. According to reports, salt water irrigation can enhance the sweetness and organic acid content of fresh tomatoes, which will enhance their flavor and flavor (Rosales et al., 2009). Without significantly reducing total production, the controlled level of stress brought on by salt water irrigation is also employed to enhance the quality and flavor of tomato processing. Similar to this, it has been shown that small water deficits can raise the amounts of potassium, hexose, citric acid, and soluble solids in tomatoes.

It has been proposed that one method for raising the quality of tomato fruit and tomato fruit derivatives is controlled exposure to stress. Salinity or water stress decreased fruit output and plant growth (leaves and stems). For all investigated parameters, water stress, however, seemed to be more harmful than salt stress. The amount of fruits produced by each plant decreased, which was the direct result of iminished pollen fertility and flowering inhibition. Both salt and water decreased the leaves' stomatal conductivity. Stomatal closure prevents plant tissue from irreversible wilting, which

Figure 1. Effect of water stress on cherry tomato leaves

Figure 2. A detail view of water stress on cherry tomato leaf



helps to maintain a reasonably high plant water potential in a hyperosmotic environment (Brandt et al., 2003).

Plants of the Solanaceae family like tometoes are vulnerable to water shortages in adolescence.

Figure 3. Water logging impact on plant. (Ezin et al., 2010)

Lack of water in plants is a result of drought. When the amount of water in the soil is insufficient to support plant growth, a drought is present. The term "drought" describes when a plant is not getting enough water from its surroundings. Lack of water in the root zone of plants might make them more susceptible to drought .

As a result of a decrease photosynthetic activity brought on by a lack of water, there will be fewer fruits and flowers. Some plants may limit their length, quantity of seeds, flowering time, and reproductive period as a result of a lack of water or a drought. Drought-affected plants, however, will have less photosynthetic activity. Lower photosynthetic activity will result in fewer fruits and lighter fruits (Nio Song & Banyo, 2011).

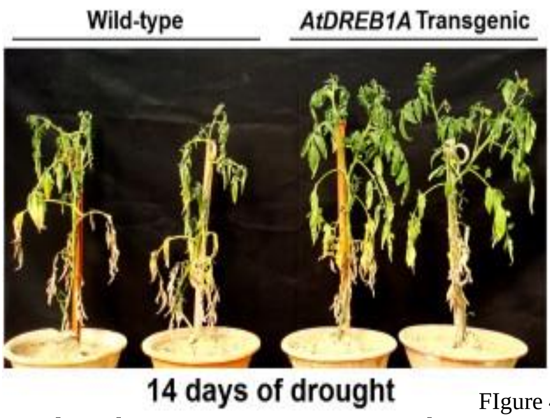


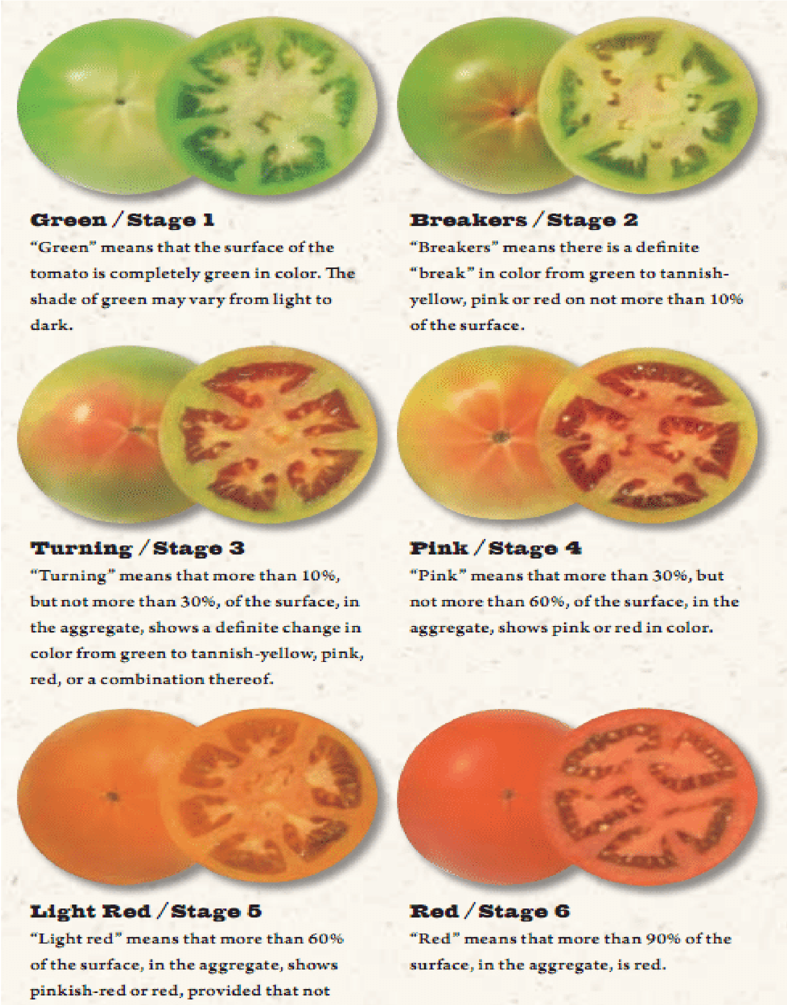
FIgure 4. Effect of drought on vegetative growth of tomato. (Manalu & Rahmawati, 2019)

Mohammed et al. (2018) When tomatoes are first developing vegetatively and later when they are in the reproductive stage, they are extremely vulnerable to drought stress. However, he emphasized that while there is a serious threat of water supplies being depleted, poor management is typically to blame for low water-related agricultural output and is a significant contributor to the growing water shortage. According to this theory, only around 50% of the water that is available is used for agriculture. The best irrigation needs result in effective water resource management to boost agricultural output. Water management techniques are methods that can be used to safeguard our natural water resources and avert circumstances that are essential for the survival and sustainability of agriculture and other economic activities. Despite the fact that the introduction of irrigation has significantly improved both crop productivity and overall agricultural performance.

3.2.3. Flooding

Flooding is a type of environmental stress that significantly reduces crop output and growth. In some places of the world, it has grown to be a major issue. Rain-fed ecosystems frequently experience waterlogging and flooding, particularly in soils with inadequate drainage. In its estimations of the world's farmland acreage and productivity, the Food and Agriculture Organization (FAO) and the International Institute for Applied Statistical Research (IIASAR) take into account pressures like flooding and waterlogging, both of which can significantly lower yields. Flooding can reduce yields by up to 10% and by up to 40% in extreme circumstances. Floods have a detrimental effect on plants' vegetative and reproductive growth because they damage their physiological function (Ezin et al., 2010). Yellowing and decaying leaves, starting with the lower leaves and continuing up the stem, are obvious signs of flooding damage. This chlorosis appears to some part to be caused by a nitrogen deficit, although it frequently appears four to six days after a flood, which is too quickly for this to be the cause. Tomato mid-leaves exhibit epinastic curvature between 24 and 48 hours following soil flooding. Typically, soil flooding has a detrimental impact on plant growth. Inhibition of nitrogen (N) uptake and the resultant redistribution of nitrogen in the shoot in flooded plants results in early withering of leaves and slowed shoot growth. After flooding starts, nitrogen concentrations in plant seedling shoots can drop quickly. This prevents leaf chlorosis, which in turn slows down the growth of the shoots and roots, the accumulation of dry matter, and the final output.

3.2.4. Harvest Ripening Timing



Tomatoes are a very perishable fruit and are subject to large post-harvest losses. However, they are capable of ripening when harvested at an early stage of maturity. Therefore, to extend postharvest time, producers typically harvest shelf-limited tomatoes either at the break stage and allow them to ripen "on the shelf" or at the mature green stage and initiate ripening by exposing them to ethylene-containing atmospheres. In contrast, most modern tomato hybrids produce fruit with a long shelf life after harvest. "Long-life" hybrids have also been developed to allow the harvesting of whole trusses instead of individual fruits. As a result, artificial ripening of early-harvested tomatoes is no longer practiced in many markets, as it also has an adverse effect on the taste and overall quality of the fruit.

However, harvesting tomato fruits with good shelf life at an early stage of maturity can still be valuable for controlling market availability, facilitating postharvest handling, and minimizing mechanical damage and losses (Han & Micallef, 2016).

Figure 5. Ripening stages of cherry tomato. (Aires et al., 2022)

Figure 6. The Ripening Stage of Tomatoes

3.2.5. Post-Harvest losses

Despite the great advantages of tomatoes, post-harvest losses of up to 40% are regarded in most regions of the world as unprofitable or unprofitable. These losses result in low returns for producers, processors, and traders;

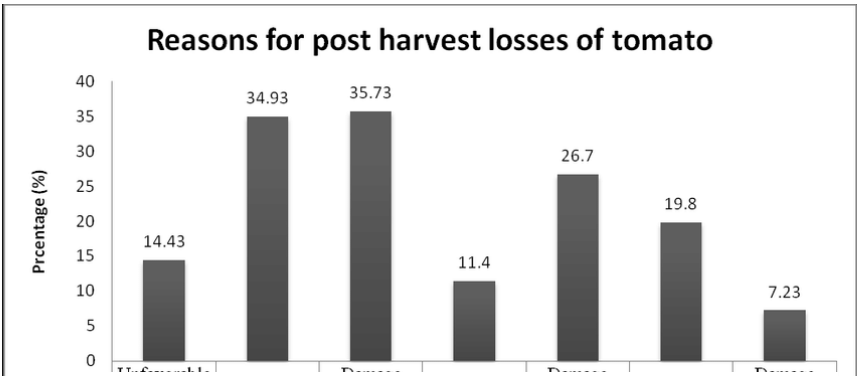


Figure 7. Indicating the ripening growth stages in details. (Aires et al., 2022)

■Series1	14.43	34.93	35.73	11.4	26.7	19.8	7.23

Figure 7. What are the major reasons for post-harvest losses of tomato fruit. (Biais et al., 2014)

(Aires et al., 2022)

ultimately, they will have an impact on the entire nation's level of self-sufficiency and earnings from foreign exchange. Postharvest losses in tomatoes can have a negative impact on a number of factors, including customer acceptance, the fruit's nutritional value, and the producers' ability to make a living. Postharvest losses in tomatoes can also be qualitative.

Determining the elements that may have an impact on the antioxidant content and postharvest quality of tomatoes is crucial. The choice of cultivar, cultural methods, timing and mode of harvest, storage, and handling procedures are all important determinants of tomato quality. Fruits and vegetables that have been harvested retain their freshness due to the interaction of their genetic makeup, physiological makeup, post-harvest physico-chemical activity, and fungal and bacterial species. (Fujisawa et al., 2014). Therefore, it is crucial to understand the pre-harvest elements that might contribute to the production of tomato fruit of the greatest quality. It is also crucial to adopt the right post-harvest handling and treatment techniques to preserve the quality and nutritional makeup of the fruit after harvest (Chen et al., 2014). Even after being harvested, the fruit continues to breathe and transpire as if it were still attached to the mother plant. Fruit senescence is accelerated by the climacteric surge in ethylene, which also enhances tomato fruit flavor. Controlling the concentration and timing of ethylene production is the aim of any postharvest management or treatment in order to ensure that the fruit reaches the consumer in the best possible eating quality (Elia & Conversa, 2012).

3.2.6. Greenhouse Approach

It is crucial to grow crops in greenhouses because they provide an advantage over open pit cultivation by separating the culture from the outside environment. Greenhouses shelter crops from bad weather and regulate variables like temperature, radiation, CO2 concentration, relative humidity, and others to provide nearly ideal microclimatic conditions for crop growth. Vegetable production in greenhouses has significantly expanded in Mexico. The most recent data indicates 12,000 hectares of greenhouses; however, 8,000 hectares of shade nets and macro tunnels are not included. We must consider issues like the effects of excessive use of mineral fertilizers, as well as the increase in their cost and availability in the future, given the current global scenario, which emphasizes the need for gentle agricultural practices for ecologically sustainable food production. New methods are made possible by technological advancements, such crop modeling in a greenhouse. An application of systematic analysis and computer technology called a crop growth simulation model incorporates several fields such crop physiology, ecology, meteorology, and agriculture. Consequently, we can increase our understanding of the system through the use of mathematical models. .

3.2.7. Selection of varieties

Genetic factors may eventually influence their antioxidant capability and how they react to biotic and abiotic stressors. In the past ten years, there has been considerable study on evaluating many kinds and cultivars for selection and identifying optimal genotype for high antioxidant capacity (Ahmad et al., 2011). (Kuti & Konuru, 2005) lycopene concentration ranged from 4.3 to 116.7 mg kg-1 when 40 tomato varieties were tested on a fresh weight basis; cherry tomato varieties had the greatest lycopene content, according to the study.

Nine commercial tomato cultivars made in Spain have lycopene contents ranging from 18.60 to 64.98 mg kg-1 fresh weight, according to their research. Lycopene levels in tomato cultivars with the Crimson gene are typically greater than those in cultivars without the gene (50.86 to 57.86 mg kg-1 fresh weight) (26.22 to 43.18 mg kg-1 fresh weight).

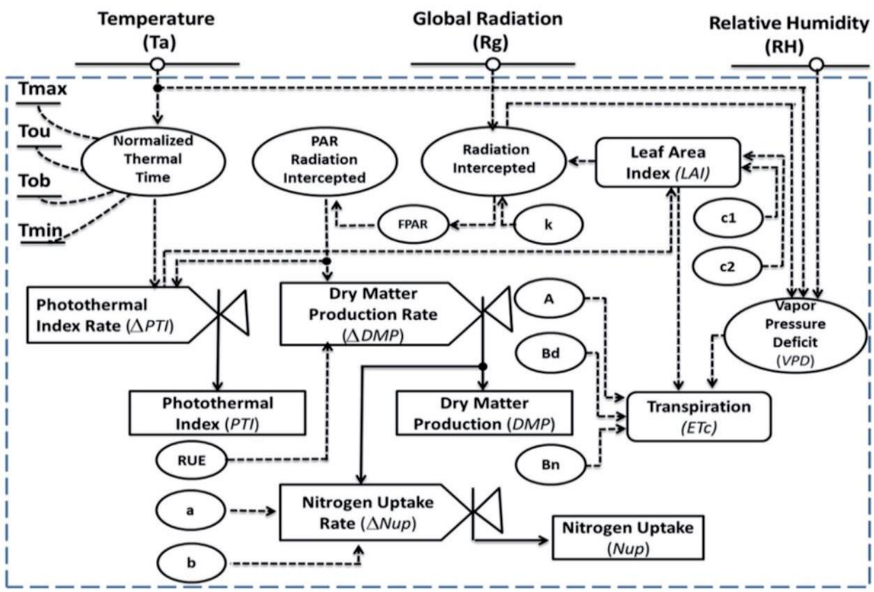


Figure 8. Model for a greenhouse tomato crop: input, output, state variables, and parameters of the crop model (Juárez-Maldonado et al., 2014)

3.3. Temperature

Temperature should be highlighted among the climatic factors that influence tomato cultivation because of its impact on the net rate of assimilation. At temperatures between 18 and 28 °C, growth efficiency is found to be higher. The distribution of photoassimilates between the fruit and the vegetative portion of the plant can also be impacted by temperature. Assimilates are preferred over fruits at high photothermal densities, at the price of vegetative growth. Similar to this, if there is no water deficit, the transfer of water to the fruit rises with temperature. Fruit's ability to absorb water is greatly decreased at temperatures of 15°C or lower. Temperature has an impact on fruit quality-related elements like color, size, and organoleptic qualities as well as cell structures. High temperatures accelerate the development of the fruit and shorten the time needed for its ripening (Shao et al., 2016).

According to reports, the ideal temperature range for lycopene generation is between 12 and 32 °C; however, within this range, the ideal levels depend on the tomato plant's cultivar, variety, and other environmental and growth factors. 20 to 24°C is the optimal temperature range for lycopene production during the day, and 18°C or slightly less at night. A favorable environment for boosting lycopene synthesis is one with a sufficiently high temperature and thick foliage to shield the fruit from direct sunshine. Lycopene production was slowed down at both hot (> 30 °C) and low (12 °C) temperatures (Dumas et al., 2003).

Lycopene production is inhibited by temperatures above 30°C but other carotenoids, which give the fruits their yellow to orange hue, are encouraged. Toor et al. (2006) explains how the summer's high temperatures have a negative impact on the lycopene levels. They also noted that the buildup of lycopene in tomato fruits was negatively impacted by the scorching summers in the Mediterranean region. 40 tomato types were cultivated in greenhouse and field circumstances; cherry tomatoes produced in greenhouses have been found to have decreased lycopene concentration due to temperatures frequently exceeding 32 °C. Lycopene levels in tomatoes can be raised by cooling the greenhouse during the summer months when there is a lot of sunshine.

3.4. Relative humidity (RH)

(Li & Willits, 2008) the recommended humidity range for tomato plants is between 65 and 75 percent at night and 80 to 90 percent during the day. The phrase "vapor pressure deficit," which refers to the difference between saturation and real vapor pressure, has been used to define the relative humidity ranges that have been shown to optimize crop output and quality.

Since it determines the water vapor differences between plant roots and leaves and subsequently the transport of water between these two places, the vapor pressure deficit is the primary factor that regulates plant water absorption. The rate of plant transpiration can be predicted by VPD expressed in kPa regardless of temperature. The rate at which tomato plants absorbed water each hour and each day was significantly impacted by VPD. The hourly rate of water uptake increased by 35 to 50% when VPD was the only controlled variable. Crop yield improved when water consumption was increased by up to 800 cc per plant each day. The relative humidity of the air has an impact on the fruit's composition as well (Harel et al., 2014). Due to stomatal closure, extremely low relative humidity (15 to 22%) has an impact on the photosynthetic rate, which reduces plant growth, fruit size, and overall production. High relative humidity reduces transpiration in plants and reduces their ability to absorb nutrients. Using a low pressure misting system, it is possible to achieve average day temperatures of up to 26°C and 70% relative humidity during the day in the Mediterranean. This improves pollen quality and fruit set, which raises tomato yield and quality (Harel et al., 2013).

3.5. Radiation Intensities

Carotenoids exist in plastids of plant cells, are linked to light-harvesting complexes in thylakoid membranes, or are present as semi-crystalline structures produced from plastids. Of the total light radiation that falls on a plant in a greenhouse, about 10% is reflected, 10% is transmitted and about 80% is absorbed; of the absorbed radiation, a small fraction (5%) is used in biological reactions such as photosynthesis, and the largest fraction is dissipated by transpiration or convection. Tomatoes cultivated in greenhouses are less susceptible to environmental influences than tomatoes grown in fields. The amount of soluble sugars and antioxidants present in greenhouse-grown tomatoes can be impacted by seasonal variations in sun exposure. Greenhouse-grown tomatoes absorb significantly less UV light than field-grown tomatoes, their antioxidant levels may vary. (Alfeo et al., 2021). Researchers discovered that exposure to light and water stress enhanced the formation of ascorbic acid in tomato fruit. When plants were moved from shade to sun at the mature green stage, the ascorbic acid concentration in ripe fruit increased by 60%.

Lycopene synthesis, on the other hand, is severely impeded by intense solar radiation, which led researchers to hypothesize that tomato fruit radiation damage may be caused by the general effects of warming on irradiated tissues. Low light levels inhibit the synthesis of pigment, which causes uneven plant coloring. Shaded fruits have a decreased carotenoid content even though the production of carotenoids in mature fruits does not require induction by light (Helaly, 2022).

3.6. Ripening conditions

The common practice is to pick ripe green tomatoes or tomatoes at the break stage and allow them to mature in transportation or at the destination because fully ripe tomatoes cannot withstand the handling necessary to transfer them from the farm to the customer. The fruits are taken when they are still green and ripe, before they become red, and even though they can continue to ripen, they end up with poor eating and nutritional qualities once they are fully ripe. This method, however, can have a negative impact on the flavor and nutritional quality. Whether the fruit ripens on the vine or off the vine, changes in antioxidant activity brought on by ripening are expected to vary. Tomato fruits collected at the fully ripe stage exhibited lower amounts of antioxidants (lycopene, -carotene, and ascorbic acid) than fruits harvested at the ripe green stage and ripened on the vine. Ripening conditions had an impact on both the kinetics of antioxidant buildup and the final content. However, following harvest, tomatoes in the break stage can be allowed to mature in a room environment without losing their marketability or nutritional value (Tilahun et al., 2017).

3.7. Storage environments

The shelf life of tomato fruits is impacted by the blending of various gases when in storage and packaging. While high carbon dioxide levels of more than 5% are thought to be hazardous to tomatoes, an environment with a low oxygen content of 3 to 5% is utilized to inhibit tomato ripening. Uneven ripening and aromas brought on by elevated ethanol and acetaldehyde are signs of low O2 damage. Anaerobic respiration can be harmful to the fruit and result in very low oxygen levels. Surface softening, discoloration, and uneven coloring can all be brought on by carbon dioxide concentrations more than 5%. Over 1% CO2 slows down ethylene's ability to accelerate ripening. For ripe green/ripe and pink/red tomato fruits, the ideal environment to prevent senescence is 3 to 5% oxygen, whereas for carbon dioxide, the ideal atmospheres are 1 to 3% and 1 to 5%, respectively (Artés et al., 2008).

3.8. Conclusion

Research that is efficiently carried out can ultimately save time and money and significantly contribute to the creation of sustainable agriculture that satisfies the world's food needs. This is possible with the use of a model that has been carefully calibrated and evaluated. The portability of models would be improved and the chance of error or misuse decreased by utilizing standard units, generating inputs and outputs, choosing variables, creating suitable documentation, constraints, and software quality assurance procedures. The development and utilization of models as a research tool can assist in identifying knowledge gaps, allowing for more effective and targeted study planning. Management of tomato quality should begin in the field and extend all the way to the end user. Production-related pre-harvest techniques should be carefully considered because they have an impact on post-harvest quality. The ability to produce the greatest quality fruit at harvest, which in turn directly affects post-harvest quality and nutritional composition, can be attributed to management expertise and knowledge of pre-harvest factors affecting tomato fruit quality and antioxidant content. The selection of the cultivar, the growing environment, and the preharvest procedures used during production all affect the postharvest quality status of tomato fruits. It is essential to harvest at the ideal time and under the ideal ripening circumstances for each variety. Tomatoes have a high-water content and are climacteric, which causes them to lose quality soon after harvest and expire quickly. Tomato quality and storability after harvest are influenced by both pre-harvest and post-harvest elements in the growing process. To reduce quality loss, these elements must be well handled, which is a difficult task for tomato growers and processors.

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Brief Curriculum Vitae

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<tr><td></td><td>Dr. Muhammad Rabnawaz Khan. He is now a visiting lecturer at Department of Agronomy UAP, AMK Campus Mardan. Previously he is a visiting lecturer at Agriculture Department, Hazara University Mansehra. He published 19 indexed international journals (Scopus: 5), 3 international proceedings. 1 International book chapter https://www.scopus.com/authid/detail.uri?authorId=57307368300. https://www.researchgate.net/profile/Muhammad-Rabbawaz-Khan.</td></tr>
<tr><td></td><td>Sayed Minhaj Ali Shah, Ph.D. Scholar at Agronomy at The University of Agriculture Peshawar. He published at least five International research articles. He is also working Agronomy Associate at Phillip Morris International Company. minhaj.sayed233@gmail.com</td></tr>
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CHAPTER 4

THE TREND TOWARDS SUPPRESSING MOST TROUBLESOME WEEDS FOR SUSTAINABLE PRODUCTION OF WHEAT

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4.1. Introduction

The global food requirement is increasing with each passing day due to the ever-increasing human population and higher quality of life, which is likely to be 9 billion in 2050. There should be at least 50% increase in agriculture production per unit area before 2050 to feed the global population (Alexandratos & Bruinsma, 2012). It is a huge challenge to increase food production despite the increasing water scarcity and increasing urbanization of fertile land (Kirby et al., 2017). Thus, it is crucial to improve the production of agricultural commodities from the current agricultural area which can be attained by reducing the yield losses on present cultivated land (Ahmad & Kirby, 2018).

Regardless, of the improved varieties and agronomic practices, there is a big disparity between the farmers' yield and the yield potential of that crop with recommended agricultural practices (Subedi & Ma, 2009). Various factors are responsible for the less production per unit area of the wheat crop, such as low-quality seeds, low seeding rate, soil salinization, imbalanced use of fertilizers, improper sowing, irrigation, and waterlogging. However, among these factors, weed infestation plays a critical role in determining the production of wheat ((Iqbal et al., 2017; Rehman et al., 2019). Weeds cause more loss (27%-38%) compared with other limiting factors such as crop varieties, plant nutrition, and plant population density (Subedi & Ma, 2009).

Weeds are concealed foes for major crops, and their severe incursion results in one of the major constraints to getting optimum yield. Weeds are liable for a drastic drop in yield (Ashiq & Aslam, 2014) because they create competition with major crop plants for water, nutrient, and light (Zimdahl, 2007), and has become the most important external biotic factor responsible for low yield if not reasonable managed. Worldwide, crop losses due to weeds are projected as 100 billion dollars (Chauhan, 2020) and 25 billion dollars are used to control the weeds (Swanton et al., 2015). Wild oat (*Avena fatua*), little canary grass (*Phalaris minor*), common Lambs quarters (*Chenopodium album*), and broad-leaved dock (*Rumex dentatus*) are the main weeds of the wheat crop which cause a considerable reduction in growth and yield (Abbas et al., 2017).

Different approaches are used to control the weeds, such as physical, chemical, biological, and integrated measures, but every single method have its pros and cons (Westwood et al., 2018). Mechanical mechanism is the oldest and most effective method to control weeds but results in soil compaction and deterioration. Soil compaction, eutrophication, erosion, and high energy consumption are the most reported drawbacks of mechanical control which can promote the deterioration of environmental resources (Majoro et al., 2020). Similarly, chemical approaches result in herbicidal resistance in weeds, human health disorder, damage to the living community, and contamination of the foodstuff (Blair et al., 2015). The application of biological approaches has gained momentum in recent years. Various biological approaches such as phytophagous insects, pathogens, and plant extracts have been adopted in recent years (Farooq et al., 2013). Whereas, these approaches have limited potential due to their slow mode of action (Petit & Bohan, 2018), quarantine constraints (Culliney et al., 2003), flexible susceptibility of crop plants towards pathogens (Ghorbani et al., 2005), mortification of plant allelochemicals (Scavo et al., 2019), lack of endurance, and diseases development through pathogens due to unavailability of conducive ecological situations (Dagno et al., 2012). Allelopathic bacteria have been investigated for their inhibition characteristics towards plant species by releasing various phytotoxic metabolites in root zone and suppress the growth of weeds. Their presence in the rhizosphere imparts continuous inhibiting stress on weed growth (Kremer, 2006). Allelopathic bacteria can suppress the growth of weeds by releasing phytotoxic metabolites such as cyanide (Zeller et al., 2007), lytic agents, cell wall and cell membrane destroying enzymes (Kremer et al., 2006), antibiotics such as 2,4-Diacetylphloroglucinol and phenazine (C. Bender et al., 1999), and plant growth regulators in excessive amount (Sarwar & Kremer, 1995) which enhance their susceptibility to plant pathogens (Omer et al., 2010). Therefore, we reviewed the important weeds of wheat in Pakistan and the prospects and potential of their control through different approaches which will be helpful for further research.

Wheat and its associated weeds in Pakistan

Wheat (*Triticum aestivum* L.) is the most substantial food crops around the world. It is reported that weed infestation is a serious problem to get optimum yield which causes 20%-30% decline in the wheat yield (Abbas et al., 2004). Weed infestation causes major yield losses to the crops than any other pest (Ali et al., 2017). There are more than 45 species of weeds infecting the growth of wheat crop (Table 1) (Basit et al., 2019). The four most problematic weeds associated with wheat crop in Pakistan are reviewed in the following section.

Table 1. Weeds associated with the wheat crop

Weeds	Reference
Phalaris minor	(Abbas et al., 2017; Hashim et al., 2019; Jabran et al., 2010)
Avena fatua	(Tasawar Abbas et al., 2017; Anwar et al., 2019; Hashim et al., 2019)
Rumex dentatus	(Anwar et al., 2019; Basit et al., 2019; Hashim et al., 2019)
Chenopodium murale	(Tasawar Abbas et al., 2017; Hashim et al., 2019)
Rumex obtusifolius	(Stilmant et al., 2010)
Euphorbia helioscopia	(Anwar et al., 2019)
Chenopodium album, Poa annua, Medicago denticulate Willd	(Basit et al., 2019)
Lolium multiflorum (Lam.)	(Martín & Scursoni, 2018)
Coronopus didymus (L.)	(Basit et al., 2019)

4.2. Wild oat

Figure 1. Wild oat

Wild oat (*Avena fatua*) belongs to the Poaceae family and is known as a notorious awful annual grassy weed all over the world which affects the grain yield of various crops such as wheat, barley, rice, and flax (Figure 1). It can survive in various ecological conditions and decreases mineral nutrient availability to major crops in the field and restricts the optimum grain production (Khan et al., 2006). It is commonly termed “Jangli Jai”. In spring wheat, wild oat causes 20%-76% loss in yield, which depends upon plant density, environmental conditions, cultivar, and other agronomic factors (Maqbool et al., 2020).

It is widely spread over an area of 11 million ha in the USA and results in the loss of trillion of dollars (Evans et al., 1991). It is also found in 24% of barley, lupine, and wheat taken from Western Australia (Martín & Scursoni, 2018). While in Western Canada, the capital spent to control wild oat is more than on any other weeds (Harker et al., 2016). In England, it is the major weed of winter cereals. Wild oat is also one of the major yield-limiting weeds in Argentina. It has been estimated that there is a 20% decrease in wheat production with a wild oat density of 100 plants per square meter (Scursoni et al., 2011). Various factors such as the time of germination of wild oat, crop density, crop specie, fertilization, and the number of seeds produced and returned to the soil affect crop yields (Scursoni & Satorre, 2005).

4.3. Little seed canary grass

Little seed canary grass (*Phalaris minor*) is considered the most severe weed associated with wheat, barley, and other winter crops (Figure 2) (Jabran et al., 2010). It is distributed worldwide on all continents of the world (Farooq et al., 2013). It is one of the major weeds causing serious damage to wheat crop in Pakistan and became the most troublesome weed for major crops in northern India during the 1970s.

Figure 2. Little seed canary

It also caused a major loss in wheat grain yield in Iran (Gherekhloo et al., 2011). It competes with wheat for fertility and moisture and results in a yield reduction of up to 90% (Chhokar & Sharma, 2008). Morphologically, it resembles the wheat plant until its maturity, but the ligule length of little seed canary grass is three times more than wheat ligule, and auricles are absent. Purple color pigment is found in the internode and stem base of little seed canary grass, and when the leaf is broken, purple sap ooze out (Singh et al., 1999). Little seed canary grass produces 300-475 seeds per plant and matures just fourteen days before wheat (YASIN, 2011).

4.4. Broad-leaved dock

Broad-leaved dock (*Rumex obtusifolius*) is a persistent plant species and spreads worldwide as a wild plant on cultivated land (Figure 3) (Stilmant et al., 2010). Its seed production is very high (60,000 seeds plant^{-1}) that persists in the soil seed bank for a long time (Tsuyuzaki, 2010). Broad-leaved dock is a sign of more nitrogen accessibility in the soil (Klimes, 1996). A certain effect of nitrogen use on its development can be projected, particularly in soils with a sufficient P and K supply. However, its seed production and germination are negatively affected by less nutrient concentration (Křišťálová et al., 2011).

Figure 3. Broad-

4.5. Lambs quarter

Lambs quarter (*Chenopodium album* L.) belongs to the family *Chenopodiaceae* (Figure 4). It is one of the 10 most damaging weeds for the optimum production of major crops. It can be found in wheat, corn, potato, sugar beet, and many other croplands. It is spread around the globe, and inhibits the germination and growth of neighboring plant species by the secretion of allelochemicals. Lambs quarter suppresses the germination percentage, shoot and root length of wheat, radish, jute, and safflower (Rezaie & Yarnia, 2009).

Figure 4. Lambs

4.6. Approaches to control weeds

The different approaches such as physical, chemical, and biological methods are being used to control weeds (Figure 5) (Farooq et al., 2017).

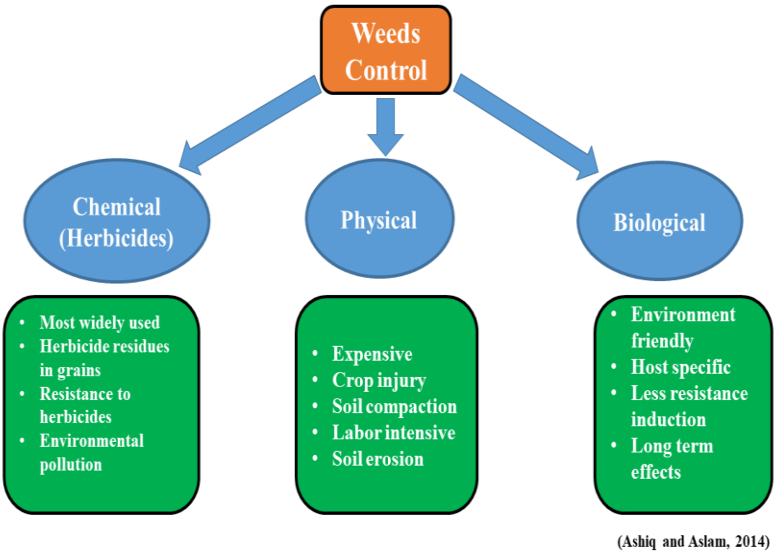

Figure 5. Flow sheet diagram of various weed control approaches

4.6.1. Physical approaches

Traditionally, weeds are removed by physical approaches such as manually or mechanically which give rise to several restrictions. Manual weeding includes the physical removal of weeds with and without hand-driven types of equipment through skilled labor by uprooting, pulling, plucking, and hoeing. It gives effective weed control in almost all crops at any growth stage and field conditions i.e. ridge, bed, and flat sowing, and in areas with cheap labor availability. The success of manual weeding lies in the availability of labor in time probably at critical stages. However, it is not feasible for weed control on a large scale because it is costly, time-consuming, and labor-intensive.

Various mechanical implements are available to control weeds, especially in the crop lines. These involve tillage implements like ploughs and weeders. Recently introduced implements used to control the weeds are torsion and finger weeding, harrowing and weeding through compressed air. The choice of implement used to control the weeds depends upon the type of crop, their growth stage, and the conditions of field and weather (Fogelberg & Gustavsson, 1998). These tools only can control those weeds that are present between crop rows without any harm to the crops. However, the method has failed to control weeds closer to crop plants and is responsible for subsoil compaction. Intensive use of these mechanical tools has resulted in soil erosion, leaching of essential plant nutrients, global warming due to high consumption of energy, development of photo-oxidants, disturbing soil fertility and structure, and deterioration of natural resources (Culliney, 2005). The efficacy of mechanical control is also too low. Soil structure is also an important factor because it should be fine and easy to perform a mechanical operation. Especially in sloppy areas, there is a risk of erosion. Meanwhile, Weather conditions should be also kept in mind to adopt a mechanical approach (Kempenaar et al., 2005).

4.6.2. Chemical approaches

The use of chemical methods to eradicate weeds gained more attention due to their quick mode of action, lower cost, lower risk of erosion, fuel-saving, and variety of application techniques (Mustafa et al., 2019). Nitrofen and Sodium pentachlorophenate were introduced in the early 1960s to inhibit the growth of barnyard grass in paddy fields. Then herbicidal field trials were conducted for chemical weed control in wheat, rice, soybean, and cotton production during the 1970s. Since the 1980s, with industrialization and rural economic development, weed control through herbicides has become more popular among farmers (Ojelade et al., 2022). The application of herbicides is proved to be an efficient technique to control weeds in a wheat field during the last decade. It is reported that more than 50 formulations were approved to be effective for controlling weeds during 1979-2006 in Pakistan, (Ashiq et al., 2007).

Pesticides are popularly used to destroy, repel, prevent, or mitigate the effect of any crop pest. While herbicides are those chemicals that specifically eliminate unwanted plants by altering or disrupting one or more of their metabolic functions (Figure 6) (Tu et al., 2001). Globally, the application of Acetolactate synthase (ALS) and Acetyl-coenzyme A carboxylase (ACCase) herbicides to control weeds is widespread (Heap, 2017). ALS is the enzyme used in the biosynthesis of branched-chain amino acids valine, isoleucine, and leucine (Kishore and Shah, 1988), and ACCase is involved in lipid biosynthesis (Délye, 2005).

(Friesen et al., 2000) reported that in wheat crops, herbicides are the key factor in most weed control practices.(Walia et al., 2000) reported that the use of tribenron methyl and metasulfuron resulted in the control of broad-leaved weeds and enhanced wheat production by 42% and 39.6%, respectively. While application of isoproturon (1.0 kg ha^{-1}) revealed good control of little seed canary grass. Better results were achieved by the combination of chemical herbicides (Malik et al., 2001). Chemical herbicides Buctril Super and Puma Super gave impressive results by 98% control of broad-leaved and grassy weeds (Cheema et al., 2006). Topic +

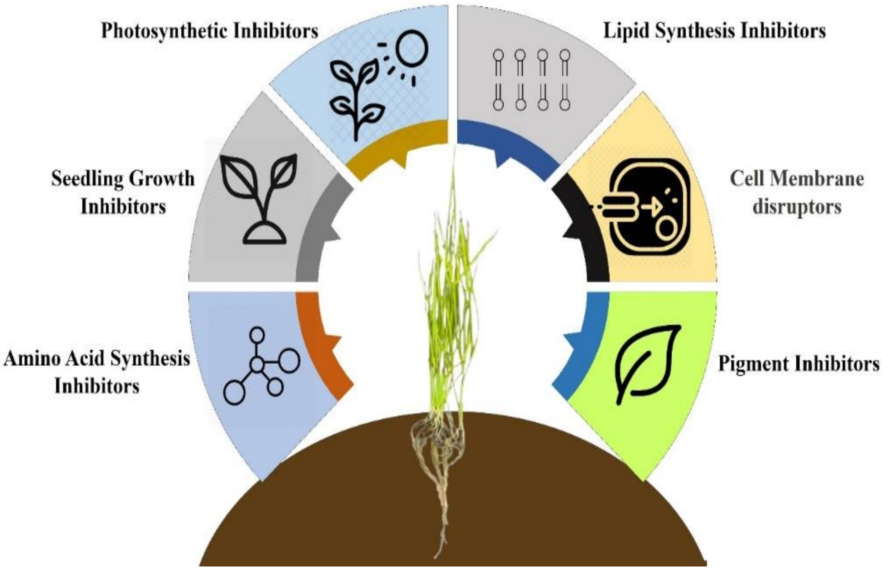

Figure 6. Possible mechanisms of chemical herbicide.

Panther and Panther revealed good results for the control of both grassy and broad-leaved weeds as compared to their weedy control. It was concluded that the use of Buctril Super (0.75 L ha^{-1}) and isoproturon (2.00 kg ha^{-1}) gave decent control of broad-leaved and grassy weeds. (Chaudhary et al., 2011) revealed that the application of chemical herbicides Atlantis, Leader, Puma Super + Starane - M, and Axial + Starane - M inhibited the growth of narrow and broad-leaved weeds and enhanced the wheat yield by 54.91%, 52.88%, 58.98% and 62.03%, respectively.

However, the chemical herbicides may contaminate the air, soils, and groundwater and adversely affect human health, microflora, and fauna along with herbicidal resistance among weeds (Tabaglio et al., 2013). Their residual effects are dangerous to human beings due to their contamination of the food and environment. It is estimated that 1 million people suffered from chronic disorders ultimately resulting in death from herbicide exposure (Blair et al., 2015). Different health concerns are related to herbicidal effects such as various types of cancer, reproductive disorders, hypertension, diseases of the heart, liver, and kidney, neurological anomalies, embryonic malformations, hormonal imbalance, congenital disabilities, and immunity loss (Alengebawy et al., 2021). Glyphosate, 2,4-D, bromoxynil, and triazines are recently reported as carcinogenic. Chemical herbicides may leach down to the groundwater and ultimately cause groundwater contamination. Approximately more than 6000 amphibian species are under intimidation due to water pollution by chemical herbicides. Moreover, comprehensive studies are needed to evaluate the negative impact of herbicides on aquatic life (Lakhani, 2015).

Different issues arise due to the extensive application of herbicides regarding human health and the environment. Induction of herbicide resistance in weeds is also the main disquiet due to the continuous and intensive application of the same herbicides (Table 2) (De Prado & Franco, 2004). More than three hundred cases of chemical herbicide resistance against fifteen herbicide families have been reported (Heap, 2017). Parasites of different pathogens and pests, natural predators, and wildlife are exposed to these chemicals and damage their lives (Alengebawy et al., 2021). The use of these hazardous chemicals is also a risk to endangered species. Less than 0.1% of applied pesticides in the field reach the target while the remaining amount causes adverse effects on non-target sites (Kumar et al., 2014).

Table 2. Most recent cases of herbicide-resistant weeds

Species	Country	Year	Site of Action
Amaranthus palmeri	United States (Connecticut)	2019	ALS inhibitors EPSP synthase inhibitors
Amaranthus tuberculatus	Israel	2019	ALS inhibitors
Apera spica-venti	Belgium	2019	ALS inhibitors
Avena fatua	Ireland	2019	ACCase inhibitors
Avena fatua	Australia (Queensland)	2018	EPSP synthase inhibitors
Chloris radiata	Colombia	2019	EPSP synthase inhibitors
Conyza canadensis	France	2019	EPSP synthase inhibitors
Conyza sumatrensis	Turkey	2019	EPSP synthase inhibitors
Echinochloa crus-galli var. crus-galli	Argentina	2019	EPSP synthase inhibitors
Eleusine indica	United States (Alabama)	2019	PSI Electron Diverter
Lithospermum arvense	China	2019	ALS inhibitors
Lolium perenne ssp. multiflorum	United States (Oregon)	2018	Long chain fatty acid inhibitors
Poa annua	New Zealand	2020	ACCase inhibitors
Rapistrum rugosum	Spain	2018	ALS inhibitors
Secale cereale	United States (Colorado)	2018	ALS inhibitors
Sorghum halepense	Australia (Queensland)	2019	EPSP synthase inhibitors

(Modified from (Heap, 2020)

Herbicides result in human health risks due to herbicide exposure, ground and surface water pollution, their effects on fauna and flora, induction of herbicide resistance in weeds, and deficiency of permitted and effective herbicides for minor crops (vegetables) are the main encouraging factors to reduce the use of chemical herbicides and to adopt some non-chemical approaches (Bourdineaud, 2022). Therefore, biological methods to inhibit the weeds might be a promising alternative supplement for the sustainable production of wheat crop.

4.6.3. Biological approaches

The use of living organisms and their metabolites to inhibit weed growth, density, and reproductive capacity is known as biological control. The application of living organisms helps to reduce the residual effects on ecology, environment, food, and human health (Charudattan, 2005). Biological control has various attractions to use as weed control due to its capability to inhibit weed growth, higher selectivity for specific plants, minimizing the cost of production, reduced resistance potential, and eco-friendly nature (Sindhu et al., 2018).

Hence, the use of biological approaches to control weeds has gained momentum. Pathogens (Dagno et al., 2012) and phytophagous insects (Denslow & D'Antonio, 2005) have been used to inhibit weeds (Farooq et al., 2013). However, there are some bottlenecks to using these approaches which include the unavailability of favorable environmental conditions for pathogens to survive and cause disease in weed plants, lack of virulence, scanty shelf life, lack of distribution to host (Dagno et al., 2012), variation in susceptibility of the host plant to the pathogen at different growth stages, a wide range of host susceptibility, appearance as a new pest of the area (Ghorbani et al., 2005), quarantine constraints (Culliney et al., 2003) and a longer period needed to control weeds through insects (McFadyen, 2000).

1. Allelopathic plant extract

Inhibition of weed growth by the application of secondary metabolites of living organisms is called allelopathy (Macías et al., 1996). The word "allelopathy" was firstly used by Molisch (Plant Physiologist) for the chemical interaction between microorganisms and plants while it is derived from the words 'allelon' means 'of each other' and 'pathos' means 'to suffer' (Lux-Endrich & Hock, 2004). Plant allelopathy is used to inhibit weed growth from the major crops (Table 3) (Farooq et al., 2013).

There are some stimuli like herbicide resistance, environmental problems, and health concerns for the researchers to find some alternative techniques to replace chemical herbicides for controlling weeds. Therefore, the use of allelochemicals as natural inhibitors released from the plants is beneficial to eliminate weeds. The use of an allelopathic extract of *Withania somnifera*, *Echinochloa crusgalli*, *Sorghum bicolor* and *Morus alba* have great potential to control weeds such as wild oat and canary grass from the wheat crop (Jabran et al., 2010).

Sesame, eucalyptus, sunflower, brassica, and tobacco have allelopathic potential to control the noxious weeds of wheat, such as wild oat and canary grass. However, allelopathic extracts of sorghum and sunflower can be used in combination to reduce the dry matter of wild oat and canary grass by 42%-62% and 36%-55%, respectively (Jamil et al., 2009). Sunflower has a good allelopathic ability to influence the growth and activity of neighboring plants (Rawat et al., 2017). The allelochemicals associated with sunflowers are about 125 in number which is phytotoxic to various weed species (Dadkhah, 2012). These allelochemicals are water-soluble, secreted by the root exudates, and leached by the rainwater. Their effect depends on the translocation, persistence in the soil (Olofsdotter, 2001), concentration, and species (Cheema & Ahmad, 1992). Thus, these properties can be used for weed management. These allelochemicals are easy to be deteriorated in the natural environment and become the main restrictions to use as inhibitors of weeds (Bajwa et al., 2019).

Table 3. Allelopathic plant extract and their target weed species

Allelopathic effect of crop	Target weed species	Reference
Black mustard Billy goat weeds Rye	*Avena fatua* L. *Echinochloa crus-galli* L. Amaranthus spp.	(Wato, 2020)
White tephrosia Wheat cultivars	*Phalaris minor* Retz. *Phalaris minor* Retz.	(Kashif et al., 2015)
Moringa oleifera with *Cannabis sativa* and *Parthenium hysterophorus*	Wheat associated weeds (*Phalaris minor*, *Chenopodium album*, *Euphorbia helioscopia*, *Carthamus oxyacantha*, *Avena fatua*, *Convolvulus arvensis*, *Fumaria indica* and *Sonchus oleraceus*)	(Gurmani et al., 2021)
Urochloa ruziziensis stems and *Sorghum bicolor*	*Euphorbia heterophylla*	(Novakoski et al., 2020)
Urochloa ruziziensis	*Ipomoea triloba*	(Foletto et al., 2012)
Sorghum (*Sorghum bicolor* L. Moench)	Weeds	(Sowiński et al., 2020)
Joint extract of mulberry (*Morus alba*), sunflower and sorghum	Wheat associated weeds	(Panda & Mahalik, 2020)
Barley (*Hordeum vulgare* L.)	Wild mustard (*Sinapis arvensis* L.)	(Farhoudi & Lee, 2013)
Black mustard plant extracts (*Brassica nigra* L.)	Lentil (*Lens culinaris Medikus*), radish (*Raphanus raphanistrum*), alfalfa (*Medicago sativa* L.) and wild oat (*Avena fatua* L.)	(Rehman et al., 2019)
Rapeseed residues	Long sandbur (*Cenchrus longispinus* Fern.) and hairy night shade (*Solanum sarrachoides*)	(Rehman et al., 2019)
Seed meal of Indian mustard	Common lambs quarters (*Chenopodium album* L.) and biomass of redroot pigweed (*Amaranthus retroflexus* L.)	(Rice et al., 2007)
Ethiopian mustard (*Brassica carinata*)	Winter weeds	(Rehman et al., 2019)

2. Allelopathic Fungi

The use of allelopathic fungi is an emerging technique for controlling weeds in field crops. Fungi can produce various kinds of phytotoxins, which can suppress the growth of weeds (Table 4). The phytotoxins such as AAL toxin, cornexistin, and tentoxin produced from fungal species have herbicidal effects. The AAL toxin inhibits the ceramide synthase which leads to sphingosine accumulation and membrane breakdown. Cornexitin is a metabolic inhibitor with a mechanism of action like that of amino acetate (Duke, 2012). Various bioherbicides have been developed containing the genus *Colletotrichum* and *Phoma* (Harding & Raizada, 2015). However, several other genera, such as *Phytophthora*, *Sclerotina*, *Puccinia*, *Alternaria*, and *Chondrostereum* have been registered for their bioherbicidal activities (Harding & Raizada, 2015). Various mycotoxins released from *Colletotrichum* species have been identified as weed control including proteases enzyme, carbohydrates degrading enzymes, and ferricrocin (siderophores) by (Jayasankar et al., 1999). However, the genus Phoma can produce phomalairdenone, epoxydonesters, putaminoxin, and nonenolides phytotoxins resulting in chlorosis and bleaching to control broad-leaved weeds (Zhou & Yu, 2004). Besides the weed suppression ability, the application of fungi has several limitations due to its parasitic nature (Hershenhorn et al., 2016). Most of the fungus species belong to Colletotrichum genera and were found to plant pathogens that can cause severe monetary losses by decreasing crop yield and deteriorating the quality of crops through postharvest damages (Münch et al., 2008). These limitations restrict the use of fungi to control weeds due to their non-specificity towards the host.

Table 4. Allelopathic Fungi and their target weed species

Species	Target weed species	Reference
Alternaria destruens	*Cuscuta*. spp.	(Simmons, 1998)
Alternaria.helianthi	*Xanthium strumarium* L.	(Abbas et al., 2004)
Alternaria sonchi	*Sonchus arvensis*	(Evidente et al., 2009)
Beauveria sp.	*Avena fatua* L.	(Cheng et al., 2021)
Colletotrichum gloesporioides	*Leguminosae, Malvaceae, Convolvulaceae*	(Mortensen & Makowski, 1997)
Colletotrichum graminicola	Gramineae	(Hoagland et al., 2007)
Colletotrichum truncatum	*Sesbania exaltata*	(Boyette, 1991)
Fusarium lateritium	*Ambrosia trifida*	(Hoagland et al., 2007)
Fusarium oxysporum	*Phelipanche ramose*	(Müller-Stöver et al., 2009)
Fusarium oxysporum sp. *Orthoceras*	*Orobanche cumana* (Sunflower broomrape)	(Müller-Stöver et al., 2009)

Phoma macrostoma	*T. officinale*	(Smith, 2016)
Phoma herbarum	*Taraxacum officinale*	(Neumann & Boland, 1999)
Myrothecium verrucaria	*S. obtusifolia* *Portulaca* spp. *Euphorbia* spp.	(Walker & Tilley, 1997) and (Boyette et al., 2007)
Phoma chenopodicola	*C. album, Cirsium arvense, Setaria viridis, Mercurialis annua*	(Cimmino et al., 2013)
Phyllachora cyperi	*Cyperus rotundus*	(Hoagland et al., 2007)
Pyricularia sp.	*Digitaria sanguinalis*	(Hoagland et al., 2007)
Sclerotinia sclerotiorum	*Cirsium arvense, Ranunculus acris*	(Bourdôt et al., 2006)
Sclerotinia minor	*T. officinale, Trifolium repens, Plantago minor*	(Riddle et al., 1991)
Myrothecium Verrucaria	*Brunnichia ovate, Campis radicans, Pueraria lobata*	(Boyette et al., 2008)

3. Allelopathic rhizobacteria

Microbial application is a technique to inhibit the most inconvenient crop pests such as weeds and give an advantage to the crop plant to grow healthy by killing or hampering the growth of weeds (Stubbs & Kennedy, 2012). Microorganisms are used as an alternative or supplementary approach to suppress the growth of weeds for reducing the cost of production and reducing the residual effects by decreasing the dependency on chemical herbicides (Mustafa et al., 2019). Bioherbicides containing microorganisms affect only desired plant species due to being more selective than chemical herbicides and reduce the induced resistance in weeds due to various modes of action (Crump et al., 1999). According to (Kremer, 2006), allelopathic bacteria are a group of living organisms that can release phytotoxic substances in the rhizosphere soil and inhibit the growth of weeds in non-host-specific and host-specific patterns (Table 5). Therefore, rhizobacteria have been introduced to control the weeds by the production of various metabolites in the rhizosphere of certain plants that are phytotoxic and inhibit the germination and growth in host-specific patterns (Sturz & Christie, 2003).

Allelopathic bacteria application seems a viable strategy to diminish the race between major crops and weeds and serve as a biological control agent for weeds (Abbas et al., 2020). Various scientists evaluated the potential of allelopathic bacteria to suppress the weed's growth. An experiment was conducted by (Dar et al., 2020) and found that the application of consortia of compatible *Pseudomonas* strains decreased root length of wild oat and little seed canary grass up to 73.8% and 53.9%, and increased seedling mortality up to 50.0% and 56.7% as compared to the uninoculated control. The decrease in weeds growth was due to cyanide production. (Abbas et al., 2021) revealed that two strains of antagonistic bacteria (*Pseudomonas fluorescens*) 7O^{0} and L9 significantly enhanced the growth and yield of wheat crop with the suppression of broadleaved dock, little seed canary grass and wild oat in three different experiments.

(Peltzer & Ash, 2005) reported that the use of bacteria has a synergistic effect on cereal crops with a reduction in weed growth. Moreover, the habit of the susceptible host and the most virulent stage of the biocontrol agent must be matched for a successful biocontrol agent (Stubbs & Kennedy, 2012). A study conducted by (Tasawar Abbas et al., 2017) concluded that the use of rhizobacteria reduced the growth of weeds (broad-leaved dock) and improved the yield of wheat in field conditions. An experiment conducted by (Omer et al., 2010) revealed that the inoculation with allelopathic bacteria reduced the growth of white clovers by up to 86%. These bacteria can inhibit the growth of dicotyledonous weed (*Chenopodium album*). Allelopathic bacteria inhibited the seed germination by 18.4%-60.5%, 18.5%-58.7%, and 15.2%-63.3% of the broad-leaved dock, little seed canary grass, and wild oat, respectively, and were non-inhibitory to the wheat crop (Abbas et al., 2017).

Table 5. Allelopathic bacteria and their target weed species

Species	Target weed species	Reference
Pseudomonas fluorescens strain D7	Downy brome (*Bromus tectorum*)	(Kennedy, 2016);
Pseudomonas fluorescens strain BRG100	Green foxtail (*Setaria viridis*)	(Quail et al., 2002)
Pseudomonas fluorescens strain WH6	Most of the weeds	(Banowetz et al., 2008)
Pseudomonas putida KT2440	Wild oat. Little seed canary grass, and broad-leaved dock	(Abbas et al., 2017)
Pseudomonas fluorescens F113		
Pseudomonas fluorescens SBW25		
Pseudomonas aeruginosa PAO1		
Pseudomonas alcaligenes NBRIC14159		

Pseudomonas fluorescens G2-11	Barnyard grass, Green foxtail, ivyleaf morningglory and field bindweed	(Li & Kremer, 2006)
Pseudomonas syringae	Luttuce, Barnyardgrass	(Kremer & Souissi, 2001)
Pseudomonas putida *P. aeruginosa* *P. alcaligenes*	Rice associated weeds (*Cyperus rotundus* and *Echinochloa colonum*)	(Abbas et al., 2020)
Flavimonas oryzihabitans	Luttuce, Barnyardgrass	(Kremer & Souissi, 2001)
Flavobacterium balusitinum	Leafy spurge	(Souissi et al., 1997)
Xanthomonas campestris pv. *Poae*	Annual blue grass (*Poa annua*)	(Imaizumi et al., 1997)
Xanthomonas campestris LVA- 987	Horeseweed (*Conyza canadensis*)	(Boyette & Hoagland, 2015)
Alcaligenes xylosoxidans	Wild radish	(Flores-Vargas & O'hara, 2006)
Acidovorax delafieldii	Velvetleaf	(Owen & Zdor, 2001)

Through various mechanisms, rhizobacteria are toxic to weeds and reduce their growth and development (Figure 7) (Stubbs & Kennedy, 2012), which mainly depends on the genotype of the host plant and bacteria (Strange, 2007). These phytotoxins can inhibit the synthesis of macromolecules, the integrity of cell membranes, and metabolism (Nehl et al., 1997). Allelopathic rhizobacteria can suppress weeds by cyanide production (Ali et al., 2017) and various plant growth regulators (Sarwar & Kremer, 1995). Moreover, they are involved in the production of antibiotics such as 2,4-diacetylphloroglucinol and phenazine (C. L. Bender et al., 1999), lytic agents, cell membrane and cell wall degrading enzymes (Kremer et al., 2006), which ultimately enhance the chance of plant susceptibility to pathogens (Omer et al., 2010). They can produce various enzymes such as urease, oxidase, catalase, and chitinase for growth inhibition of weeds (Abbas et al., 2017). 2-Aminophenoxazone, phenazine-1-carboxylic acid, and 2-aminophenol are the secondary metabolites released from strain 3366 of *Pseudomonas syringae* involved in the inhibition of downy brome (Gealy et al., 1996). The cell wall and cell membrane of plants were disrupted by the release of these enzymes and/or phytotoxins from bacteria, which ultimately reduced seedling growth (Souissi et al., 1997). The antibiotics released from bacterial strain CHA0 (*P. fluorescens*) such as 2, 4-DAPG were phytotoxic to many plants (Keel et al., 1992). The release of a volatile metabolite (Hydrogen cyanide) negatively affected the growth and metabolism of roots by obstructing cytochrome oxidase respiration. While the amount of HCN produced depends upon the availability of precursors (cyanogenic glucosides, glycine, proline, and methionine) (Bekhit et al., 2018; Schippers et al., 1990).

Different environmental factors such as soil water potential, light intensity, and nutrients as well as the composition of root exudates, may play vital roles in this regard (Schippers et al., 1990). *Acidovorax delafieldii* and *Pseudomonas putida* are two important strains to produce HCN and play a significant role in the growth inhibition of velvet leaf (*Abutilon theophrasti*) (Owen & Zdor, 2001). Production of HCN is the primary factor to inhibit the growth of various weed species (Souissi et al., 1997). Reduced or modified presence of substrates for manufacturing phytotoxic metabolites (Zeller et al., 2007), diverse selectivity of the plant to phytotoxic substances (Owen & Zdor, 2001), and root colonization of non-host plants are the factors involved in inhibiting weeds (Kennedy et al., 2001).

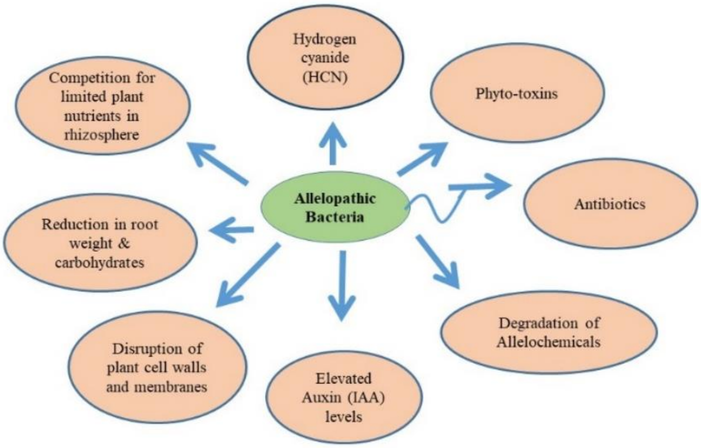

Figure 7. Different mechanisms of allelopathic bacteria for weed suppression**.**

However, there is some restriction to the use of rhizobacteria to control the weed species on a commercial scale which involve their large-scale production, storage, effective biocontrol agent, shelf life, the persistence of microorganism, and distribution to the host plant (Hussain & Farooqi, 2021).

4.7. Integrated weed management

The application of allelopathic bacteria is beneficial because of its low cost and very low hazardous effects on the environment compared to chemical herbicides (Hajek & Eilenberg, 2018). The use of these allelopathic bacteria with other weed control approaches such as agrochemicals and cultural management practices is the best strategy until now to improve the production of major crops and reduce the infestation of wild oat (Kremer & Kennedy, 1996).

An integrated weed management strategy is the most effective approach to control weeds. Therefore, the use of allelopathic bacteria is reliable when used with a reduced dose of chemical herbicides (Greaves & Sargent, 1986). Integrated use of chemical herbicides at a reduced dose with allelopathic bacteria should be encouraged for sustainable crop production (Culliney, 2005). (Kremer & Kennedy, 1996) stated that the use of allelopathic bacteria with reduced herbicides (metribuzin and diclofop) significantly suppressed the growth of downy brown and jointed goatgrass. The application of chemical herbicides metribuzin and rimsulfuron at low doses with fungi *Ascochyta caulina* suppressed the growth of *Chenopodium album* (Vurro et al., 2001). The use of a reduced dose of herbicides with *Pyricularia setariae* hampered green foxtail growth (Peng & Byer, 2005). (Bailey et al., 2000) revealed that the use of *pseudomonas syringae pv. targeti* with the reduced dose of herbicide is beneficial for the control of Canadian thistle weed. Therefore, the combined application of allelopathic bacteria and reduced dose of chemical herbicides is a good technique for the control of weeds.

4.8. Conclusion and future directions

Weeds are the most limiting factor that reduces the growth of major crops and causes a significant reduction in crop yield. Manual control is not economically feasible to control weeds at a large scale because it requires high labor and capital. Mechanical control is a good approach to suppress weeds, but is unable to control weeds in rows of major crops, and also may result in erosion and high energy consumption. Chemical control is a famous and easy method to control weed densities, but continuous use of the same chemical herbicide may result in the induction of resistance against it and environmental degradation. Therefore, the use of allelopathic bacteria is a good choice to control weeds instead of chemical herbicides due to their environment-friendly nature. There are some constraints to use allelopathic bacteria as bioherbicides such as production, effective biocontrol agent and their large-scale production, persistence in soil, and their distribution to host plants. Furthermore, extensive field evaluation is needed to evaluate their characteristics and performance in diverse ecological conditions. However, the use of allelopathic bacteria would be more beneficial to control weeds when being used with a reduced dose of herbicide and plays an important role in the sustainability of crop production.

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Conflicts of Interest

The authors declare no conflict of interest.

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Brief Curriculum Vitae

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Experience and Research Interest: Soil Science, Plant Nutrition, Soil Microbiology, Plant Growth Promoting Rhizobacteria (PGPR), Production of Biofertilizers, and Biopesticides, Sustainable agriculture, Use of Organic amendments, Biochar and its modification to Carbon Sequestration and Climate Change mitigation.

CHAPTER 5

INVESTIGATION OF FERTILITY STATUS OF AGRICULTURAL SOILS IN BİLESUVAR PROVINCE OF THE REPUBLIC OF AZERBAIJAN

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5.1. Introductıon

The natural environment is incomplete without soil. It is just as important as rivers, rocks, plants, and animals. It provides a habitat for numerous organisms and has an impact on the distribution of plant species. It is a source and a reservoir for atmospheric gases (such as oxygen and carbon dioxide) and controls the flow of water and chemicals between the earth and the atmosphere. Not only do soils record human activities of the past and present, but they also reflect natural processes. As a result, they belong to our cultural heritage. Examples include altering land for agriculture and burying archaeological remains.

The growth of the oil industry in and around Baku marked the beginning of environmental issues in Azerbaijan. Later, the Caspian Sea and other offshore regions were added to it. Prior to 1920, oil was the source of pollution; however, during the Soviet era (1920-1991), the sources of pollution increased, and as other industries and the agricultural sector developed, so did the extent and scope of pollution. All of nature's components - air, water, and soil - are currently polluted in Azerbaijan. However, the extent and consequences of environmental pollution vary from region to region (Bayramlı, 2020).

In Azerbaijan, the industries, agriculture, and transportation sectors are the most significant contributors to environmental pollution. The country's oil industry contributes more to environmental pollution. The natural properties of soil, air, and water are negatively impacted by oil extraction, transportation, and processing pollution, which has reached levels that pose a health risk to humans. According to Asian Development Bank (2005), the metallurgical industry, which has grown rapidly since the 1950s, has polluted the country's environment in the western and northern parts and destroyed some forests.

In Azerbaijan, soil surveys have been conducted for more than a century. The 1970s of the XIX century are regarded as the beginning of the development of soil science in Azerbaijan. Deforestation and poor land management are to blame for the erosion of 42.5 % of Azerbaijan's land. There are cultivated areas on 33.7 % of these lands, highlands on 68.1 %, pasture meadows on 15.2 %, fruit on 15.9 %, vineyards on 23.9 %, and forest areas on 26 % of these lands. 15% of the country's land is covered by semi-deserts. Mining has been responsible for the growth of heavy industry, transportation, the oil industry, the production of organic and mineral resources, pollution, and soil degradation in large areas since the second half of the 20th century. The topsoil has been deteriorated and destroyed as a result of the rapid rate of industrial development. Unsuitable layers of career polygons, anthropogenically disturbed areas, and large forests, pastures, and meadows are rarely created during the construction of roads and pipelines (Abbasov et al., 2019).

Due to its strong binding to particle surfaces and extremely low solubility in phosphate minerals, phosphorus' predominant properties in soil result in low soil solution concentrations. This means that phosphorus is a constraint on crop growth. According to Haygarth et al. (2013), phosphorus fertilization is an essential component of crop production systems in the majority of nations and is therefore required to maintain profitable crop production.

Potassium can make plants better able to withstand the drought. With a variety of modifications, the soil's potassium content may rise. Soil potassium fixation decreases when organic fertilizers are applied, leading to an increase in potassium release. Under water stress, application of phosphorus fertilizer increases root biomass, photosynthesis rate, and leaf water content (Bader et al., 2021).

Soil contains calcium (Ca), which is an essential nutrient for soil organisms and plants (Marschner, 1995; Chenu et al., 2015). Fertility of the soil is largely determined by the total or exchangeable calcium content of the soil. Multivalent Ca^{2+} cations also serve as bridging cations, which is important for the formation of structure and the aggregation of the soil. According to Rowley et al., (2018), this function is essential for the stabilization of soil carbon as secondary carbonates or organic matter.

There are generally four fractions of soil magnesium: organic complex, structural, rapidly exchangeable, and slow exchangeable (acid soluble) forms. The final one explains the bioavailability variations; The easily movable form of magnesium, which is slowly replenished by soil reserves, buffers magnesium's absorption by plants from the soil solution. The plant's supply of magnesium is influenced in large part by the texture of the soil. According to Mayland and Wilkinson (1989), magnesium is a mineral that can be found in clay minerals and is linked to cation exchange sites on clay surfaces. As a result, clay soils typically contain sufficient magnesium for the needs of plants, whereas sandy soils frequently lack magnesium.

Although soil iron concentrations are typically high, variations in its availability can result in a deficiency. Iron deficiency is common, especially in soils with a pH higher than 7.5 and a lot of calcium carbonate ($CaCO_3$ or lime). As the pH of the soil decreases, iron solubility increases significantly. When lime soils become saturated, bicarbonate (HCO^{3-}) can form, which hinders plants' ability to absorb iron (Alhendawi et al., 1997). As the soil dries out and warms, this inhibition typically lasts only a short time, and iron deficiency symptoms go away (Jones, 2020).

The functional groups of soil reactive particles and their capacity to absorb water are two other factors that influence total soil Cu availability. According to Bradl (2004), the proportion of clay mineral content, iron (Fe) oxides, iron hydroxides, aluminum (Al), manganese (Mn), carbonates, and organic matter (OM) increases the sorption capacity.

Zinc deficiency is expected to rise from 42% to 63% by 2025 due to the ongoing depletion of soil fertility. Depending on the soil's pH, zinc that is applied exogenously to plants in the form of zinc sulfate also transforms into non-existent forms like Zn(OH) and $Zn(OH_2)$. According to Beulah et al., (2017), zinc is one of the essential micronutrients required for optimal plant growth and plays an important role in metabolism.

The eleventh most abundant element in the earth's crust is manganese (Mn). In terms of abundance, compounds with manganese in them follow iron (Fe) in the earth's crust. The soil's total manganese content ranges from 20 $mgkg^{-1}$ to 3000 $mgkg^{-1}$, with an average of 600 $mgkg^{-1}$. Clay minerals and organic matter absorb divalent manganese, and divalent manganese ions (Mn^{2+}) are the most important nutrients for plants. Manganese is present in exchangeable manganese, manganese oxide, organic manganese, and Ferro-manganese silicate minerals in soil. The manganese ion (Mn^{2+}) is comparable in size to magnesium (Mn^{2+}) and ferrous iron (Fe^{2+}), and it has the ability to take their place in elements found in iron oxides and silicate minerals. Soil manganese reactions are quite intricate. Soil aeration, organic matter, pH, and moisture all have an impact on the amount of manganese in the soil (Mousavi et al., 2011). Some chemical and physical soil analyses in this study have revealed the fertility status of agricultural lands in the Azerbaijan province of Bilesuvar.

5.2. Materıals and Methods

Jackson's (1967). method was used to collect soil samples from 267 different locations on agricultural lands in the Azerbaijani province of Bilesuvar. The collected soil samples were transported to the laboratory and prepared for the required analysis. However, pH, salt, lime, organic matter, available phosphorus, exchangeable K, Ca, Mg, and available Fe, Cu, Zn, and Mn were examined in soil samples (Sağlam, 2012), as were texture analyses (Demiralay, 1993). They were extracted with 0.005 M DTPA +

0.01 M $CaCl_2$ + 0.1 M TEA (pH 7.3) for the analysis of some available micro elements in agricultural soil samples (Lindsay & Norvell, 1978), and the extract contained the available Fe, Cu, Zn, and Mn. The ICP-OES apparatus was used to calculate their quantities. The fertility status of the agricultural lands in the Azerbaijani province of Bilesuvar was revealed after the research's findings were compared to the critical adequacy values that had been established. Research area are given in Figure 1.

Figure 1. Research area in Bilesuvar Province, Azerbaijan.

5.3. Results nd Dıscussıon

1. pH Values of the Soils

It was determined that the soil samples' pH values ranged from 7.7 to 8.5. 95.13 % of these values are categorized as "slightly alkaline" and 4.87 % as "alkaline." It has been determined that the majority of soil samples fall into the slightly alkaline category.

2. Lime Content of the Soils

It was found that the lime content of the soil samples ranged from 0.9 % to 25 %. A total of 12.73 % of the soils are categorized as "high calcareous," 23.60 % as "medium calcareous," 63.30 % as "calcareous," and 0.37 % as "little calcareous." The majority of the agricultural soils studied fall into the "calcareous" category, and it has been determined that these soils have high lime content values.

3. Organic Matter Content of the Soils

The organic matter content of the soil samples ranged from 0.9 % to 4.1 %. The evaluations revealed that 0.75% of the soils have "very little," 50.93 % have "little," 41.20 % have "medium," 6.37 % have "good," and 0.75 % have "high." It was discovered to have "level organic matter." When these results are looked at, it becomes clear that the rate of organic matter in this area, where agriculture is done, is "little" at 50.93 %.

4. Texture of the Soils

Almost 55.80 % of the soil samples taken from the research area were classified as "clay"; 19,10 % of the soil samples taken from the research area were classified as "silty clay"; 4,87 % of the soil samples taken from the research area were classified as "clay loam"; 19,90 % of the soil samples taken from the research area were classified as "silty clay-loam" and 0,37 % of the soil samples taken from the research area were classified as "loamy". More than half of the soil samples were found to be "clay" texture.

5. Some Nutrient Element Contents of Agricultural Land Soils in the Bilesuvar Province, Azerbaijan

Available Phosphorus Contents of the Soils

The amount of phosphorus available to plants in the soil ranged from 25.9 mgkg^{-1} to 437 mg kg^{-1}, according to the results of an analysis of the soils in the province of Bilesuvar. 13.48 % of the soils in the research area have "excess" available phosphorus and 86.52 % have "too excess" available phosphorus. Figure 2 shows that these values indicate that the soils in the study area contain the high available phosphorus.

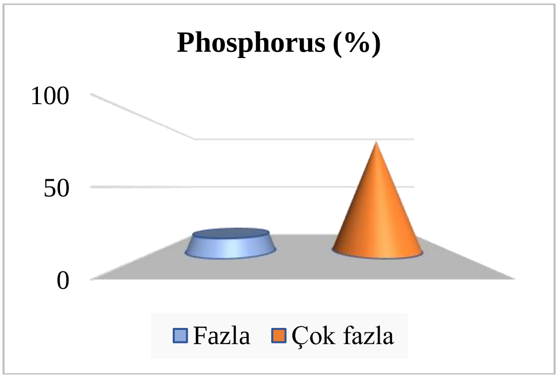

Figure 2. Available phosphorus content (%) in the soil samples of the study area

Exchangeable Potassium Contents of the Soils

When soil samples from the research area are examined for their exchangeable potassium content, it is discovered that the potassium content ranges from 688 mgkg^{-1} to 3667 mgkg^{-1} (Alpaslan et. al., 1998), when soils' exchangeable K content was categorized, 10.49 % had "excess" and 89.51 % had "too excess" potassium content (Figure 3). It is evident that the potassium content in the agricultural soils of the province of Bilesuvar is high enough for plants to thrive.

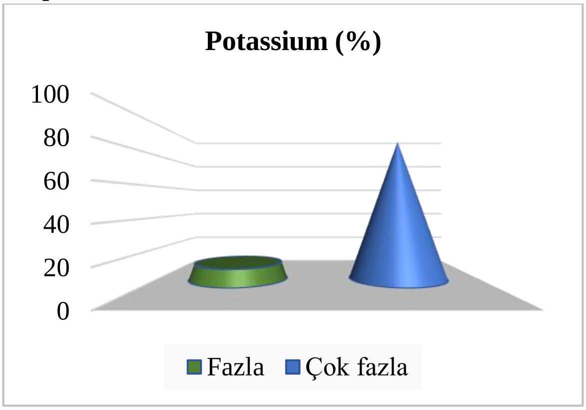

Figure 3. Exchangeable potassium content (%) in the soil of the study area

Exchangeable Calcium Content of the Soils

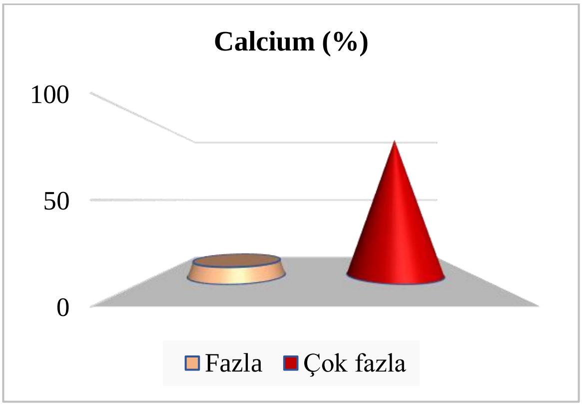

Figure 4. Exchangeable calcium content (%) in the soils of the study area

It has been determined that the exchangeable calcium content of the soils in the study area ranges from 4480 mgkg^{-1} to 95579.4 mgkg^{-1}. 9.74 % of soils have "excess" and 90.26 % have "too excess" levels of exchangeable calcium when the values are interpreted. Figure 4 shows that these findings indicate that the soil's exchangeable calcium content is excessive for plants and well above the normal range.

Exchangeable Magnesium Content of the Soils

The research area's soils content an exchangeable magnesium content that ranges from 627 $mgkg^{-1}$ to 3733 $mgkg^{-1}$. The soils' exchangeable magnesium content was determined to be "excess" by 77.53 % and "too excess" by 22.47 %. Figure 5 shows that these values indicate a high exchangeable magnesium content in agricultural soils in the province of Bilesuvar.

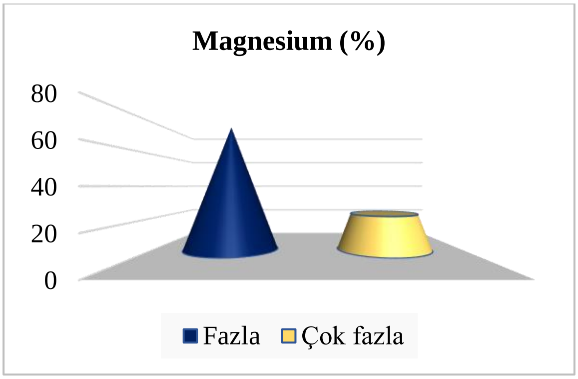

Figure 5. Exchangeable magnesium content (%) in the soils of the study area

Available Iron Content of the Soils

The levels of iron available to plants in the study area's soils ranged from 20 $mgkg^{-1}$ to 158 $mgkg^{-1}$. Figure 6 shows that the results of the analysis showed that all of the soil samples taken from agricultural areas had a "high" available iron content.

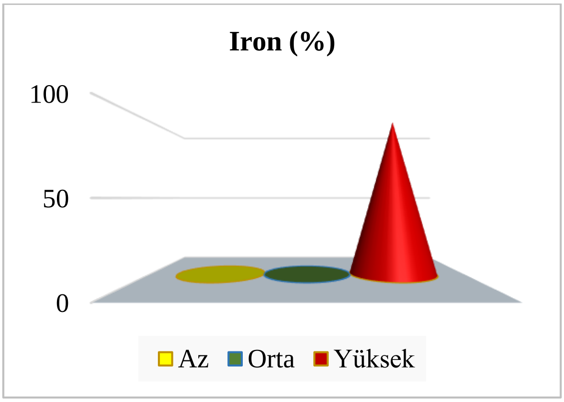

Figure 6. Available iron content (%) in the soils of the study area

Available Copper Content of the Soils

The available copper content in the soil samples taken from the research area ranged from 2.6 $mgkg^{-1}$ to 21.5 $mgkg^{-1}$. According to these findings, the available copper content of all agricultural soils in the province of Bilesuvar was found to be "sufficient" (Figure7).

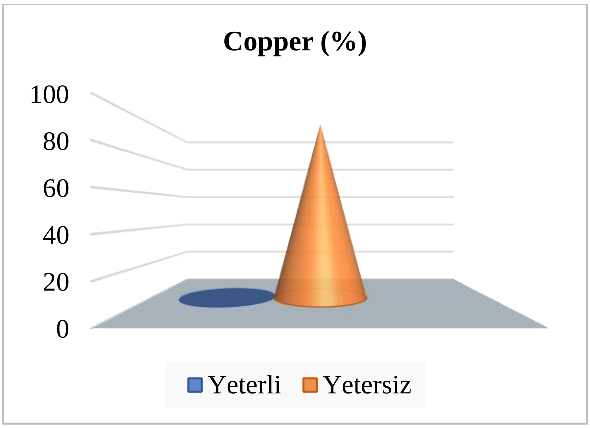

Figure 7. Available copper content (%) in the soils of the study area

Available Zinc Content of the Soils

The study area's soils' available zinc content ranged from 0.6 $mgkg^{-1}$ to 11.9 $mgkg^{-1}$. When the Figure 8, it is found that 2.62 % are "insufficient"; 81.65 % are "sufficient"; 14.23 % are "high"; and 1.5 % are "excess." It was found to have "sufficient" available zinc in it. Figure 8 shows that the available zinc content of soil samples taken from the research area is typically sufficient when these results are evaluated.

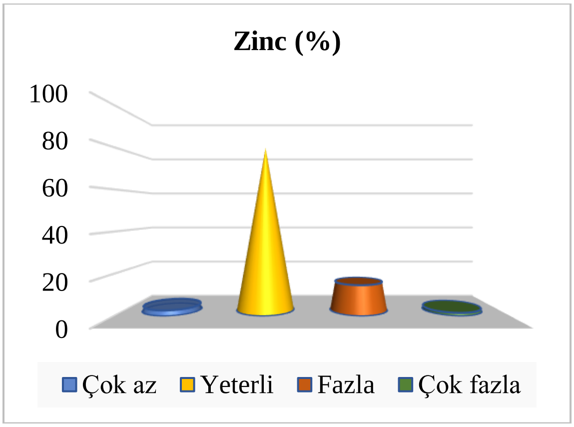

Figure 8. Available zinc content (%) in the soil of the study area

Available Manganese Content of the Soils

The available manganese content of the soils in the research area ranges from 81 $mgkg^{-1}$ to 456 $mgkg^{-1}$, according to the findings of the analysis. According to Figure 9, the available manganese content of the soil was divided into two categories: "excess" for 40.82 % of the soils and "too excess" for 59.18 % (Figure 9).

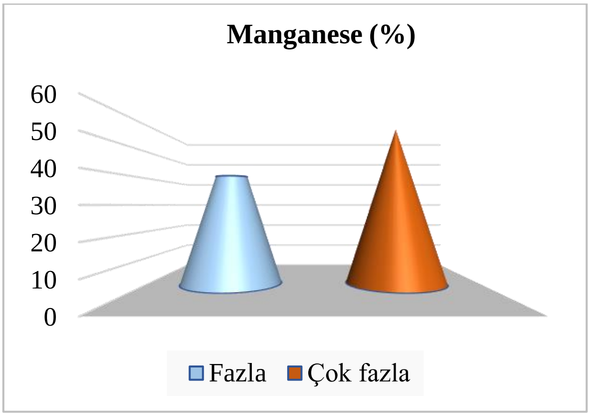

Figure 9. Available manganese content (%) in the soils of the study area

5.4. Conclusıon and Suggestıons

Soil samples from 267 different agricultural lands within the borders of the Republic of Azerbaijan's Bilesuvar province were analyzed for some macro nutrient element contents and some micro nutrient elements content as well as their physical and chemical properties.The soil samples taken from the research area were compared in terms of pH, organic matter, and lime content. The obtained results indicate that the agricultural land soils in Bilesuvar province have a pH value between 7.7 and 8.5 and contain slightly alkaline soils at a rate of 95.13 %.

In agricultural areas, the amount of organic matter in the soil is a crucial component for the growth of plants. The organic matter content of the soil samples taken from the area under study ranged from 0.9 % to 4.1 %. The evaluations revealed that 50.93 % of them had a low organic matter content and 0.75 % had a high organic matter content. When these results are looked at, it becomes clear that the amount of organic matter in this area where agriculture is done is usually "insufficient"

When the values for the texture classification of the soil samples taken from the research area are examined, 55.80 % of the soil samples are classified as "clay," 19.10 % as "silty clay," 4.87 % as "clay loam" and 19 % as "silty clay loam." Additionally, 0.37 % of the soil samples have a "loamy" texture. In agricultural regions with a variety of soil textures, it was observed that more than half of the soil samples were "clay" texture class.

According to the findings of the macro nutrient element analyses that were carried out on the soil of the province of Bilesuvar, the amount of available phosphorus that was accessible to plants in the soil ranged from 25.9 mgkg^{-1} to 437 mgkg^{-1}. 13.48 % of these soils have "excess" and 86.52 % have "too excess" available phosphorus, according to the findings.

The soil samples' exchangeable potassium content ranges from 688 mgkg^{-1} to 3667 mgkg^{-1}, according to the results of the analysis. At a rate of 10.49 %, the soils' exchangeable potassium content was categorized as "excess" and at a rate of 89.51% as "too excess" The agricultural soils of the Bilesuvar province have been found to have a high exchangeable potassium content for plants.

The soil samples' exchangeable calcium content was found to range from 4480 mgkg^{-1} to 95579 mgkg^{-1}, according to the evaluation. 9.74 % of the soils have "excess" and 90.26 % have "too excess" exchangeable calcium. These findings suggest that the soil's exchangeable calcium content is significantly above the normal range and may be toxic to plants.

The soil's level of exchangeable magnesium ranges from 627 mgkg^{-1} to 3733 mgkg^{-1}. It was found that the exchangeable magnesium content of the soils was 77.53 % high and 22.47 % too high when compared to the exchangeable magnesium reference values that should be found in the soil. These numbers indicate that the exchangeable magnesium content of agricultural soils in the province of Bilesuvar is higher than the limit.

Despite the fact that the amount of available iron to plants in their soils varied between 20 mgkg^{-1} and 158 mgkg^{-1}, the analysis results revealed that all soil samples had a "high" available iron content.

The available copper content of the soil samples taken from the research area ranged from 2.6 mgkg^{-1} to 21.5 mgkg^{-1}, and the available copper content was found to be "sufficient" in all agricultural soils of the Bilesuvar province.

The soils' available zinc content ranged from 0.6 mgkg^{-1} to 11.9 mgkg^{-1}. It was determined that the available zinc content was at a "sufficient level" in 81.65 % of the soil samples when the available zinc limit values that should be found in the soil content and the results of the analysis were evaluated together.

The analyzed soil samples had available manganese contents ranging from 81 mgkg^{-1} to 456 mgkg^{-1}. When the available manganese levels in the soil were categorized, it was found that 40.82 % of the soils had "excess" manganese and 59.18 % had "too excess" available manganese.

The results of this study, which was carried out within the boundaries of the province of Bilesuvar, revealed that the nutrient content of agricultural soils was typically above the limit. When taken as a whole, agricultural soils have a low level of organic matter and are clay texture class, generally. At the same time, it is evident that the soil's limits for available phosphorus, exchangeable potassium, calcium, and magnesium macro nutrients are exceeded. According to the findings of the analyses, it is necessary to carry out the necessary research in the agricultural lands of the province of Bilesuvar in order to bring the soil's macro nutrient element contents and physical, chemical, and chemical components down to a level that is balanced. On the other hand, it should be decreased of salty in the soils and organic matter amounts of the soils should be increased. For this purpose, more organic fertilizers should be applied to the soils for plants.

Acknowledgement
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Brief Curriculum Vitae

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CHAPTER 6

THE ANALYSİS OF COMPETİTİVENESS OF BOK CHOY PLANT AGRİBUSİNESS DEVELOPMENT *(Brassica rapaL)* ON HYDROPONİCS AXİS SYSTEM

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6.1. Introduction

Indonesia is an agrarian nation in which the agriculture sector drives economic growth. The focus of Indonesia's agricultural growth is agriculture centered on agribusiness. Horticulture is in high demand since its harvest time, especially for vegetables, is shorter than that of other food crops. Horticulture is a part of the agricultural industry, which supports the national economy due to its high economic value, a source of economic growth with a very promising future in terms of comparative advantage and competitiveness. (Dirjen Hortikultura, 2016).

Vegetables are one of the annual crops that are frequently farmed by farmers, and these plants have enormous potential and are required by a large number of people. Every year, the number of veggies grown has increased. According to the statistics in Horticultural Agriculture Statistics (SPH), 10 vegetable commodities are included. Some recapitulation of the 2016 seasonal vegetable planting data, as seen in graph 1.1, where each product has a distinct number of regions.

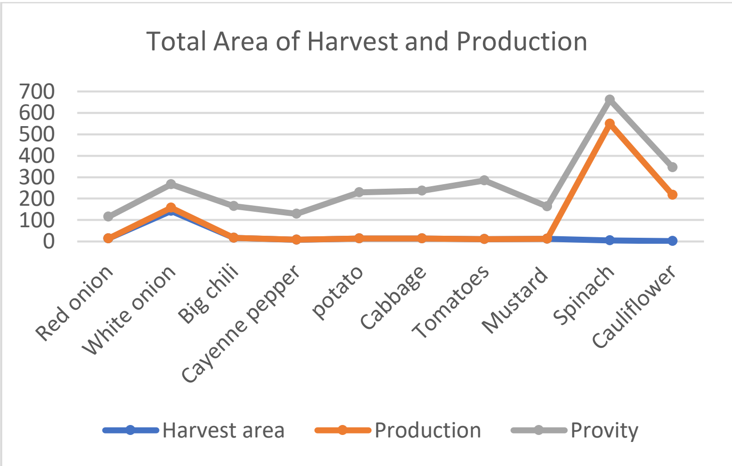

Figure 1. Total Area of Harvest and Production. Source: Horticultural Agriculture Statistics (SPH)

The Majalengka Regency is an agricultural region that cultivates several sorts of vegetables utilizing traditional techniques. The village of Gunungmanik, which is an agricultural production center in the Talaga District of Majalengka's Majalengka Regency, has attracted an increasing number of hydroponic growers over time. Hydroponic enthusiasts in Majalengka have established the Majalengka Hydroponic Community, whose KOHIMA is not just a pastime but also an economic prospect. Bok Choy is one sort of vegetable that is grown utilizing the hydroponic technique. The KOHIMA Bok Choy factories have been able to satisfy market demands both within and outside the area. The expansion in vegetable crop business players, particularly Bok Choy plants, is squeezing the ability of other producers to increase their output, It is essential to understand the competitiveness of Bok Choy plant agribusiness in order to choose the most effective and suitable tactics for increasing comparative advantage and competitive advantage.

Axis system hydroponics is the simplest and most often utilized system, especially among novices. Using some type of wick, the wick system passively transports nutrients from the inside of the tank to the growing environment. A wick hydroponic system is ideal for growing little plants. This hydroponic method is ineffective for plants with a high water requirement. This mechanism is mostly dependent on the axis that connects the nutrient solution in the tank. The capillary action of the axes transports water and nutrients to plant roots. (Amiira, 2015).

In light of this background, research is required to assess the agribusiness competitiveness of Bok Choy plants grown in hydroponic wick systems. This research is entitled “The Analysis of Competitiveness of Bok Choy Plant Agribusiness Development *(Brassica rapa L)* On Hydroponics Axis System”. The purpose of the research are Analyzing the advantage of creating agricultural plants in hydroponic axis systems in terms of competition and Analyzing the viability of the competitive advantage of agricultural development of Bok Choy plants in the hydroponic axis system

6.2. Method

This research was carried out between November and August of 2019 in Gunungmanik Village, Talaga District, Majalengka Province.

6.2.1. Research Engineering

This type of research employs a quantitative description. Descriptive method, according to Sugiyono (2005: 21), is a method that summarizes or analyzes a study result but does not make larger implications. This study was undertaken deliberately or with purpose. The approach used to identify respondents is *Total Sampling*, often known as a census, in which samples are drawn from the population as a whole.

According to (Suharsimi Arikunto, 2006) if there are less than 100 people in a population, it is preferable to collect a sample of all of them. All KOHIMA members from the areas of Ligung, Cikijing, Talaga, and Majalengka were surveyed. As many as 10 individuals responded.

6.2.2. Analysis Techniques

Diamond porter's is utilized to identify the state characteristics that influence the amount of hydroponic competitiveness. Tambunan (2013) defines competitiveness as the capacity of a commodity to enter a market and survive in that market.

Competitive Analysis (Analysis of the circumstances at the Bok Choy Plant in Light of Belin's Four Theories) (Porter, 1990). These four aspects are resource factors, demand circumstances, structure, competition and strategy, as well as linked and supporting industries.

Comparative Analysis of Competitiveness Using the Formula

RCA ij = $\frac{Xij/xit}{wj/wt}$

Where :

xij = Bok Choy plant supply value per member per week

xit = Annual supply value of Bok Choy plant members

wj = Supply value of Bok Choy plants of all members per week

wt = Bok Choy plant supply value of all members per year

6.3. Results and Discussion

6.3.1. Description of the Establishment of the Majalengka Hydroponic Community

In the beginning, in 2016, they began doing modest experiments with their expertise. At that time, hydroponic enthusiasts in Talaga District's Gunungmanik Village initiated the formation of a community known as KOHIMA , initially, there were around 10 members, but as more people were interested in learning about hydroponics, the membership grew to 40 individuals, due to the fact that not all KOHIMA members are interested in hydroponics, ten members are no longer active, and the total number of KOHIMA members is currently ten, the criteria to join KOHIMA is to plant in the members' houses.

6.3.2. Competitive Competitiveness Results

Competitiveness is aware of the aspects that affect competitiveness in the growth of Bok Choy farming enterprises among KOHIMA members. For factor analysis employing Diamond Porter-based analytical tools, which comprise condition factors, demand conditions, market structure, and associated sectors (partners). Using a sample size of 10 respondents and a scale of 1 to 4 based on the degree that influences the competitiveness of members of the Bok Choy plant agribusiness growth, the most important factor was determined. 4 (very decisive), 3 (defining), 2 (slightly decisive), and 1 (not decisive). The competitiveness scale is then aggregated into a value that may be measured by category:

2,0 – 2,5 = Low
2,6 – 3,0 = Medium
3,1 – 3,5 = High

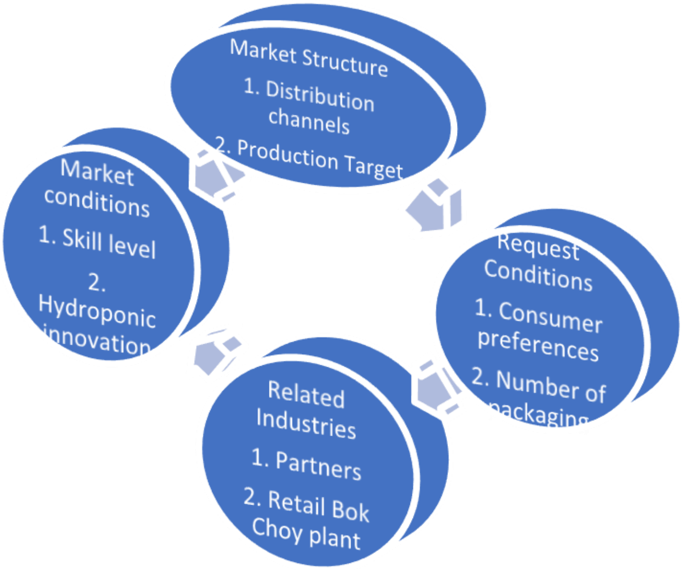

Figure 1. Using Diamond Porter, analyze how to make Bok Choy Plant's agribusiness more competitive.

The results of the Diamond Porter analysis indicate that the hydroponic cultivation innovation skill level statement has an average value between 3.1 and 3.5 in the high category, the conclusion is that the statement has a significant impact on other statements. While production targets are deemed insufficiently significant on the competition for the growth of Bok Choy agribusiness, partners and product distribution channels are categorized as low category criteria with an average score between 2.0 - 2.5.

Figure 1 illustrates the four essential elements of *Porter's Diamond Theory* that have an impact on the direction of Bok Choy 's agribusiness growth. These elements are as follows:

1. Market structural aspects, including manufacturing objectives, distribution methods, and market data.
2. Demand conditions factor, consumer preferences with the number of consumers.
3. Consider condition, cultivation innovation, skill level, and seed supply.
4. Partners and retail of Bok Choy plants are among the industry-related aspects.

6.3.3. Comparative Competitiveness Results

The variable under consideration is the ratio of a product's (Bok Choy) supply performance to the total supply value of a KOHIMA member. If RCA > 1, then the product (Bok Choy) has a significant competitive advantage. Nonetheless, if RCA is < 1, it is concluded that the product has no comparative advantage and is weakly competitive.

With the RCA (*Revealed Comparative Advantage*) formula, there are ten KOHIMA respondents who generate Bok Choy plants.

$$\text{RCA ij} = \frac{Xij/xit}{wj/wt}$$

Where :

xij = Bok Choy plant supply value per member per week

xit = Annual supply value of Bok Choy plant members

wj = Supply value of Bok Choy plants of all members per week

wt = Bok Choy plant supply value of all members per year

Based on the RCA calculations in the formula, the production of Bok Choy plants in agribusiness development for responses 1-10 is less than 1 (RCA <1), indicating that the supply of Bok Choy plants lacks a comparative advantage and has weak competitiveness. This demonstrates that the average KOHIMA member farming Bok Choy using the hydroponic method does so as a hobby and not as a business due to restricted acreage, and that KOHIMA members do not rely solely on petai for their livelihood, therefore time limitations in upkeep are also limited. In the future, though, the members will turn hydroponics into a company.

6.3.4 The Advantages of Bok Choy Plants

The advantages of hydroponics, which are the competitive advantage of Bok Choy vegetable culture, are that it is ecologically friendly, the goods produced are hygienic, the plants grow quickly, the harvest quality is preserved, and the harvest amount can be enhanced. Hydroponic vegetables are also healthier due to the absence of industrial heavy metal contamination in the soil, the fact that they are fresh, sustainable, and easy to digest. Hydroponic cultivation does not require a huge plot of land, but it should be considered in agriculture because it may be carried out in the backyard, on the roof of the home, or in other locations.

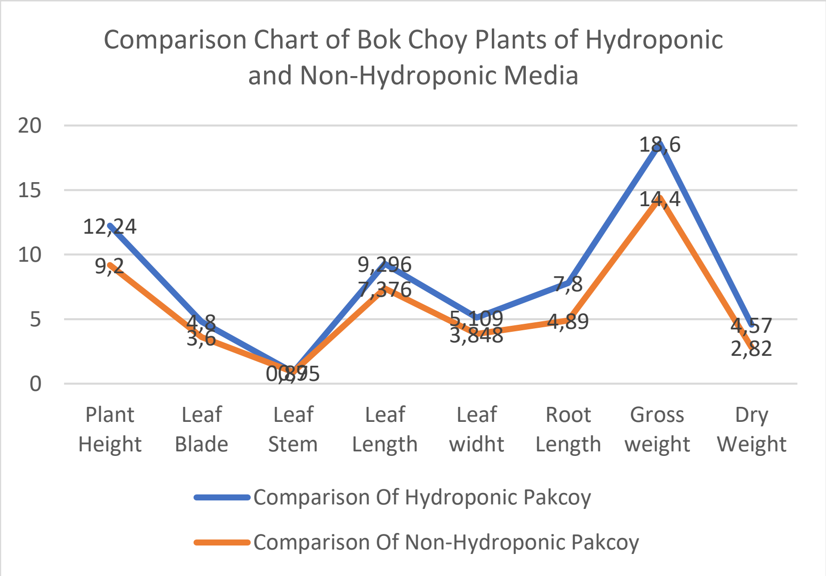

Figure 2. Comparison of Bok Choy Plants for Hydroponic and Non-Hydroponic Media

The graph above demonstrates that husk charcoal hydroponic media is significantly superior to soil and non-hydroponic media for growing mustard greens (Bok Choy). Because hydroponic material contains the necessary nutrients for the growth of mustard greens (Bok Choy).

6.4. Conclusion

Based on the results of the RCA technique of comparative competitiveness of Bok Choy 's agribusiness growth with 10 respondents, it can be concluded that Bok Choy lacks day power or is only marginally competitive. This is due to the fact that, in general, KOHIMA members engage in Bok Choy plant hydroponics as a pastime and not as their primary source of income.

6.5. Recommendations

For the development of oakcoy plant agribusiness in KOHIMA, the proportion of agribusiness that has the smallest impact on consumer preferences and production goals must be enhanced.

By enhancing the quality of Bok Choy plants, greatly expanding market share, and implementing other innovations linked to technology development, the development of Bok Choy agribusiness, which does not have above average competitiveness, must be enhanced.

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CHAPTER 7

INNOVATIVE APPROACHES TO IRRIGATION AND FERTILIZATION IN GREENHOUSES AND OPEN FIELDS

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7.1. Introduction

The source of life for people is water and agriculture. Humans cannot live without these two. When we look at human communities, they lived in places suitable for water and agriculture. Fresh water resources are decreasing day by day due to climate change. Due to this decreases, the importance of water has increased even more. 70% of usable water in the world are using in agriculture. With the development of industry, the use of water is increasing. With the decrease in water in the world, a choice must be made between the two sectors. We will get rid of hunger by using water in agriculture. Or the use of water in the industry will be preferred.

The world population is increasing by an average of 70 million every year. However, the agricultural areas used in the agricultural sector are decreasing. For such an increasing population, it is necessary to increase productivity in agriculture. For this, water, which is a common good, must be used in the most efficient way. Water, which is a common good, is increasingly commercialized and turned into a private good. This shows a change in the policies produced on water (Çamurcu 2015).

The rate of living in rural areas was approximately 70%, 50 years ago (Yalçın et al., 2016). However, migration to cities continues for various reasons and the rural population is decreasing day by day. The population ratio, which was 50% in rural areas 20 years ago, has decreased to 20% on average today (Yoloğlu et al., 2020). With a rapid urbanization, water consumption per person has increased. Water consumption is approximately four times faster than the population growth rate (Sevinç et al. 2016).

Water alone is not enough for plants to grow. Sun, plant nutrients and other things are needed for the growth of plants. The more balanced these needs of the plants are met, the higher the productivity. They need plant nutrients to get better yield from plants (Bolat et al. 2018). Some of these elements are found in the soil. However, for a balanced growth and yield, it is necessary to give these nutrients to the plants during the development period. These nutrients are called fertilizers (Çokuysal 2017). Fertilizers can be given to the plant in different ways (Dağhan 2017). Some of these methods are; By mixing with the soil before planting, by mixing with the soil during hoeing, by applying micro elements from the leaves, by mixing with irrigation water, etc. (Karaşahin 2017).

7.1.1. Water Presence in the World

The world is a very rich place in terms of water. Approximately 75% of the world is covered with water (Can et al. 2002). But a very large part of this water consists of salt water. Most of the remaining fresh water is found in glaciers and snow layers. Figure 1 shows the proportions of water in the world.

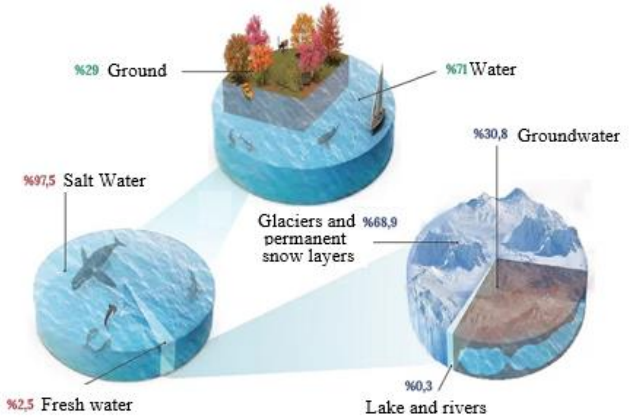

Figure 1. Earth's waters and their proportions

The world seems to be rich in water. But the amount of usable water (fresh water) is very small. The world is divided into two regions, the northern hemisphere and the southern hemisphere. The water rates in the two regions are different. Figure 2 shows the proportions of land and water in both regions.

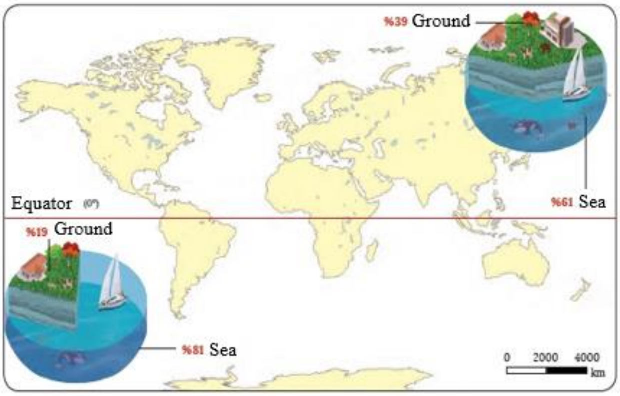

Figure 2. Waters in the northern and southern hemispheres of the world and their proportions

The northern hemisphere has fresh water twice as much land as the southern hemisphere. This causes a decrease in water rates. With the change of water ratios, changes occur in temperature and humidity ratios.

7.1.2. Water Presence in Turkey

There are many water resources in Turkey. The most important of these are forests. Forests should not be considered only as a source of oxygen. Forests are natural dams. Forests slow the rate of water and cause it to feed underground water resources.

The pastures have a very important task such as the infiltration of rain water into the soil. Thus, instead of a rapid flow from the surface, rain water feeds the ground water. This causes an increase in our water availability. As the pastures are used for other purposes instead of their main function, it causes a decrease in our groundwater. This has been happening much more in recent years. Agricultural lands, which are the most important assets of Turkey, have been used for other purposes in recent years due to the high return of other sectors. This causes a decrease in agricultural lands.

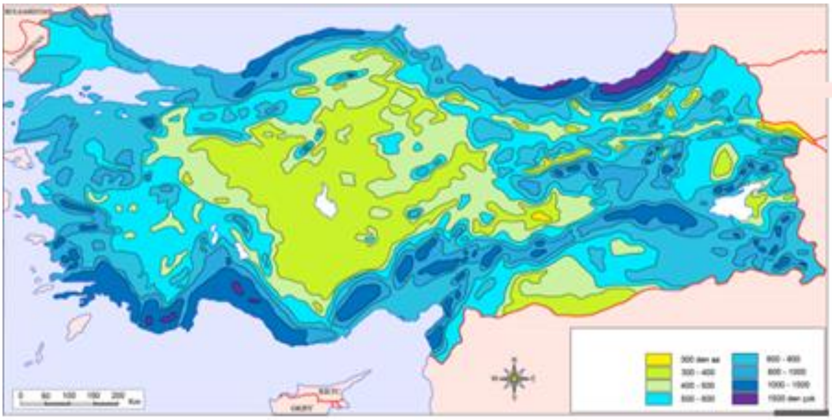

Figure 3. Annual precipitation amounts of Turkey are shown.

There is approximately 500 billion m^3 of rainfall annually in Turkey. But half of this water cannot be used because of evaporation. Most evaporation occurs on soil and plants. A quarter of the precipitation enters the seas, lakes and rivers. Here, water from rivers and lakes is used. Since the waters going to the seas are mixed with salt, it is very costly to use. Separation of salt water is both difficult and expensive. Approximately 70 billion m^3 of annual precipitation is mixed with groundwater (Ögenler ve ark. 2017). Figure 3 shows the annual precipitation in Turkey.

In our country, there are underground and surface waters, as well as underground and surface waters from neighboring countries. Surface waters; It is very easy to use the water in rivers and lakes. The use of groundwater is sometimes not preferred in terms of economic and technical aspects. Figure 4 shows the surface water resources of Turkey.

Figure 4. Surface water resources of Turkey.

7.1.3. Agricultural Production and Water Use

About 10% of the land on earth can be used as agricultural land. This comes with very low usage. About a quarter of such a small use consists of grazing lands. This requires a very large production with a small amount of agricultural land. Despite the increasing population, there is a decrease in agricultural lands. This means higher productivity in agriculture is needed. Technology should be used for this (Aydoğdu et al. 2015).

The use of water in agriculture alone does not mean that it is used for the needs of its people. In agriculture, planting is also done to meet the needs of animals. By comparison, more water needs to be consumed for the production of animal products. If it is shown as an example; It is necessary to produce 1kg of milk and consume $0.9m^3$ of water, but to produce 1 kg of potatoes, it is necessary to consume $0.2m^3$ of water.

Turkey has very large agricultural areas. Most of these agricultural lands are also irrigated. The irrigable agricultural areas are increasing day by day. With the dams, ponds and drillings built, irrigable agricultural areas are increasing.

7.1.4. Irrigation Methods

We can express irrigation as follows. When the plant cannot meet the water it needs naturally, it is given to the plant when and in the amount it needs. There are different methods of irrigation. Surface irrigation methods: keel, pan, long pan and furrow. Pressure irrigation methods: sprinkler and drip The irrigation method to be used varies according to reasons such as open or closed land, plant type, soil slope, and climatic conditions.

7.2. Methods

Agriculture is an indispensable part of humankind. Agriculture is necessary for people to live. While the number of people is increasing day by day, agricultural areas are decreasing. For these reasons, there are many studies on the agricultural sector. Irrigation systems are at the forefront of these. Irrigation systems are made as surface irrigation, pressure irrigation and subsurface irrigation.

Kanber and his friends have studied about surface irrigation. No external factors are used for surface irrigation. Irrigation is done completely according to the slope. The water moves according to the slope. Channels are opened for the movement of water. The sizes of these channels vary according to the condition of the plants. Since the dimensions of the channels are adjusted manually, the efficiency drops a lot. Although the productivity is very low, it is the most used irrigation method (Kanber et al. 2003).

When it comes to pressurized irrigation, the first thing that comes to mind is the drip system. Pressure irrigation includes sprinkler, mini spring and drip systems. In the pressurized system, an external energy is needed. With this energy supplied from outside, water is sent by pressure. Although drip systems are expensive, their efficiency is very high. For these reasons, it is preferred day by day. Barunkaya worked on drip systems. It has increased efficiency by making different applications in my drip system. Barunkaya has installed four different drip systems. With this system, the plant started to yield in 20, 30, 35 and 40 days. The drip system has achieved very high efficiency (Barunkaya 2019).

7.3. Material and Method

In the study, it was aimed to increase the productivity by irrigation and fertilization according to the needs of the plant grown in the greenhouse. While doing this, the possibility of remote monitoring and control is provided. Greenhouses are outside the residential areas. For this reason, it is very costly to go and irrigate. With the automation system developed in this study, remote irrigation and fertilization were performed and the costs were minimized. The general study of the study is shown in Figure 5.

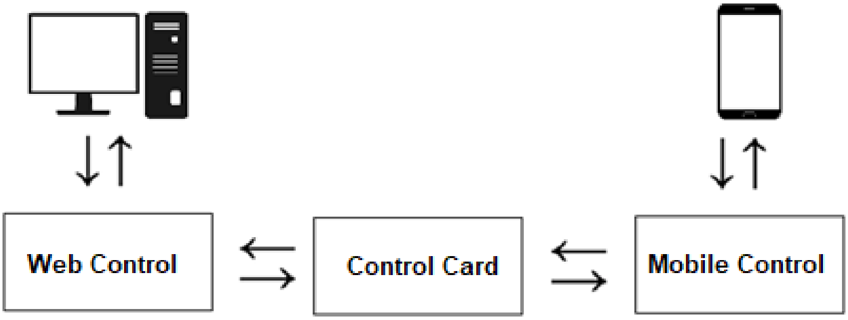

Figure 5. General operation.

In the developed automation system, the water needs of the plants are met by drip irrigation. The fertilizer mixture is prepared in the tank. The automation system gives the fertilizers from these tanks to the irrigation water at the required rate during irrigation. In this way, plant nutrients are delivered to the plants along with the irrigation water.

In addition, the pH level of the irrigation water is also important. When the pH of the water is not suitable, plants may not be able to take in nutrients. An acid tank has been added to the system to balance the acidity in the system we have developed for this purpose. The pH sensor in the automation system is used to create the pH grade water suitable for the plant. The pH level of the water is measured instantly and the required acid is given to the irrigation water from the tank.

Especially in soilless agriculture, irrigation water and all the nutrients needed by the plant should be met. In the developed automation system, the nutrients needed by the plant are automatically balanced. This shows its effect in terms of yield and quality in plants in our study.

The automation device developed in the study is tested in the field. Positive results were obtained thanks to automation in the trial areas. Figure 6 shows the automation device used in the open field in the blueberry plant in Mersin region.

The realized application was run in more than one place. Figure 7 shows the automation device used in the open field in the blueberry plant in Milas. In the continuation of this study, it is planned to use artificial intelligence algorithms to determine the acid and fertilizer rates to be given to the irrigation water by looking at the EC and pH values of the water obtained by drainage, especially in soilless agriculture. Thus, the amount of fertilizer that the plant can use will be determined. Therefore, the amount of fertilizer to be given to the irrigation water will be given in a more balanced way thanks to artificial intelligence.

Figure 6. Automation device used in open field in blueberry plant in Mersin region.

In this way, not using too much fertilizer and not using too much water will provide great savings in terms of cost. In addition, giving too much fertilizer to the plant reduces the yield. In particular, thanks to the balanced and sufficient supply of fertilizer to the plant, yield and quality will increase.

Figure 7. Automation device used in open field in blueberry plant in Milas region

7.3.1. Control Card

The control card is the main brain of the system. All transactions are made from the control card. Temperature, humidity, wind speed, wind direction and all other sensors are connected to the control card. The data coming from the sensors are processed on the control card. Figure 8 shows the control card used in the system.

Figure 8. Control card.

7.3.2. Mobile Control

One of the most important advantages of the implemented system is the possibility of remote monitoring and control. Greenhouses or fields are located outside the residential areas. Traveling back and forth to irrigate plants is costly. Another cost is time. The time required for irrigation varies according to the type of plant. At least two hours are required for irrigation. Efficiency is increased by remote irrigation. In the study, it offers the opportunity to control from all places where there is internet.

All people have cell phones. The mobile phone is always with us. The easiest and simplest method for remote control of the system is the mobile application. With the mobile application, the control of the greenhouse or field is always provided. For this purpose, a mobile application was implemented in the study. Figure 9 shows the mobile interface used in the system.

Figure 9. Mobile interface.

The sensors are displayed first on the mobile interface. Outdoor temperature and humidity values are very important for irrigation. Indoor and outdoor temperature and humidity values are displayed in the sensors section of the mobile interface. The irrigation time of the plant varies according to the indoor and outdoor values. Considering these values, less or more irrigation is done. In this way, productivity increases. The most important part of irrigation is to give the plant as much water as it needs.

There are also outdoor wind speed and wind direction values in the sensors section. Outdoor wind speed is very important especially for greenhouses. After the wind speed exceeds a certain value, it creates great problems in greenhouses. For this reason, all vents are closed automatically when the wind speed exceeds a certain speed. It can destroy greenhouses at high wind speeds. The wind direction is important for the position of the ventilation flaps. In which direction the wind blows, the ventilations in that direction are closed, and the ventilations in the opposite direction are opened. Thus, it is ensured that the greenhouse is not damaged.

Ventilation can be adjusted according to the user's request. In addition, the automation system can open and close the ventilations at certain rates in order to maintain the temperature and humidity in the greenhouse. In the irrigation system, it can be turned on and off remotely. In addition, irrigation can be done by preparing a daily or weekly irrigation program. Thanks to the irrigation program, forgetting an irrigation caused by the users is prevented.

Figure 10. Device interface.

The work performed is controlled from the screen on the device as well as the mobile application and web control. Figure 1.10 is the screenshot on the device. Management is provided with the touch screen on the device. The device can be controlled both from the interface on itself and from the mobile interface at the same time. The interfaces of the two applications are different.

In the automation device developed in the study, the farmer can be informed in cases involving risk. For example, the temperature drops to levels that will harm the plant, and the wind speed rises above the limits. Notifications can be set according to the data coming from all sensors in the automation system. These notifications are sent to the farmer's phone via SMS.

In the automation system, a record of all transactions made is also kept. In this way, the processes made during the plant production period can be followed and evaluated.

7.4. Content/Result and Discussion

The system realized is also an experimental study. The system is also used in a real environment. The irrigation system was remotely controlled and monitored. The amount of water used was calculated. It was calculated how much productivity increase was made from the irrigation system. For the system, two separate irrigations were made inside the greenhouse. It is an irrigation done without an automation system in the first irrigation. The other irrigation was carried out with the automation system we have developed. Figure 11 shows the amount of water used in two different systems.

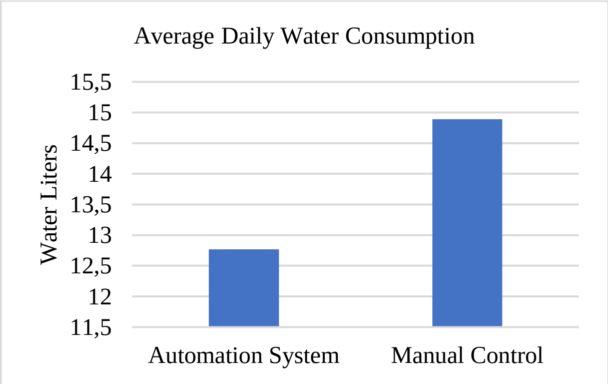

Figure 11. Average daily water consumption

The daily water consumption of the plant varies. In the study, daily water consumption was taken into account for a healthy result. When the daily water consumption was examined, the normal irrigation was 14.89 liters. In the system made with the automation system, the average daily water consumption was 12.7 liters. The automation system we have developed has achieved a 14.90% efficiency increase.

Strawberry plant was used in the study. Strawberry plant was grown in two different environments. One side is grown as calcine. The other part was grown by automation. The same type of strawberry was used as the comparison would be made in the two systems. Strawberries were also planted. The environment of strawberries was exactly the same. The same product was grown in two different systems. The grown urea were collected. The results were compared. Figure 12 shows the crops produced in two different systems.

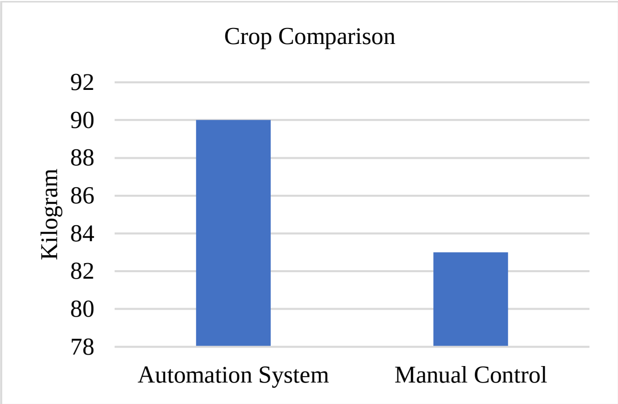

Figure 12. Crop quantities

Under normal conditions, 83 kilograms of products were grown. 90 kilograms of products were grown with the automation system. The products grown with the automation system were irrigated as necessary. For this reason, the amount of crops has increased.

7.5. Conclusion

Water is indispensable for plants. Without water, plants cannot grow. The plant should be given the required amount of water. Too much or too little water reduces productivity. Irrigation takes the longest time in plants. Irrigation in plants takes both time and cost. With this study, productivity increase in irrigation has been achieved. The work can be monitored and controlled from both web and mobile applications. Thus, irrigation can be done remotely without going to the greenhouse or field. This saves both travel costs and time. Sensors were added to the study and the information inside and outside the greenhouse was monitored. Thanks to these, better irrigation was made. With the wind speed and wind direction data, the greenhouse is protected from external effects. With this study, 14.90% productivity increase was achieved in the irrigation system. An 8.43% increase in crop productivity was achieved.

7.6. Recommendation

Artificial intelligence application will be added to the system in the next study. Detection of plant diseases and nutrient deficiency will be made by using image processing techniques. Thus, nutrient deficiency of the plant and early diagnosis of diseases will be ensured. In this way, productivity will be increased.

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Brief Curriculum Vitae

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CHAPTER 8

PROMOTING ADVENTITIOUS ROOT FORMATION IN RAMSEY ROOTSTOCK BY IMMERSING HARDWOOD CUTTINGS IN HOT $CaCO_3$ SOLUTION

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8.1. Introduction

Proper rootstock choice in viticulture has a substantial role in overcoming various biotic and abiotic stress agents in prevailing vineyard circumstances (Kok, 2020). Some attributes of grapevine, including relations grapevine-water, phenology, vigor, production and quality of grapes are quite influenced by preferred grapevine rootstock for grape growing (Keller, 2020).

Some of grapevine rootstocks may exhibit great difficulties in adventitious rooting when the propagated via hardwood cuttings. Although hardwood cuttings of *Vitis vinifera* varieties are easily rooted, some species of grapevine rootstocks are difficult-to-rooting (Winkler et al., 1974). Fundamental mechanisms that induce or regulate the initiation and development of adventitious roots on stem cuttings from woody species is an abstruse physiological, genetic and environmental process and still extensively unknown (Pijut et al., 2011).

Variation in adventitious root formation capacity of cuttings in plant species has been associated with numerous factors, including season, genotype-specific, cuttings position and plant hormone concentration (Kibbler et al., 2004; Amri et al., 2010). It has been usually acknowledged for a long time that high auxin and low cytokinin ratios have including effects on adventitious root formation (Kuroha et al., 2005). Sugar availability is another major factor in determining adventitious rooting in the cuttings as well as hormone signals (Abarca, 2021).

Grapevine rootstocks differ from each other in terms of rooting abilities of their cuttings. It is well-known in viticulture fact that 41B, 140Ru, 420A, Dodridge and Salt Creek from grapevine rootstocks have been commonly known to have unsatisfactory rooting potential (Çelik, 2011). Low rooting ability of hardwood cuttings in some grapevine rootstocks is serious problem, affecting production negatively in viticulture. In this circumstance, it could be utilized from various applications for enhancing rooting success of hardwood cuttings from difficult-to-root grapevine rootstocks (Çelik, 2011; Ağaoğlu, 2002; Kok, 2018).

One of the applications to improve rooting rates of cuttings is immersing application of hardwood cuttings in hot water or calcareous containing water for a certain time. The aim of this study is to determine the effects of immersing hardwood cuttings with low rooting ability in

$CaCO_3$ solutions with various doses and temperatures on adventitious root formation of Ramsey rootstock.

8.2. Material and Methods

8.2.1. Research site

This research was conducted in plant rooting systems belonging to Department of Horticulture, Faculty of Agriculture, Tekirdağ Namık Kemal University, Turkey (40°59′33.45′′N-27°34′44.28′′E, 19 m. a.s.l.) in 2017.

8.2.2. Plant material

In the research, it was utilized from hardwood cuttings of grapevine rootstock *Vitis* x *champinii* (Planch.) Ramsey as plant material. The rootstock *Vitis* x *champinii* (Planch.) Ramsey has been widespread employed in different grape growing regions of the world. The most striking features of this grapevine rootstock are that it is a nematode resistant rootstock and has an excessive vegetative growth. However, its hardwood cuttings have recalcitrant attributes to rooting (difficult-to-root).

8.2.3. Preparation of hardwood cuttings

In the study, hardwood cuttings of grapevine rootstock were purveyed from mother grapevines of rootstock Ramsey grown in Manisa Viticulture Research Institute, Manisa, Turkey. For the preparation of hardwood cuttings, one-year-old canes were selected from mother grapevine rootstocks and these were prepared according to grapevine hardwood cutting standard, with a length of 30 cm, a diameter of 8-10 mm and 3-4 buds.

1.2.4. Preparation of $CaCO_3$ solutions and immersion treatments of hardwood cuttings in hot $CaCO_3$ solution

Prior to research, $CaCO_3$ was planned to be used as a source of calcareous and chemical $CaCO_3$ (>99.5%) was purchased from Merck Company. During the preparation of $CaCO_3$ solutions (calcareous water), it was utilized from four different doses (0, 7.5, 15 and 30 mM) of $CaCO_3$ and three different temperature ranges (T_1: 20-22 °C, T_2: 30-32 °C and T_3: 40-42°C) of $CaCO_3$ solution. For the implementation of immersion treatments, rectangular plastic containers of 1010 x 690 x 610 mm were used and different doses of $CaCO_3$ solutions with varying temperatures were filled in these containers. In the study, immersion type water heater resistances with 1500 W of power and working with 220 V potential were used to heat $CaCO_3$ solutions in the plastic containers. After hardwood cuttings had prepared according to standard for grapevine rootstock hardwood cutting, these were fully immersed in hot $CaCO_3$ solutions at below-mentioned doses and solution temperature ranges for 96-hour (Table 1).

Table 1. Immersion treatments of hardwood cuttings in $CaCO_3$ solution

$CaCO_3$ solution temperature ranges (°C)	**$CaCO_3$ dose (mM)**	**Immersion time (hour)**
T_1 (20-22)	0	96
	7.5	96
	15	96
	30	96
T_2 (30-32)	0	96
	7.5	96
	15	96
	30	96
T_3 (40-42)	0	96
	7.5	96
	15	96
	30	96

8.2.5. Rooting of hardwood cuttings

After waiting of hardwood cuttings in $CaCO_3$ solutions completed, these were taken out of plastic containers filled with $CaCO_3$. Subsequently, whole hardwood cuttings were moved onto rooting mediums, comprising sand-perlite for their rooting. In the course of hardwood cuttings rooting, necessary cultural practices such as irrigation and shading were conducted.

8.2.6. Measurements and calculations used in the research

After 90-day period for rooting of hardwood cuttings were completed, these were disrooted from rooting mediums and later, measurements and calculations mentioned-below were successively performed for hardwood cuttings.

8.2.7. Determination of shoot attributes of hardwood cuttings

Bud bursting rate (%), shoot length (cm), shoot fresh weight (mg), leaf number of shoot (no.) and SPAD value of leaf were calculated and measured.

8.2.8. Determination of root attributes of hardwood cuttings

Adventitious rooting rate (%) adventitious root number (no.), adventitious root length (cm), adventitious root fresh wight (mg) and callus weight of hardwood cutting basal (mg) were calculated and measured.

8.2.9. Calculation of SPAD value of leaf

Leaf chlorophyll content in leaves of hardwood cutting was measured by means of a portable SPAD instrument (SPAD-502, Konica Minolta).

8.2.10. Statistical analysis

The research was organized based on completely randomized parcels with four replicates and two factors. Each replicate consisted of 20 hardwood cuttings. Analysis of variance (ANOVA) was performed through using statistical software TARIST. Differences among the means were compared through Fisher's least significant difference (LSD) test at 5% level.

8.3. Result and Discussion

Table 2 point out that interaction means of $CaCO_3$ solution temperature x $CaCO_3$ dose about shoot and root attributes of hardwood cuttings are not statistically significant at 5% level. Pertaining to current study, main effects of $CaCO_3$ solution temperature and $CaCO_3$ dose on shoot and root attributes of hardwood cuttings are respectively shown in Figure 1-20.

As far as bud bursting rates are concerned, it is observed in Figure 1 and 2 that main effects of $CaCO_3$ solution temperature and $CaCO_3$ dose have no significant effects on bud bursting rates ($p<0.05$). In present study, bud bursting rate means ranged from 70.62 (T_3: 40-42 °C) to 76.56% (T_2: 30-32 °C). On the other hand, the highest bud bursting rate mean was recorded for 30 mM $CaCO_3$ treatment (84.16%) when the compared to 0 mM $CaCO_3$ treatment (59.16%).

Table 2. Interaction means of $CaCO_3$ solution temperature x $CaCO_3$ dose about shoot and root attributes of hardwood cuttings

$CaCO_3$ solution temperature ranges (°C)	**$CaCO_3$ dose (mM)**	**Bud bursting rate (%)**	**Shoot length (cm)**	**Shoot fresh weight (mg)**	**Leaf number of shoot (no.)**	**SPAD value of leaf**	**Adventitious rooting rate (%)**	**Adventitious root number (no.)**	**Adventitious root length (cm)**	**Adventitious root fresh weight (mg)**	**Callus weight of cutting basal (mg)**
T_1 (20-22)	**0**	60.00	5.56	500.00	4.01	21.77	33,75	2.25	2.71	173.75	582.49
	7.5	72.50	6.62	687.50	5.16	24.67	47.50	4.00	5.03	322.40	542.23
	15	78.50	7.00	820.00	5.71	29.69	66.25	5.75	7.50	626.00	484.25
	30	83.75	9.03	980.00	6.60	34.22	85.00	6.57	9.25	746.10	814.75
T_2 (30-32)	**0**	65.00	5.93	545.00	4.39	22.15	37.50	2.87	3.87	202.12	480.25
	7.5	75.00	6.97	705.00	5.26	26.02	57.50	4.75	6.05	495.00	574.00
	15	80.00	7.41	890.00	6.02	31.06	72.50	6.05	7.87	678.30	691.32
	30	86.25	9.83	1017.50	6.81	35.10	88.75	7.21	10.03	815.00	877.25
T_3 (40-42)	**0**	52.50	4.99	420.00	3.85	20.42	26.25	1.50	1.82	129.95	390.50
	7.5	70.00	6.32	632.50	4.72	23.58	43.75	3.75	4.10	288.75	483.50
	15	77.50	6.59	775.00	5.35	28.46	62.50	5.50	7.87	540.59	605.61
	30	82.50	8.15	935.00	6.17	32.28	78.75	6.27	8.52	700.80	733.75
	$LSD_{5\%}$	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Means within columns followed by the same letter are not significantly different at 5% level

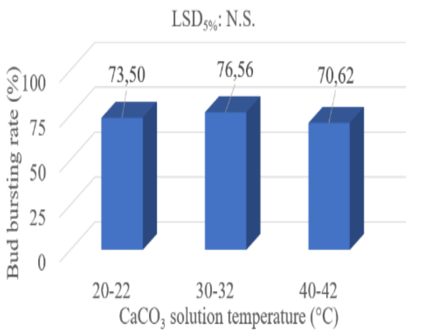


Figure 1. Main effect of $CaCO_3$ solution temperature on bud bursting rate

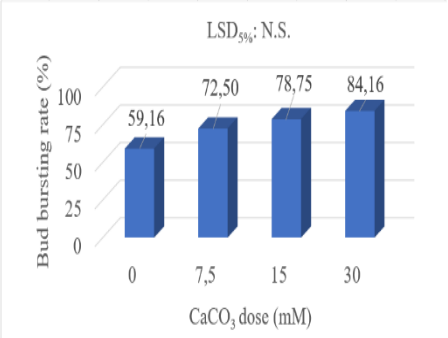


Figure 2. Main effect of $CaCO_3$ dose on bud bursting rate

When it comes to shoot length depicted in Figure 3 and 4, it is noteworthy that the main effects of $CaCO_3$ solution temperature and $CaCO_3$ dose have important effects on shoot length ($p<0.05$). In the study, the highest shoot length means were respectively 7.53 cm for T_2 (30-32 °C) treatment, 7.05 cm for T_1 (20-22 °C) treatment and 6.51 cm for T_3 (40-42 °C) treatment. Besides, 30 mM $CaCO_3$ treatment caused the highest shoot length mean (9.00 cm) compared with 0 mM $CaCO_3$ treatment (5.49 cm).

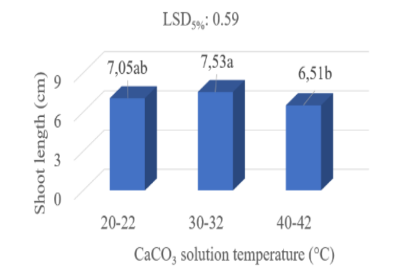


Figure 3. Main effect of $CaCO_3$ solution temperature on shoot length

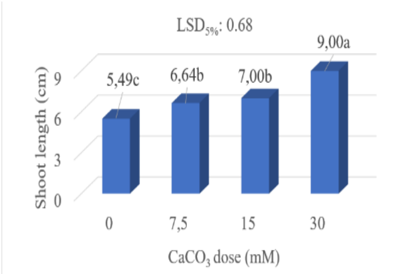


Figure 4. Main effect of $CaCO_3$ dose on shoot length

As far as shoot fresh weight is concerned displayed in Figure 5 and 6, main effects of $CaCO_3$ are statistically found to be significant ($p<0.05$). While the highest shoot fresh weight mean was 789.37 mg for T_2 (30-32 °C) treatment, the lowest shoot fresh weight mean was 690.62 mg for T_3 (40-42 °C) treatment. Moreover, the highest shoot fresh weight mean was recorded for 30 mM $CaCO_3$ treatment (977.50 mg) and were followed by $CaCO_3$ treatments of 15 mM (828.33 mg), 7.5 mM (675.00 mg) and 0 mM (488.33 mg).

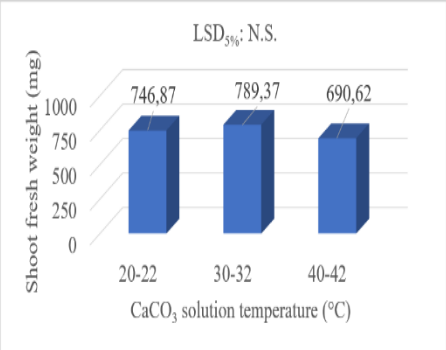


Figure 5. Main effect of $CaCO_3$ solution temperature on shoot fresh weight

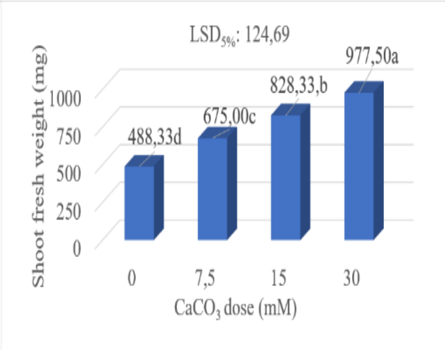


Figure 6. Main effect of $CaCO_3$ dose on shoot fresh weight

From the point of view of leaf number of shoot demonstrated Figure 7 and 8, main effects of $CaCO_3$ dose have significant effects on leaf number of shoot ($p<0.05$). In the research, the highest leaf number means of shoot were successively obtained from T_2 (30-32 °C) treatment (5.62 no.), T_1 (20-22 °C) treatment (5.37 no.) and T_3 (40-42 °C) treatment (5.02 no.). Furthermore, among $CaCO_3$ doses, leaf number means of shoot varied from 4.08 (0 mM) to 6.53 no. (30 mM).

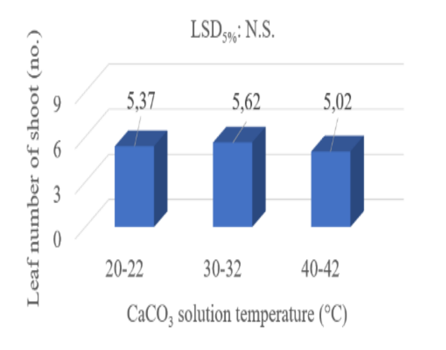


Figure 7. Main effect of $CaCO_3$ solution temperature on leaf number of shoot

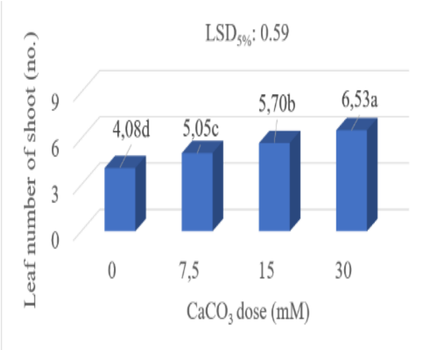
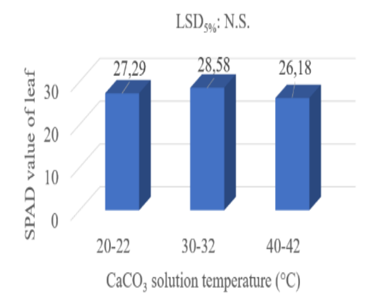


Figure 8. Main effect of $CaCO_3$ dose on leaf number of shoot

Concerning SPAD value of leaf represented in Figure 9 and 10, main effects of $CaCO_3$ dose is statistically determined to be significant ($p<0.05$). In current study, the highest SPAD value mean was recorded for T_2 (30-32 °C) treatment (28.58) when the compared to T_1 (20-22 °C) treatment (27.59) and T_3 (40-42 °C) treatment (26.18). On the other hand, 30 mM $CaCO_3$ treatment resulted in the highest SAPD value mean (33.87) than $CaCO_3$ treatments of 0 mM (21.45), 7.5 mM (24.75) and 15 mM (29.73).



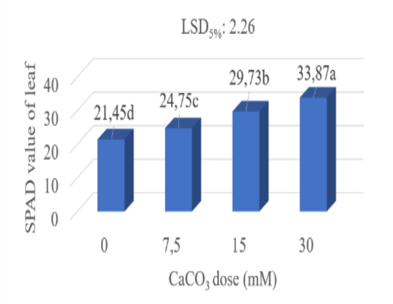
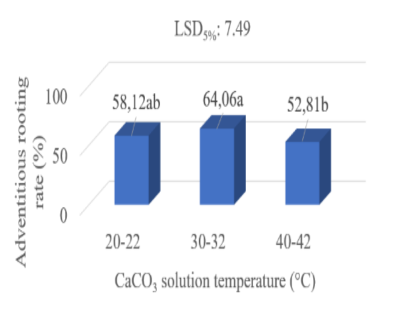


Figure 9. Main effect of $CaCO_3$ solution temperature on SAPD value of leaf

Figure 10. Main effect of $CaCO_3$ dose on SAPD value of leaf

Root emerging organically from any section of plant other than the radical or previously differentiated cells are referred to adventitious roots (Casson & Lindsey, 2003). With respect to adventitious rooting rates displayed Figure 11 and 12, main effects of $CaCO_3$ solution temperature and $CaCO_3$ dose are statistically determined to be significant ($p<0.05$). In present study, the lowest adventitious rooting rate mean was 52.81% for T_3 (40-42 °C) treatment whereas the highest adventitious rooting rate mean was obtained from T_2 (30-32 °C) treatment (64.06%). Moreover, 30 mM $CaCO_3$ treatment led to the highest adventitious rooting rate mean (84.16%) than $CaCO_3$ treatments of 0 mM (32.50%), 7.5 mM (49.58%) and 15 mM (67.08%).



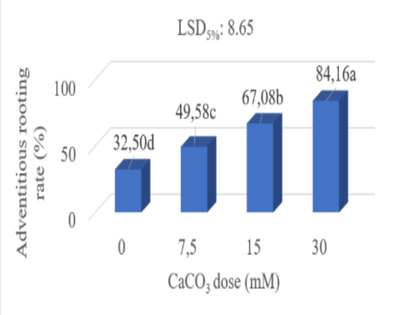


Figure 11. Main effect of $CaCO_3$ solution temperature on adventitious rooting rate

Figure 12. Main effect of $CaCO_3$ dose on adventitious rooting rate

The rooting of a cutting or its recalcitrance to rooting are complex attributes that are frequently regulated by means of many genes (Sharma et al., 2015). In the matter of adventitious root number indicated in Figure 13 and 14, it is viewed that main effects of $CaCO_3$ solution temperature and $CaCO_3$ dose have significant effects on adventitious root number ($p<0.05$).

While the highest adventitious root number mean was 5.22 no. for T_2 (30-32 °C) treatment, the lowest adventitious root number mean was 4.25 no. for T_3 (40-42 °C) treatment. By the same token, 30 mM $CaCO_3$ treatment caused the highest adventitious root number mean (6.68 no.) and were followed by $CaCO_3$ treatments of 15 mM (5.76 no.), 7.5 mM (4.16 no.) and 0 mM (2.20 no.).

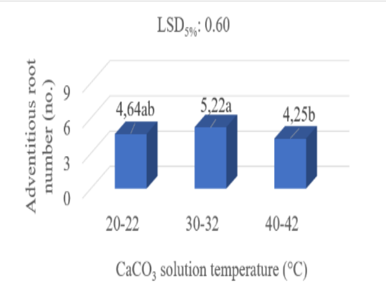


Figure 13. Main effect of $CaCO_3$ solution temperature on adventitious root number

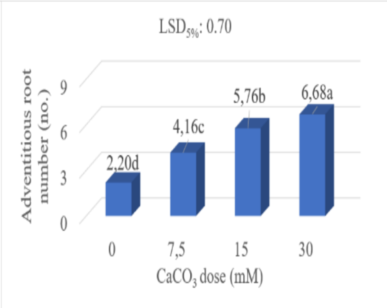


Figure 14. Main effect of $CaCO_3$ dose on adventitious root number

Concerning adventitious root length, main effects of $CaCO_3$ solution temperature and $CaCO_3$ dose are statistically found to be significant ($p<0.05$). In the study, the highest adventitious root length means were respectively 6.95 cm for T_2 (30-32 °C) treatment, 6.12 cm for T_1 (20-22 °C) treatment and 5.58 cm for T_3 (40-42 °C) treatment (Figure 15). Further, among $CaCO_3$ doses, adventitious root length means varied from 2.80 (0 mM) to 9.26 cm (30 mM) (Figure 16).

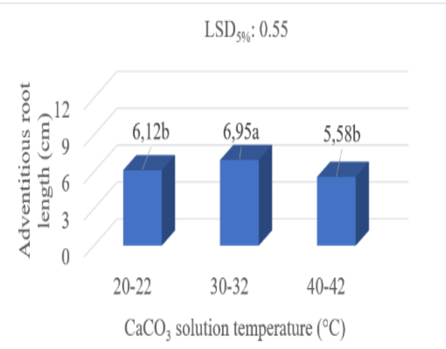


Figure 15. Main effect of $CaCO_3$ solution temperature on adventitious root length

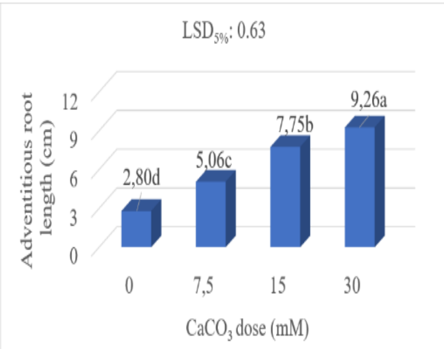


Figure 16. Main effect of $CaCO_3$ dose on adventitious root length

As for adventitious root fresh weight shown in Figure 17 and 18, main effects of $CaCO_3$ dose have crucial effects on adventitious root fresh weight ($p<0.05$). In current study, the highest adventitious root fresh weight means were successively obtained from treatments of T_2 (30-32 °C) (547.60 mg), T_1 (20-22 °C) (467.06 mg) and T_3 (40-42 °C) (415.02 mg). Moreover, the highest adventitious root fresh weight means were recorded for $CaCO_3$ treatments of 30 mM (753.96 mg) and 15 mM (614.96 mg) when the compared with $CaCO_3$ treatment of 7.5 mM (368.71 mg) and 0 mM (168.60 mg).

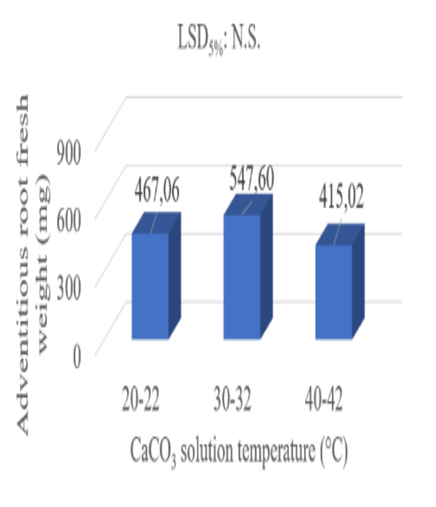


Figure 17. Main effect of $CaCO_3$ solution temperature on adventitious root fresh weight

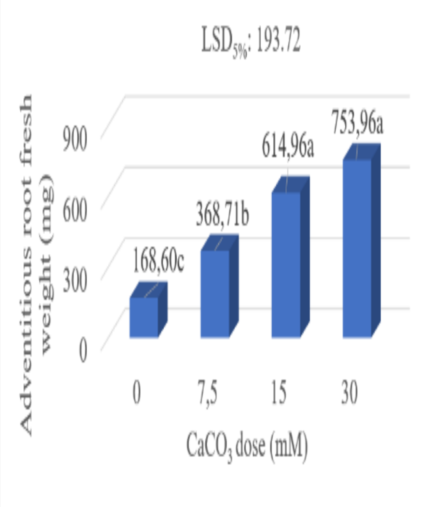


Figure 18. Main effect of $CaCO_3$ dose on adventitious root fresh weight

With regard to callus weight of cutting basal, main effects of $CaCO_3$ solution temperature and $CaCO_3$ dose are statistically determined to be significant effects ($p<0.05$). The highest callus weight means of cutting basal was obtained from T_2 (30-32 °C) treatment (655.70 mg) and were followed by treatments of T_1 (20-22 °C) (607.49 mg) and T_3 (40-42 °C) (553.34 mg) (Figure 19). However, 30 mM $CaCO_3$ treatment result in the highest callus weight mean of cutting basal (808.58 mg) compared to 0 mM $CaCO_3$ treatment (475.49 mg) (Figure 20).

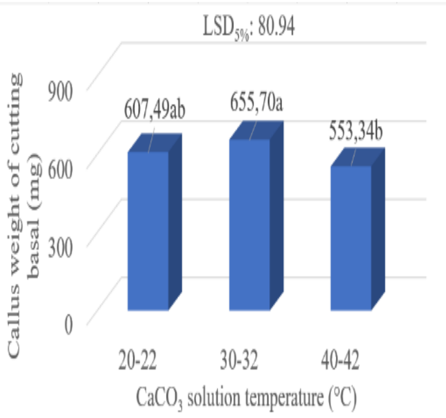


Figure 19. Main effect of $CaCO_3$ solution temperature on callus weight of cutting basal

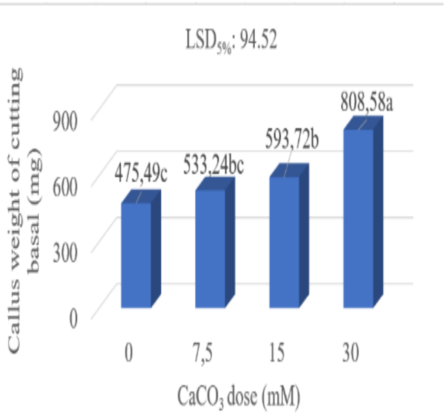


Figure 20. Main effect of $CaCO_3$ dose on callus weight of cutting basal

8.4. Conclusion

Adventitious root formation is one of the most important characteristics for woody plant species propagated by means of vegetative methods as well as grapevine rootstocks. The low rooting ability of hardwood cuttings taken from some grapevine rootstock species is one of the important difficulties encountered in viticulture. In present research, hardwood cuttings were immersed in different doses of $CaCO_3$ solutions with varying temperatures in order to increase their rooting ability. As a consequence of this research, the most favorable results about root attributes of hardwood cuttings were successively obtained from T_2 (30-32 °C), T_1 (20-22 °C) and T_3 (40-42°C) from temperature ranges of $CaCO_3$ solution. On the other hand, research findings revealed that rising doses of $CaCO_3$, including 7.5 mM, 15 mM and 30 mM also caused better improvements in adventitious root formation of hardwood cuttings and especially, 30 mM $CaCO_3$ dose gave rise to the best adventitious root formation of hardwood cuttings of Ramsey rootstock.

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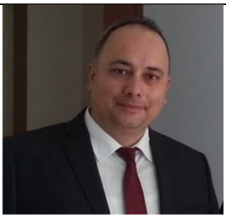
Brief Curriculum Vitae



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CHAPTER 9

CURRENT DEVELOPMENTS IN AGRICULTURAL WASTE MANAGEMENT: PRODUCTION OF NANOMATERIALS BY GREEN SYNTHESIS AND THEIR USE AS ADSORBENTS

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9.1. Introduction

Nanotechnology refers to the promising technology applied at the nanoscale, which means processing materials at the molecular or atomic level to create new materials with superior optical, reactive, catalytic, conductive, or magnetic properties (Jain et al., 2021; Dermates et al., 2018). The unique properties of nanomaterials could be used for applications that benefit society (Bhushan, 2017). While nanotechnology represents a huge trend in this sense, it gained an official identity with the 21st Century Nanotechnology Research and Development Act in 2003 (US Senate, 2003). Nanotechnology is currently applied in various technology and industry sectors such as pharmacy, food safety, energy, and computer (Dermates et al., 2018).

The presentation of Nobel Prize-winning physicist R. Feynman at the national conference held in the USA, in 1959 is considered to be the first academic talk about nanotechnology (Baig et al., 2021). The successful results of studies using nanotechnology in waste management in recent years have made this approach seem promising and nanomaterials have been frequently used in waste management (Cheriyamundath & Vavilala, 2020). Although the rapid progress of research in nanomaterials science shows increasing potential, there is not much information about their application on an industrial scale.

Nanomaterials are defined as natural or manufactured materials where more than 50% of the particles are in the 1-100 nm size range (Baig et al., 2021; Dermates et al., 2018; Bleeker et al., 2013). Nanoparticles vary in magnitude, surface area, form, charge, solubility, etc. They have unique chemical and biological features depending on the conditions (Gatoo et al., 2014). In order for these particles to behave well as an adsorbent in waste management, for example, in wastewater treatment, researchers try to synthesise nanoparticles with desired properties in this context.

Nanotechnology has found wide use in wastewater treatment, especially in the scope of adsorption applications, which is effective in removing a wide variety of water pollutants by providing low cost, high efficiency, simplicity of use, and flexibility. In addition, there are various studies in the area of nanotechnology to invent superior nanoparticle combinations that could effectively remove the complications of disseminating metals from aqueous solutions (Hussain et al., 2019; Dharmapriya et al., 2021). In addition, due to their active surface areas and high porosity, nano adsorbents are highly effective in adsorbing pollutants of different sizes without emitting any hazardous discharge (Pacheco et al., 2006).

Numerous investigations have been carried out on various subjects for revealing the physical properties of nano-sized structures more clearly, producing new nanomaterials, and using them in the solution of environmental problems. With the help of the superior properties of nanostructured particles, they have been used in many industrial fields, especially in medicine, electrical-electronics, biomedical, automotive, and chemistry sectors (Hristovski et al., 2007). Nanoparticles could be metallic (silver, gold, copper, palladium, platinum, etc.), metal oxide-based (bonding the metal center with oxo (M-O-M), hydroxo bridges-based (M-OH-M), alloy-based (alloys produced with different element combinations) and magnetic. They can be of different types, such as magnetic components (iron, nickel, and cobalt), or chemical component (Pal et al., 2019).

In this study, the method of green synthesis, which is an environmentally friendly method that aims to reuse waste, reduce energy requirements and use natural materials for the environment, has been investigated in detail. This method removes the hazardous effects on the environment and human health due to the toxic metabolites concerned with the traditional approach (Cifci, 2022). In this way, it is considered a less harmful, sustainable, and cost-effective option than physical and chemical techniques (Ying et al., 2022).

9.2. Nanoparticle Synthesis Methods

The physicochemical and biological methods used for nanoparticle synthesis are divided into two categories as top-down and bottom-up approaches (Siddiqi & Husen, 2017). In the top-down approach, nanoparticles are produced by size reduction with the help of various methods, and in the bottom-up approach, nanoparticles are produced by bringing together small structures such as atoms and molecules or by allowing them to self-assemble. Nanoparticle synthesis methods are summarised in Figure 1.

Commonly adopted top-down approaches are chemical etching, sputtering, laser ablation, and mechanical milling. The methods used in the bottom-up approach are sol-gel process, laser pyrolysis, aerosol process, and vapour deposition methods (Pal et al., 2019). Strong reducing agents such as sodium citrate, organic solvents, and sodium borohydride are used in chemical nanoparticle synthesis. As the physical and chemical methods require a long time, high pressure, temperature, and dangerous chemicals could be produced, so their environmental damage could be high (Ying et al. 2022).

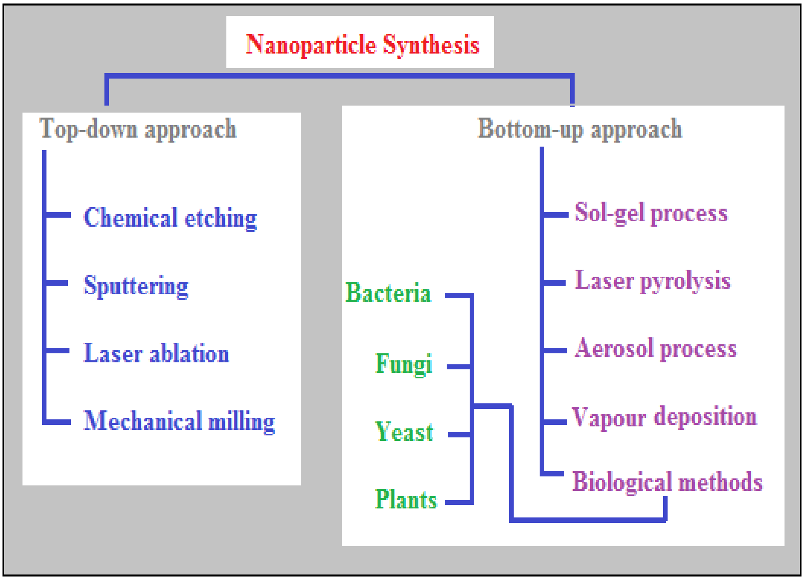

Figure 1. Methods for Nanoparticle Synthesis (Pal et al., 2019)

Biological synthesis methods, therefore, could be used as an alternative to physical and chemical synthesis methods for the synthesis of nanoparticles. In the biological synthesis method, bacteria, fungi, algae, and plants could be used. This synthesis method also has disadvantages as it progresses slowly; includes the pathogenicity problem and it is not sustainable due to large-scale application difficulties. In addition, nanoparticles produced by these methods could be used in limited areas due to their low biocompatibility and stability.

In the green synthesis of nanoparticles, various biomaterials and especially plant and plant wastes (leaf, flower, stem, fruit, and root, etc.) are used for bio-reducing metal ions to nano size. Bioreduction or green synthesis methods, which are other methods used for metallic nanoparticle synthesis, are included in the bottom-up approach. The steps of nanoparticle production by green synthesis are given in Figure 2.

It is widely accepted that the nanoparticle production process in this way is more efficient, simple, relatively easy, large-scale applicable, and economical than other production methods. Nanoparticles synthesised by this method do not show toxic effects and their stability is good. Nanoparticles such as zinc oxide, gold, iron, and silver could be produced by green synthesis. The agents in charge of the bioreduction of metal ions are polyphenols, terpenoids, polyols, etc. and they could be found in agricultural wastes, especially in plant extracts as phytocompounds.

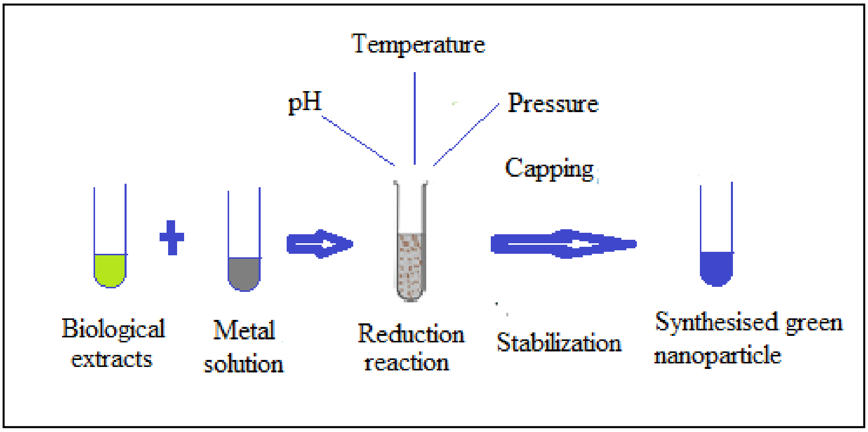

Figure 2. Nanomaterial Production Steps with Green Synthesis Approach (Patra & Baek, 2014)

Biomolecules which are found in plant extracts (for instance, amino acids, enzymes, polysaccharides, proteins, vitamins and organic acids, and citrates) that carry out the bioreduction of metal nanoparticles are harmless to the environment. Nanoparticles produced in this way could show superior antioxidant, antimicrobial, and catalytic properties. Scientists have been conducting numerous studies on the usage areas, advantages and disadvantages, and development of nanoparticles produced by the green synthesis method.

The nano-sized metal oxide production by green synthesis takes place in a special reaction with the help of the polyphenols in the plant extract and the metal compound turns from pale green to dark green or black in a very short time at room temperature.

9.2.1. Nanoparticle Production from Agricultural Wastes by Green Synthesis

Increasing concern about how to minimise or eliminate the use of environmentally threatening substances by following the principles of green chemistry has led to the development of a cheap and non-hazardous green synthesis technique. Plant-derived green synthesis has aroused great repercussions in recent years, as plant extracts perform their function in less time than microorganisms. For this reason, the number of studies showing that various plant by-products or wastes could be used as an alternative to chemical and physical synthesis is increasing rapidly. Recently, black and green tea leaves and extracts have been used frequently for the synthesis of nanoparticles (Huang et al., 2014; Wang et al., 2014).

Green synthesis has many merits over traditional methods. For example, it is cost-effective, environmentally friendly, and does not necessitate the use of high-pressure, energy, or toxic chemical reagents (Asghar et al., 2018). Green synthesis is also defined as the synthesis of nanoparticles from metal salts using polyphenols in various plant extracts (Sirdeshpande et al., 2018). Thus, this method offers a sustainable and reliable approach. Green synthesis aims to reduce the harmful effects of conventional chemical synthesis methods and, in particular, to reduce the use of toxic chemicals (Kurhade et al., 2021). In addition, green synthesis is a slow-paced technique and is suitable for the production of materials in a limited number of sizes and shapes, since plant-based products or wastes are used for the process (Kharissova et al., 2013).

Researchers have focused on the development of highly efficient materials such as activated carbon, zeolite, or nano-particles for the removal of dyes in wastewater by adsorption techniques within the scope of waste management (Aydın et al., 2022; Cifci & Aydin, 2022; Cifci et al., 2022; Jabbar et al., 2022; Mahmoodi et al., 2019; Ramesh et al., 2012). The reason for using such adsorbents is their high adsorption performance. However, the synthesis of such materials has been reported to cause pollution as it requires some toxic chemicals (Nguyen et al., 2022). For this reason, the "green synthesis" method, which is applied without using any chemicals or only using few toxic materials, draws attention to the scope of waste management (Cifci, 2022). Many studies have shown that natural compounds from plant extracts could act as reducing and stabilising agents during green synthesis (Diallo et al., 2021; Sharma et al., 2016; Hano & Abbasi, 2022).

Studies show that adsorbents produced by green synthesis could show better adsorption performance. Plants-based wastes have a wide variety of secondary metabolites (Asghar et al., 2018). Therefore, they could be used especially for the synthesis of nanoparticles (Sun et al., 2014). A variety of tea (such as green and black) are produced from the plant-named as *Camellia sinensis* (Figure 3), which grows in tropical and humid regions of Asia, primarily in China, Sri Lanka, and India also contains polyphenols (Asghar et al., 2018; Shah et al., 2015). The existence of flavonoids, tannins, ascorbic acid, terpenoids, and phenolic compounds was also detected in the *Costus woodsonii* plant (Figure 4), which is commonly called red button ginger

(Ling et al., 2020). In nano-technological applications, the *Costus woodsonii* plant extract has been used to generate ZnO nanoparticles, which exhibit high potential in the fields of photocatalysis and photoluminescence (Khan et al., 2019a, 2019b). These studies show that the surface of nanoparticles could be enveloped with some bioactive agents of the leaf extract of the *Costus woodsonii* plant and hence green nanoparticles could have better surface chemistry than traditionally synthesised ones.

Chemicals such as sodium borohydride or carbon monoxide, which act as reducing agents in the synthesis could be used to obtain, for example, Fe_3O_4 nanoparticles, but they have adverse environmental effects (Zhou et al., 2001). Therefore, it is important to prepare Fe_3O_4 with the green synthesis approach using environmentally friendly materials that are advantageous in terms of compatibility with pharmaceutical and biotechnological applications (Kharissova et al., 2013). There are studies supporting the green synthesis of Fe_3O_4 nanoparticles using various agricultural wastes such as *Grape proanthocyanidin* seed extract, *Perilla frutescens* leaf extract, *Caricaya papaya*, *Plantain bark* extract, *Sargassum muticum* seaweed, and *Zanthoxylum armatum* (Narayanan et al., 2012; Basavegowda et al., 2014; Ramesh et al., 2018; Latha & Gowri, 2014; Venkateswarlu et al., 2013; Mahdavi et al., 2013).

Figure 3. *Camellia Sinensis* Plant Used for Green Synthesis

Figure 4. Plants Used for Green Synthesis (*Costus Woodsoni)*

These plants provide convenience to researchers in terms of their various benefits and their availability in certain regions. For example, *Zanthoxylum armatum* is a medicinal herb which is widely used in India in the control of hyperglycemia, and in the treatment of cholera, skin diseases, and oral and dental diseases (Hynniewta & Kumar, 2008).

Figure 5. Plants Used for Green Synthesis (*Azadirachta indica)*

Also, manganese has many oxidation states (Tran et al., 2022). Mn_3O_4, one of the most stable manganese oxides, has been used in the catalytic decomposition of carcinogenic formaldehyde and hydrogenation of alcohols (Sackey et al., 2021; He et al., 2021). However, Sharma et al. (2016) produced Mn_3O_4 nanoparticles in spherical shapes with an average size of 20–30 nm by green synthesis using the leaf extract of *Azadirachta indica* (Figure 5) plant species. Diallo et al. (2021) investigated the same plant waste for the biogenic synthesis of monophasic Mn_3O_4 nanoparticles. In conclusion, in optical studies, it has been observed that single-phase crystal nanoparticles exhibit wide photoluminescence in the range of 300-700 nm, which is desired for emission devices.

9.2.2. Factors Affecting Nanoparticle Production by Green Synthesis

The most significant factors that affect the production of nanoparticles by the green synthesis method are; the pH of the reaction medium, reaction temperature, pressure, and reaction time (Doğan, 2019; Sathishkumar et al., 2010; Armendariz et al., 2004; Patra & Baek, 2014). The pH of the reaction medium plays a vital role in the formation of nanoparticles. Depending on the pH change, the hydrogen ion concentration in the solution could cause differences in nanoparticles' sizes and shapes (Doğan, 2019). Larger particle size is obtained at low pH values rather than high pH values (Sathishkumar et al., 2010).

With the increase in pH, the formation of nucleation centers also improves, and accordingly, the reduction of metallic ions to metal nanoparticles also rises. At the same time, the pH of the solution medium affects the functional groups' activity in the extracts of plants and the reduction rate of metal salts. Armendariz et al. (2004) investigated the effect of pH on Au nanoparticle synthesis using the *Avena sativa* (oat) plant and found that nanoparticles with large sizes (in the range of 25-85 nm) appeared at pH 2, and smaller sizes of nanoparticles showed at pH 3 and 4. It was also determined that nanoparticles appeared at a higher rate. The reason for this is explained by the agglomeration of the reaction to form large nanoparticles at low pH values, and the formation of more Au(III) complexes bound to plant biomass with carbonyl and hydroxide groups that are functional for Au to bind at higher pH values.

Temperature is another significant factor affecting the size, shape, and formation rate of nanoparticles. Just like the pH effect, the formation of nucleation centers increases with rising temperature, which improves the rate of biosynthesis. Therefore, temperature affects the structural properties of nanoparticles (Patra & Baek, 2014). However, at low temperatures, nanoparticles tend to be triangular and spherical, while at higher temperatures they tend to take the shape of nanorods and platelets (Doğan, 2019).

Pressure application to the reaction medium in nanoparticle synthesis is also important in terms of creating varieties in the shape and size of the synthesised nanoparticles (Abhilash, 2012). It is stated that metal ions' reduction by using biological agents is faster under atmospheric pressure conditions (Tran et al., 2013).

The incubation time of the nanoparticle reaction significantly affects the quality and morphology of the nanoparticle. Darrouddi et al. (2011) synthesised AgNP at different incubation times (1, 3, 6, 24, and 48 hours). It was determined from the measurements of Transmission Electron Microscope (TEM) that the average size of the synthesised AgNPs was <20 nm and that the average size decreased to about 5 nm at the end of the 48-hour incubation period.

9.2.3 Use of Nanomaterials Produced by Green Synthesis in Pollution Removal

Numerous studies have been conducted in which nanoparticles produced by green synthesis are used to solve environmental problems such as the elimination of pollutants from wastewater. In this field, many elements such as manganese and iron have been the focus of the researchers. For this, agricultural wastes from tea plants (green or black), lavender, mango, peppermint, etc. were used for the green synthesis of iron nanoparticles. Many materials have been developed by using wastes from plants and it has been reported that the adsorption capacities and catalysis potentials of iron nanoparticles acquired by this technique are high, particularly in dye removal (Ying et al., 2022). For instance, the adsorption capacity of Bordeaux Red dye with iron oxide nanoparticles obtained by using *Cucurbita moschata* leaf extract was 59.98 mg/g, while the adsorption capacity of Malachite Green, Rhodamine B, and Methylene Blue using iron nanoparticles prepared with tea plant extract was 190.3, 182.4 and 186.93 mg/g, respectively (Xiao et al., 2020; Barizao et al., 2020). Examples of the use of the green synthesis method for the removal of dyes, metals, and other pollutants in wastewater are given in Table 1.

Table 1. Studies Using the Green Synthesis Method for Removal of Pollution from Wastewater

Pollution	**Type of Nanoparticles**	**References**
Methylene Blue	3D bio-adsorbent (corn straw core and chitosan)	Liu et al. (2020)
	Loofah fiber-based adsorbents	Liang et al. (2021)
		Zhao et al. (2022)
	Graphene oxide with lemon juice	Mahiuddin & Ochiai, (2021)
	Copper oxide with *Punica granatum* leaf extract	Vidovix et al. (2019)
	Fe_3O_4 with leaf extract of *Zanthoxylum armatum DC*	Ramesh et al. (2018)
Malachite Green	*Calliandra Haematocephala* adsorbent	Sirdeshpande et al. (2018)
	Neem sawdust adsorbent	Khattri & Singh (2009)
	Mn_3O_4 with *Costus woodsonii* flowers extract adsorbent	Tran et al. (2022)
Cationic and anionic dyes	Iron nanoparticles	Huang et al. (2014)
		Shahwan et al. (2011)
Bismarck Brown R.	f-$CdWO_4$ adsorbent	Fatima et al. (2019)
Organic dye	ZnO – $CdWO_4$ adsorbent	Fatima et al. (2021)
	ZnO with *jujube* fruit extract	Golmohammadi et al. (2020)
Congo Red	p-NiO/n-ZnO adsorbent	Bhatia & Nath (2020)
Rhodamine B	Magnetite	Belachew et al. (2016)
Acid and basic dye	Carbon with iron-coated mint leaves	Cifci (2022)
Textile dye	Iron oxide with pomegranate seeds extract	Bibi et al. (2019)
Removal of heavy metal ions	Hydrogel	Dharmapriya et al. (2021)
Removal of Pb(II) from Aqueous Solution	Carbon nanospheres	Hussain et al. (2019)
Removal of Cu(II) from aqueous solutions	Tannin-polyethyleneimine	Jiang et al. (2020)
Removal of Cu(II) ions	Palm leaves	Fathy et al. (2019)

from synthetic wastewater		
Cadmium removal from aqueous solutions	Tangerine peel extract	Ehrampous et al. (2015)
Removal of Chromium(VI) from aqueous solutions	Poly (pyrrole methane)-	Ji et al. (2021)
	Fe_2O_3-Ag nanocomposite with *Psidium guajava* leaf extract	Biswal et al. (2020)
	Graphene sand composite	Dubey et al. (2015)
	Peganum harmala seed	Fazlzadeh et al. (2017)
	Graphite layered hydroxides	Hu et al. (2019)
Removal of pharmaceutical pollutants from wastewater	Copper nano-adsorbent	Husein et al. (2019)
Removal of toxic water contaminants	SiO_2 nano-adsorbent	Sharma et al. (2022)
Removal of fluoride from water	Iron nano-adsorbent	Ali et al. (2015)
Nitrate removal in wastewater	Eucalyptus leaves extracts	Wang et al. (2014)

9.3. Conclusion and Recommendations

Most of the research that has been conducted so far is normally carried out in research laboratories of a certain capacity. It has been observed that there is no application related to the production of adsorbent by green synthesis at a pilot plant or industrial scale. It is recommended to encourage initiatives to create areas where nanoparticles are systematically produced and used in the environmental sector. For example, pilot applications could be initialised to use iron nanoparticles derived from inexpensive natural materials, which are widely investigated for heavy metal removal and disinfection of wastewater in smaller-scale nanotechnological applications in waste management.

It is known that green synthesis has disadvantages as they provide non-uniform particle sizes, low yield, and local and seasonal availability of raw materials could be problematic. However, low-cost raw materials and energy savings by green synthesis make this method more advantageous compared to others. It is seen that the unique properties of nanomaterials and the robust compatibility of these materials with current conventional treatment techniques are remarkable in waste management.

Nanoparticles could easily be inhaled, ingested, or swallowed. It is recommended that before the widespread application of nanotechnology in the agricultural waste management industry, the fate of these materials and their potential impact on human health and the environment need to be determined in much more detail. It is also necessary to determine the effects of nanomaterials on the ecosystem and to establish a rational authorised framework for their environmental applications by optimising the technological advantages and possible risks.

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CHAPTER 10

AGRIBUSINESS AREA DEVELOPMENT BASED ON LOCAL SUPERIOR POTENTIAL

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10.1. Introduction

Law No. 23 of 2014 on "regional government" states that the implementation of agricultural development is the authority and responsibility of regional governments. Based on their authority, local governments should be able to optimize the utilization of existing agricultural resources as a whole in order to achieve community welfare. Development in a region is basically determined by the potential available in the area, thus policies for the regional level set by the government should refer to all the potential in the area that has the opportunity to be improved, especially in the field of agriculture. Therefore, it is appropriate for each region to manage and develop potentially superior products or commodities in a better direction based on a specific location. In order for superior potential products or commodities in the region to become the main driver or leverage of economic development, a more in-depth analysis of the criteria and characteristics of these commodities is needed based on the criteria of their superiority, the business system, or the suitability of the place of growth and business feasibility. Based on the results of this analysis, it is expected that related commodities can be developed according to the capacity and carrying capacity of the potential resources available in the area through the development of agribusiness based on local potential commodities.

The ability to use the potential resources owned by a region can determine the success of the region in improving its regional leverage. Several regions in Indonesia in general still have non-ideal human development index values thus many efforts need to be made to increase development, especially in the economic sector. The human development index, as we know, is one of the indicators in assessing development success. Based on this, Sukabumi Regency does not yet have a superior commodity/product/service that can become regional leverage at present, and also the development of the region has not been focused. In addition, Sukabumi Regency as the largest Regency in Java and Bali has not been optimal in utilizing its natural resource potential. Based on this, this research is directed at developing local potential commodities that can be used as an effort to increase location-specific agricultural development in Sukabumi Regency through the development of agribusiness areas based on local superior potential. Sukmawani Reny and Sri Ayu Andayani (2020) in previous research successfully formulated a model of work and performance in the development of local superior commodities, and this model was chosen as the basis for this research (Figure 1)

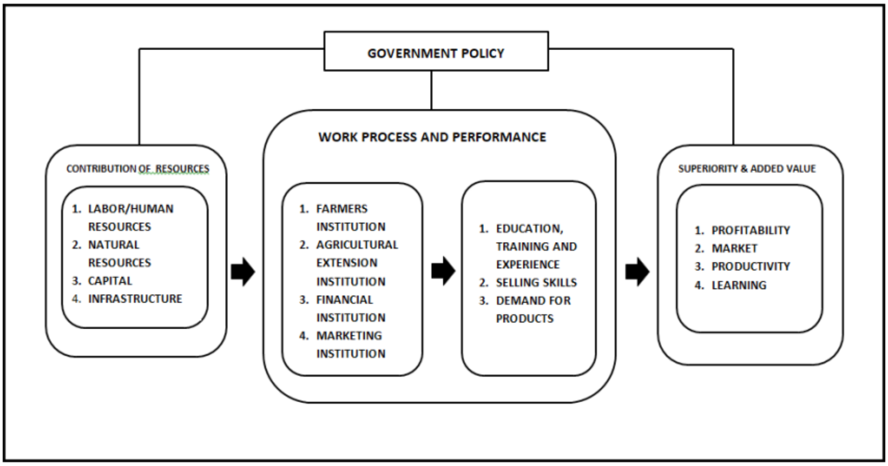

Figure 1. Working Model Design for Local Superior Commodities
Source : Sukmawani Reny & Sri Ayu Andayani (2020)

It is believed that the development and application of the working model and performance of this superior commodity development can increase the economic productivity of the community. While the purpose of this research is to maximize the potential of regional natural resources through the development of agribusiness areas based on local superior potential through the development of export products/commodities, product/commodity-based clusterization, integrated production center development, and sustainable business scale development.

10.2. Research Methods

Based on the type of data, this research is a combined quantitative and qualitative research and employs the survey method. The research is conducted in Sukabumi Regency and is divided into 7 research areas. This research is the first year of a three-year research program. The research design can be seen in Figure 2.

Based on the figure 2, the program to be implemented is clearly aimed at developing local potential-based agribusiness areas. The analysis of determining superior potential is not only from the aspect of demand but also supply. In addition, the analysis will be carried out based on data obtained from survey results and the results of government policy decisions at the regency, provincial, and national levels. Thus, the data collected is both secondary and primary data.

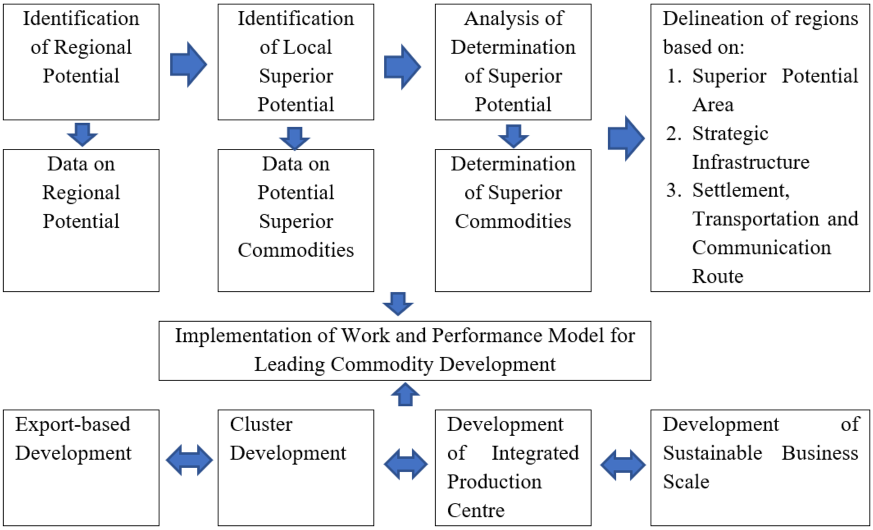

Figure 2. Research Design

Finally, in the third year, it is expected that the results of this research can maximize the potential of regional natural resources in Sukabumi Regency in the development of agribusiness areas based on local superior potential through export product/commodity development, product/commodity-based clustering, development of integrated production centers, and development of sustainable business scale.

10.3. Result and Discussion

This research is the first stage of a three-year research plan. In this initial stage (first year), the results obtained were in the form of regional potential and local superior potential from seven regions in Sukabumi Regency. In detail, the sub-districts in the seven regions of Sukabumi Regency can be seen in Table 1.

Based on Table 1, the total number of sub-districts in the seven regions of Sukabumi Regency is 47. This is also the reason why Sukabumi Regency is divided by region so that the potential superior commodities can be identified based on these regions. The consideration is that sub-districts within one region have elements of proximity and characteristics based on geography and topography that are not too different.

Table 1. List of Sub-Districts in Sukabumi Regency, West Java, Indonesia

No	**Area**	**Sub-District**	**No**	**Area**	**Sub-District**
1	Area 1	Sukalarang	4	Area 4	1. Warungkiara
		2. Cireunghas			Bantargadung
		3. Kebonpedes			3. Simpenan
		4. Gegerbitung			4. Palabuhanratu
		5. Cisaat			5. Cikakak
		6. Gunung Guruh			6. Cisolok
		7. Sukaraja	5	Area 5	1. Nyalindung
		8. Sukabumi			2. Purabaya
		9. Kadudampit			3. Jampang tengah
2	Area 2	1. Cicantayan			4. Lengkong
		2. Caringin	6	Area 6	1. Jampangkulon
		3. Cibadak			2. Waluran
		4. Nagrak			3. Cimanggu
		5. Ciambar			4. Kalibunder
		6. Cikidang			5. Ciemas
		7. Cikembar			6. Ciracap
3	Area 3	1. Kalapanunggal			7. Surade
		2. Kabandungan			8. Cibitung
		3. Bojong Genteng	7	Area 7	1. Pabuaran
		4. Parungkuda			2. Sagaranten
		5. Cidahu			3. Curugkembar
		6. Cicurug			4. Cidadap
		7. Parakansalak			5. Cidolog
					6. Tegalbuleud

Basically, a region is a dynamic system in which there is an interaction between natural resources (biological), non-biological resources (artificial), human resources, and business activities. According to Alkadri, 1999, regional development is an effort to build and develop a region through a spatial approach that should take into account sociocultural, economic, environmental, and institutional aspects in an integrated manner. Alkadri's (1999) statement was reinforced by Nugroho & Dahuri (2002) who revealed that formulating a development program and policy related to the economic sector must pay attention to regional, environmental, and social aspects. These three aspects are a unity to achieve optimal and sustainable welfare. The goal of obtaining welfare can be realized when the relevant region has dynamic conditions when faced with competition. Based on this, Alkadri (1999) emphasized that the condition of an area must be taken into consideration in the concept of regional development.

Mangiri and Widiati (in Alkadri, et al., 1999) suggest that one of the concepts of regional development should be resource-based. This is based on the differences in the quantity and quality of resources available between one region and another. Thus, the choice of strategies that can be carried out in applying the concept includes regional development based on: (1) input, but a surplus of human and natural resources; (2) capital and management resources; (3) art, culture, and natural beauty; and (4) spatial planning (strategic location).

In addition to the concept above, regional development can also be carried out based on ecology. Ecology-based regional development has developed from the realization that regional development that only focuses on economic aspects without paying attention to the environment and nature will cause damage. Rees (in Carley & Christie, 2000) stated that on the one hand, regional development must pay attention to nature and the environment; but on the other hand, the needs of society are also highly dependent on a variety of ecological resources, which in turn can lead to exploitation of nature to meet these needs. The impact of such occurrences is getting bigger and causing wider social costs as well. Therefore, it is important to identify the potential of a region from various aspects to discover what resources it has that can be used as a basis for developing its potential.

The results of the identification of regional potential in Sukabumi Regency are based on the potential of natural resources, economic resources, and sociocultural and institutional resources. From the results of this identification, a recapitulation of data on the potential of each region in Sukabumi Regency was obtained as follows:

Table 2 shows that the potential of each region in Sukabumi Regency is almost the same, but in some areas, there are different potentials. However, in general, the identification results show that each region in Sukabumi Regency has good potential based on natural resources, economic resources, sociocultural and institutional resources. Then, it depends on the people to properly manage and develop this potential so as to improve agricultural development in the region. Based on the potential in Table 2, data on potential superior commodities in each region in Sukabumi Regency is obtained and presented in Table 3.

Table 2. Data on Regional Potential in Sukabumi Regency, West Java, Indonesia

Area	Natural Resource Potential	Economic Resource Potential	Socio-cultural Potential	Institutional Potential
1	Farmland, inland waters, mountains	Agriculture, livestock, fisheries, tourism, industry, hospitality	Sundanese culture, farming, trading	Extension institutions, farmers, cooperatives, farmer associations, water-using farmer associations, fishermen institutions, irrigation management
2	Farmland, mountain, river, forest	Industry, agriculture, trade	Sundanese culture, farming, trading, fishing	Extension institutions, farmers, cooperatives, farmer associations, water-using farmer associations, fishermen institutions, irrigation management
3	Agricultural land, energy, minerals, mountains, rivers	Agriculture, livestock, industry, mining	Sundanese culture, farming, trading, kasepuhan (traditional village)	Extension institutions, farmers, cooperatives, farmer associations, water-using farmer associations, fishermen institutions, irrigation management
4	Farmland, plantation, beach, sea, forest, river	Fisheries, marine, plantation, tourism, hospitality	Sundanese culture, farming, trading, kasepuhan (traditional village)	Extension institutions, farmers, cooperatives, farmer associations, water-using farmer associations, fishermen institutions, irrigation management
5	Farmland, rivers, mountains, minerals	Agriculture, livestock, plantation	Sundanese culture, farming, trading, miners	Extension institutions, farmers, cooperatives, farmer associations, water-using farmer associations, fishermen institutions, irrigation management
6	Agricultural land, minerals, sea, river, forest	Fisheries, marine, plantation, tourism, hospitality	Sundanese culture, farming, trading, fishing, miners	Extension institutions, farmers, cooperatives, farmer associations, water-using farmer associations, fishermen institutions, irrigation management
7	Farmland, river, forest	Agriculture, plantation, livestock	Sundanese culture, farming, trading	Extension institutions, farmers, cooperatives, farmer associations, water-using farmer associations, fishermen institutions, irrigation management

Table 3 showed data and information related to potential superior commodities in Sukabumi Regency according to the Agriculture Office of Sukabumi Regency (2020).

Table 3. Superior Potential Commodities in Sukabumi Regency in 2020

NO	Description	Realization of Planting Area, Harvesting Area, Productivity, and Production			
		Planting Area (Ha)	Harvesting Area (Ha)	Productivity (Kw/Ha)	Production (Ton)
I	Rice Plant				
	1.1. Paddy rice	175.657	141.814	57,67	817.787
	1.2. Upland rice	33.684	31.208	36,38	113.547
2	Palawija (secondary crops)				
	Corn	21.633	31.694	55,49	175.864
	Soy beans	17.429	23.664	12,04	28.496
	Peanuts	4.754	3.953	16,48	6.514
	Mung beans	334	676	12,33	833
	Cassava	8.976	4.923	241,96	119.117
	Sweet Potato	978	895	157,98	14.140
3	Vegetables				
	Shallot	46	68	89,38	608
	Chilli	1.123	1.260	122,12	15.386
	Tomato	704	716	205,18	14.444,6
	Napa cabbage	2.078	2.066	113,94	23.540
	Long beans panjang	846	818	150,70	12.327
	Eggplant	498	470	174,51	8.202
	Spring Onion	634	638	89,82	5.731

Source: Strategic Plan of the Department of Agriculture 2021 - 2026 (processed)

Based on the table, it appears that the determination of these commodities is only based on the supply aspect in terms of planting area, harvest area, and production. In addition to rice, secondary crops, and vegetables, the Agriculture Office of Sukabumi Regency also determines various fruit commodities that are potentially superior as shown in Table 4.

Based on potential commodities data in Tables 3 and 4, by looking at the distribution in each region in Sukabumi Regency, the superior potential commodity data per region is obtained as shown in Table 5.

Table 4. Superior Potential Fruit Commodities in Sukabumi Regency

No	Fruit Type	Production (quintal)	No	Fruit Type	Production (quintal)
1	Avocado	3.955,7	10	Pineapple	99,5
2	Mango	8.975,5	11	Banana	105.454,3
3	Rambutan	1.623,9	12	Snakefruit	321,7
4	Durian	2.991,6	13	Star fruit	309,3
5	Hamlet	609	14	Jackfruit	3.709,7
6	Orange	299,8	15	Mangosteen	1.871,1
7	Guava	8.155,9	16	Breadfruit	1.028,7
8	Sapodilla	1.338,8	17	Soursop	1.084,9
9	Papaya	10.996,6			

Source: Strategic Plan of the Department of Agriculture 2021 - 2026 (processed)

Table 5. Superior Potential Commodities per Region in Sukabumi Regency

Area	Superior Potential Commodity			
	Rice	Palawija/Secondary Crops	Vegetables	Fruits
1	Paddy rice	Sweet Potato	Napa cabbage, Shallots	Banana
2	Paddy rice	Cassava	Chilli	Mangosteen
3	Paddy rice	Cassava	Long beans	Orange, Papaya
4	Paddy rice	Cassava	Eggplant	Durian, Banana, Papaya
5	Paddy rice, Upland rice	Corn, Sweet Potato, Peanuts	Tomato	Durian
6	Paddy rice, Upland rice	Mung beans, Soy beans	Tomato	Mango, Orange
7	Paddy rice, Upland rice	Corn, Peanuts	Eggplant	Durian, Papaya

Source: Strategic Plan of Regency Agriculture Office and Sukabumi Regency in Figures, 2022 (processed)

Table 5 shows that the local superior potential commodities of each region in Sukabumi Regency are quite diverse. Potential local superior commodities per region identified from this study are only seen based on supply aspects, namely planting area, harvesting area, population, total production, and suitability based on the growing requirements of each commodity. To obtain data on local superior potential commodities that are really chosen to be developed in a focused manner in order to increase regional leverage, further studies through various methods are needed. According to Sukmawani, Reny (2015), a commodity is said to be superior not only based on basic analysis or the amount of production and area alone but also should be seen from the demand aspect, namely according to the criteria of superiority and competitiveness, both comparatively and competitively.

The definition of an agricultural area according to Permentan No. 18 of 2018 is "a combination of agricultural centres that meet the minimum limits of the economic scale of exploitation and the effectiveness of regional development management in a sustainable manner and are functionally related in terms of natural resource potential, socio-cultural conditions, production factors, and the existence of supporting infrastructure". Based on this definition, after knowing and choosing which commodities have superior potential, the next step is regional delineation. Delineation is very important to identify functions and variables in an area through mapping based on its functional characteristics so as to determine priorities. Delineation in this study will be conducted in the second year due to the large area of Sukabumi Regency which requires a long time for mapping. Delineation will be conducted based on areas of superior potential, strategic infrastructure, settlements, transportation routes, and communication routes. Based on the delineation results, strategies and programs will be designed to implement the performance model of local superior commodity development in achieving export products/commodities, product/commodity-based clusterization, integrated production development, and sustainable business scale development. The stages of determining strategies and programs refer to the stages as shown in Figure 3.

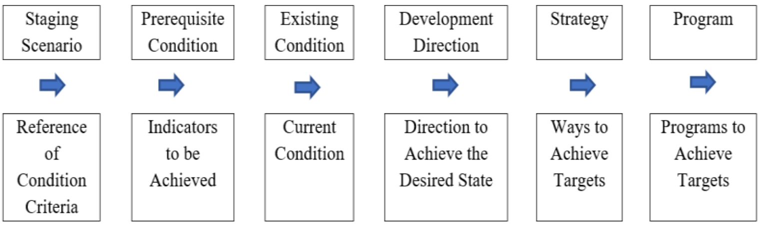

Figure 3. Stages in Setting Strategies and Programs

Agriculture is an economic sector that has an important and strategic role in national development. This is partly because agriculture is a source of basic human needs that absorbs a lot of labor and contributes considerable foreign exchange to Indonesia. Based on this, agricultural development with various strategies and innovations must continue to be realized in order to achieve agricultural development goals.

Efforts that can be made to accelerate the achievement of agricultural development goals include developing agricultural areas. The development of agribusiness areas based on superior potential commodities is expected to achieve more participatory and efficient agricultural development goals.

The results of this study are specifically directed at the above objectives. However, the initial stage of the study was only to identify the potential in each region of Sukabumi Regency that became the research locus. Based on the superior potential identified, Sukabumi Regency has ample opportunities to increase its regional leverage by maximizing the management and development of the region in a focused manner.

10.4. Conclusion

Sukabumi Regency as a whole has the potential of natural resources, economy, socio-culture, and institutions that are not much different from one region to another. Based on its agricultural potential, each region in Sukabumi Regency has the opportunity to develop rice, secondary crops, vegetables, and fruits according to the potential of each region. Further studies are needed to determine the superior potential commodities to be developed in each region up to its delineation so that the performance model of local superiority-based agribusiness area development can begin to be studied and applied.

10.5. Recommendation

Based on its authority, the local government should be able to optimize the utilization of potential resources available for the achievement of community welfare

Utilization of all potential resources can be done through the development of agribusiness areas based on local superior commodities.

The development of agribusiness areas in Sukabumi Regency can be carried out by optimizing the potential of natural, economic, socio-cultural, and institutional resources owned by each region in Sukabumi Regency.

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CHAPTER 11

ENVIRONMENTAL IMPACT OF ORGANIC FARMING PRACTICES

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11.1. Introduction

The main objectives of the agricultural sector are; 1) produce high-quality and efficient production to meet the growing demand for food, 2) improve biodiversity and natural resources, and 3) protect human and animal health. Today, however, agricultural production is carried out by ignoring these purposes. These agricultural systems, called conventional agriculture, cause many environmental effects such as soil erosion and degradation, soil pollution, reduction in biodiversity and greenhouse gas emissions (Ponisio et al., 2015). Intensive use of chemicals (fertilizer and pesticide) and irrigation water in conventional agriculture are the main factors causing environmental degradation. Organic agriculture, which has emerged as an alternative to conventional agriculture, includes human and environment-friendly production systems that aim to restore the natural balance in the ecological system (Magkos et al., 2006). Organic agriculture has a higher performance than conventional systems in terms of species richness and existence, soil fertility, nutrient uptake, water infiltration rate, water holding capacity, energy use and efficiency. The main strategies of organic agriculture are 1) applying appropriate rotation systems, 2) applying compost, 3) using appropriate physical, mechanical and biological methods to prevent diseases, pests and weeds, and 4) using organic methods in animal production (Shi-ming and Sauerborn, 2006). These practices improve production, food safety and environmental impact.

Consumers' demand for accessible, environmentally friendly, nutritious and safe food is increasing. However, the cause-effect relationship between organic food consumption and consumer health is still not fully known (Simith-Spangler et al., 2012). Moreover, organic farming can have environmental impacts similar to land use in conventional systems. In order to reduce these effects, IFOAM (International Federation of Organic Agriculture Movements) needs organic farms to be protected from all kinds of pollution and to protect the genetic diversity of agricultural systems and their environment. Organic farming increases soil fertility, nutrient cycling and retention, water storage, disease/pest control, pollination, and other positive agricultural inputs and ecosystem services. However, it was suggested that the use of animal manure in organic agriculture can be a source for some particulate matters (PM2.5 and PM10) and facilitate their transport (Udewige et al., 2015; Arbex et al., 2007). It is also proposed that some pathogens in animal manure and also phosphorus from organic inputs may cause a number of diseases related to human health with their environmental impact (Mathis et al., 2005; Uriu-Adams and Keen, 2005).

However, there are no substantiating documents regarding the impact of organic agriculture on human health. In fact, there are some studies showing that organic products have lower concentrations of pesticide residues and the concentrations of nitrate and Cd than conventional products (Bara´nski et al., 2014; Dangour et al., 2010; Huber et al., 2011).

The environmental impacts of organic agriculture can be grouped under six headings: 1) Soil quality, 2) Air quality, 3) Water quality, 4) Biodiversity, 5) Energy use and 6) Land requirement.

11.2. The effect of organic farming applications on soil quality

Soil quality has emerged as a concept that provides the main link in fulfilling the main objectives of sustainable agriculture with management practices that protect agriculture. The determination of soil quality and health and their direction of change over time is the main indicator of sustainable agricultural management. Soil quality and health is an important concept that determines agricultural sustainability, environmental quality and ultimately plant, animal and human health (Okur, 2017). Soil quality varies depending on the physical, chemical and biological properties of the soil. To characterize soil quality, chemical and physical properties are more prominent than biological properties. Because they are easier to analyze and predict. In fact, in order to reveal the status of soil quality, it is absolutely necessary to reveal the biological definition and amount. The total species diversity in soils, the number and activities of beneficial microorganisms, and even the genetic diversity of soils are among the ecological indicators of soil quality.

Soil quality is defined as soils that are rich in organic matter, fertile, have good physical, chemical and biological properties. If a proper land management is applied to these soils, they will preserve these values for many years. Organic farming systems increase carbon accumulation in the soil and create a suitable environment for the development of soil fauna and flora. These soils can host many and very different groups of microorganisms. Microbial communities with greater diversity in organic farming systems require less energy to maintain their vitality. In this case, the carbon in the organic matter is not released as CO_2 but instead participates in the C cycle in the soil system. In soils where organic farming has been realized for a long time, biologically active soil organic matter also increases due to the increase in organic matter. This situation causes more microbial biomass, more active soil respiration and higher N-mineralization rate in organically managed soils compared to conventional soils (Okur, 2017). The studies found that organic soils had higher micro and macro-biological activity and higher populations of bacteria, fungi, mites, earthworms and springtails (Gomiero, 2013).

Soil fertility in organic agriculture is more dependent on organic manure applications than conventional agricultural soils. Because 1) mineral fertilizers are not applied for the N needs of plants and microorganisms, 2) there is a higher dependence on soil functions and soil organic carbon services, resulting in higher soil organic carbon stocks and conversion rate, and 3) there is a positive correlation between organic matter supply and turnover in soils (Leithold et al., 2015). Kasper et al (2015) found higher SOC stock due to crop rotation in organic soils in Austria compared to conventional agricultural soils. On the other hand, the accumulation of SOC in organic farming practices is also explained by more transformation of plant carbon into soil microbial biomass (Kallenbach et al., 2015). In a 6-year long trial in the USA, a higher soil quality was determined in organic agricultural soils with more C and N accumulation than conventional soils (Delate et al., 2017). According to the data in the Table 1, organically managed farmland in Chine for 2013 supplied significant contributions to C-equestrian (Meng et al., 2017). Higher water holding capacity and less soil loss due to erosion occurred in organic farming soils (Gomiero et al., 2011). The increased stability of aggregates due to the addition of organic fertilizer and post-harvest wastes makes soils under organic agriculture more resistant to erosion (Lynch, 2014).

Table 1. C sequestration in organic agriculture

Crops	Organic farmland ($x10^3$ ha^{-1})	Soil C sequestration ($x10^3$ t CO_2-eq yr^{-1})
Vegetables	48	35
Fruits	211	124
Tea	53	31
Other crops	846	124
Total	1158	314

Source: *(Meng et al., 2017)*

11.3. The effect of organic farming applications on air quality

It is estimated that about 25% of anthropenogic greenhouse gas emissions comes from agricultural (Edenhofer et al., 2014). The three main greenhouse gases are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), which are also produced by the C and N cycles in the soil. Since agricultural areas cover large areas on earth, they have significant effects on

C and N cycles in soils. Therefore, these three greenhouse gases emerge because of agricultural activities. Agriculture, which is currently an important source of greenhouse gases, has also great potential to reduce the accumulation of these gases in the atmosphere. Ecosystem processes can also reduce these greenhouse gas increases through the storage of CO_2 in plants, land and oceans. About half of the CO_2 emitted from fossil fuels accumulates in the atmosphere. The other half is adsorbed by the ocean and terrestrial ecosystems (IPCC, 2001).

Organic farming not only enables ecosystems to better adapt to the effects of climate change, but also offers great potential for reducing emissions of agricultural greenhouse gases (Burdick 1994). Organic farming systems have 48 to 66 % lower CO_2 emissions per hectare than conventional systems (Stolze et al. 2000, Haas & Köpke 1994). The reason for this difference; 1) use of animal manure to maintain and increase soil fertility, 2) no use of mineral fertilizers and pesticides, 3) less use of high energy consuming feedstuffs (Haas & Köpke 1994, Stolze et al., 2000). Almost 70 % of CO_2 in organic farming comes from fuel consumption and machinery production, while 75 % of CO_2 emissions in conventional systems come from N-fertilizers, feeds and fuels (Haas et al., 1995). Soil carbon stocks and sequestration rates were found to be significantly higher in organic plant production systems than in conventional systems (Lori et al. 2017).

With management systems such as organic agriculture that apply compost and manure to the soil, carbon input into the soil is increasing. Minimum or no tillage techniques that reduce the rate of organic matter decomposition in the soil also increase the carbon stocks of the soil. Following the adoption of practices or land uses that increase carbon stocks, soil carbon can increase between 20 and 30 years (Paustian et al., 2006). Ogle et al (2003) examined the results of 126 studies and reported that the C stocks in the 0-30 cm soil layer increased by 10-20% in the zero-tillage agricultural lands compared to the lands with intensive tillage.

About 90% of N_2O in the atmosphere occurs during microbial transformations in soil and water. N_2O emission from soils is the loss of available nitrogen from soils. Significant N_2O emissions occur during nitrification or denitrification of nitrogen entering by mineral and organic fertilizers, biological nitrogen fixation and harvest residues. In general, organic systems have lower nitrogen inputs and therefore lower N_2O emission potential. However, providing a balanced plant nutrient requirement is typically more difficult in organic systems. Significant N_2O emissions occur when the nitrogen in the organic fertilizer is high, while yields decrease when the available nitrogen is low (Clark & Tilman 2017, Lynch et al. 2011).

About two-thirds of anthropogenic methane production is thought to originate from agricultural activities (rice fields and animal husbandry) (Watson et al., 1996). Methane, which is produced during the anaerobic decomposition of organic fertilizers, occurs less in natural uncultivated soils. There is no data on the effects of organic farming on methane emissions.

Over 30 years, the Rodale Institute's Farming Systems Trial (FST) showed that the conventional systems emit nearly 40% more greenhouse gases (GHG) per pound of crop produced than the organic systems. While the biggest GHG emissions from direct inputs in the conventional system came from fertilizer production and on-farm fuel use, in the organic system came from fuel use and seeds (Figure 1).

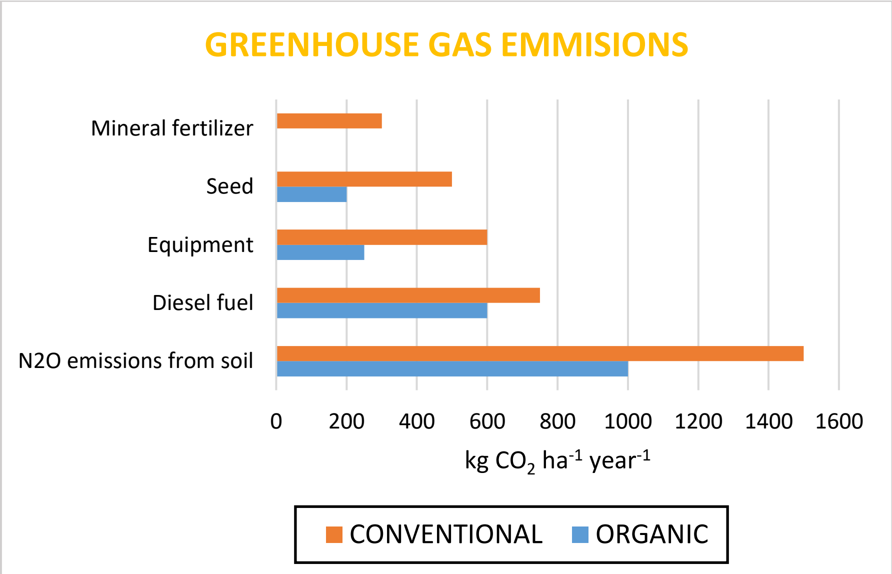

Figure 1. Comparing conventional and organic farming in terms of greenhouse gas emissions. Source: (*Anonymus, 2023*)

11.4. The effect of organic farming applications on water quality

The most important cause of pollution of groundwater and surface waters are the use of pesticides and synthetic fertilizers in agricultural lands. The presence of various metals and chlorine in the active ingredients of the agricultural chemicals (pesticides) causes an increase in metal levels and conductivity in water resources located around agricultural areas. In addition, due to the impurities in the synthetic fertilizers, it is possible for metals such as Chromium (Cr), Nickel (Ni) and Molybdenum (Mo) to mix with the soil and thus be transported to the receiving water environments (Alloway 1995). In addition, chemicals from fertilized and pesticide-treated agricultural lands is transported into surface waters by erosion and into groundwater by leaching. One of the most important pollutants in groundwater is the leached nitrate from nitrogen fertilizer. The colloids such as clay minerals and humic matters cannot adsorb nitrate with negative charge, so it leaches and reaches the ground water. Even under ideal conditions, plants use only 50% of the nitrogen fertilizers applied to the soil, 2-20% is lost by evaporation, 15-25% is complexed with organic compounds found in clay soil, and the remaining 2-10% is transported to on the surface and ground waters (Cüre, 2022). Since synthetic fertilizers and pesticides are ban in organic agriculture, the possibility of contamination of underground and surface waters with chemicals is greatly reduced. Stolze et al (2000) stated that the reduction of nitrate rates in organic farming compared to conventional farming changed between 40% and 64%. The reason for the lower nitrate leaching rates in organic farming soils is that the use of nitrogen fertilizers obtained by chemical methods is prohibited. In addition, the total amount of animal manure to be used in organic production cannot exceed 170 kg N^{-1} ha-^{1} year.

On the other hand, the risks of pesticides allowed for use in organic farming on water quality have not been adequately studied yet (Stockdale et al., 2001). Regarding the leaching of nitrate from soils, two effects may occur in organic farming; 1) The nitrogen uptake efficiency of the plants may increase so that the amount of nitrate that has the potential to be leached in the soil may decrease, or 2) The amount of nitrate resulting from animal manure, green manure and compost used in organic agriculture may be high and thus nitrate leaching may increase (Gomiero et al., 2001). In order to synchronize the nitrogen in the soil, it is necessary to determine the most appropriate time for tillage (Stockdale et al., 2001). Appropriate timing of tillage is the most influential tool available to farmers to manage N synchrony (Lorenz and Lal, 2016). Tillage before green manuring can synchronize N-mineralization and nitrogen uptake of the plant. However, late or end-of-season tillage can increase nitrate leaching by stimulating inorganic nitrogen sources that are asynchronize with the plant's nitrogen uptake time (Finney et al., 2015). A study in England compared nitrate leaching from organic and conventional agricultural soils under rotation. Nitrate losses in the arable crops period were found to be 47 and 58 kg N ha^{-1} in organic and conventional systems, respectively, but the nitrate losses between the two systems in the grass period was similar (Stopes et al., 2002). While nitrate loss was determined as 20 mg per lysmeter in organic oil seed pumpkin - potato rotation in Hungary, it was determined as 280 mg per lysmeter in conventional soils in the same rotation (Biro et al., 2005).

Although synthetic pesticides are prohibited in organic agriculture, some non -synthetic pesticides, such as solutions containing Cu, are widely used. These chemicals may have negative effects on aquatic life. The use of fungicides containing Cu in potatoes, vineyards, hops and some vegetables reaches 3-4 kg Cu ha^{-1} $year^{-1}$. Intensive studies are carried out with the use of botanicals that can be easily degradable instead of these fungicides (Niggli, 2015).

11.5. The effect of organic farming applications on biodiversity

Biodiversity is the number, variety and variability of living organisms in an environment and is an important driver for the sustainability of agroecosystems and the production of stable quality food (Gomiero et al., 2011). A high biodiversity improves ecosystem services, including the mineralization of nutrients, the formation of soils, regulation of hydrological processes, detoxification of noxious chemicals and the biological control of pests. Hole et al. (2005) perused 76 studies and reported an important positive effect of the organic management practices on biodiversity. Comparing organic and conventional farms, organic farm soils showed 30% higher species diversity and 50% more flora and fauna than conventional farms (Bengtsson et al., 2005; Fuller et al., 2005).

Table 2. According to the studies carrying out in 1981-2003 years, the study number showing positive, negative or mixed/no difference were compared in organic versus conventional farming.

Taxon	Positive	Negative	Mixed/No difference
Birds	10	0	4
Mammals	3	0	0
Butterflies	4	0	3
Spiders	8	0	3
Earthworms	8	0	6
Beetles	16	2	5
Other arthropods	10	5	4
Plants	23	1	3
Soil Microorganisms	18	1	11
Total	100	9	39

Source: (*Hole et al., 2005*)

However, the effects vary with crop, the organism group studied, and the ratio of arable land in the surrounding landscape. For example, tachinid parasitoids were found to be higher in organic farming soils than in conventional soils (Inclán et al., 2015). Higher biodiversity includes various taxonomic units of soil microorganisms, insects, mammals, weeds and flowers, and birds (Hole et al., 2005; Kragten and de Snoo, 2008; Frieben and Köpke, 1995).

It has been determined that the number and diversity of bees increases in regions with more organic farms, which increased pollination in crops and wild plants (Rundlöf et al., 2008). The reason for the high biodiversity of species in organic farming systems is due to the prohibition of pesticides, herbicides and fast-release synthetic fertilizers in these farming systems. In addition, it is known that crop rotation and mechanical weeding are also effective on increasing biodiversity (Hole et al., 2005). Table 2 shows the results of a review of literature published between 1981 and 2003. It was compared biodiversity in organic and conventional farms and found that organic farming generally had positive impacts on many species (Hole et al., 2005).

11.6. The effect of organic farming applications on energy use

Agricultural systems have significant effects on climate change and fossil fuel consumption because of the production of mineral fertilizers, the management of agricultural fields and operating machinery. Organic agriculture is an agricultural system that is suitable for energy use and efficiency, both per hectare and farm product. But, this situation is not only suitable for the poultry and fruit sector (Lynch et al., 2011). However, direct energy input per unit area is similar in organic and conventional production. The biggest energy difference between organic and conventional agriculture comes from the energy consumed in the production of synthetic fertilizers (Halberg, 2008; Tuomisto et al., 2012). Some researchers (Bertilsson et al., 2008) suggested that conventional systems produce more energy per hectare and bound more solar energy than organic systems. The lower yield in organic farming systems, and the resulting lower energy production per unit area, means that more land will be needed to produce the same amount of energy. This larger land requirement in organic farming systems should also be taken into account in calculating the energy balances of agricultural systems (Bertilsson et al., 2008). In addition, when comparing conventional and organic farming systems, not only agricultural production but also energy consumption in post-harvest management ways and distribution networks need to be considered. However, little information is available regarding energy use in processing, packaging, storage and distribution between organic and conventional systems. (Ziesemer, 2007).

According to the long-term data of the Rodal institute, the difference between direct and indirect energy consumption in organic and conventional agricultural systems is given in Figure 2. In general, organic farms consumed less energy than conventional farms. Direct energy consumption (labor, fuel, and equipment) is 63% and 27,5% in organic systems and conventional systems, respectively. Indirect energy consumption (production and transportation of off-farm inputs, such as seed, soil fertility, herbicide) is calculated as 37% for organic systems and 72,5% for conventional systems.

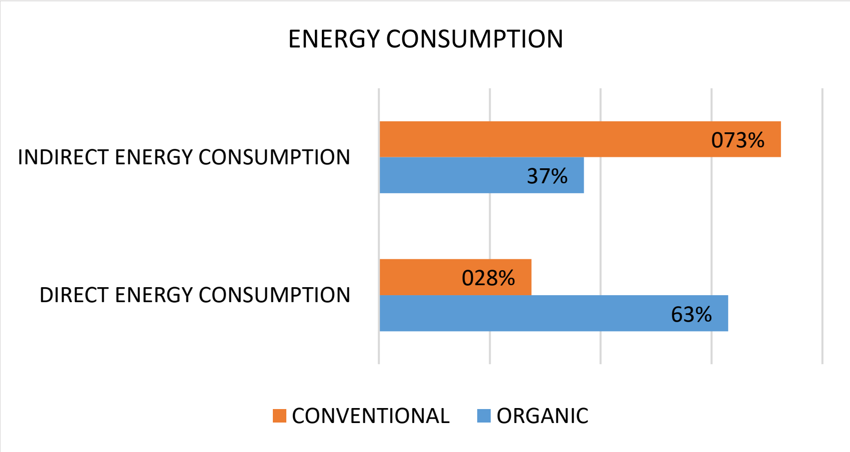

Figure 2. Comparing conventional and organic farming in terms of energy use. Source: (*Rodale Institute, 2011*).

11.7. The effect of organic farming applications on land requirement

Land use is important for the proper consumption of land, which is a scarce resource. Mistakes in land use cause various environmental problems, such as decreased biodiversity and increased amount of CO_2 released into the atmosphere. For this reason, it is necessary to use land and other natural resources more effectively during agricultural production. Organic systems have lower land use efficiency than conventional systems. Yield of organic products is lower than conventional products. Thus, organic agriculture relies on more land to produce the same amount of food compared to conventional agriculture. According to a meta-analysis on organic agriculture in ten developed countries, land use efficiency in organic agriculture is 20% lower than in conventional agriculture (Mondelaers et al., 2009). In order to obtain a unit of product in organic agriculture, 9%-214% more land is needed compared to conventional ones. In animal production, these rates vary between 6%-346%. This situation could threaten forests, wetlands and grasslands as organic farming spreads around the world (Crowder and Reganold, 2015). Pickett (2013) argues that organic farming will become less important in the future due to climate change and increasing world population. However, the demand for organic products is still increasing in the world and therefore organic farming areas are increasing (Willer and Lernoud, 2015). Figure 3 shows the ten countries with the largest areas of organic agricultural land.

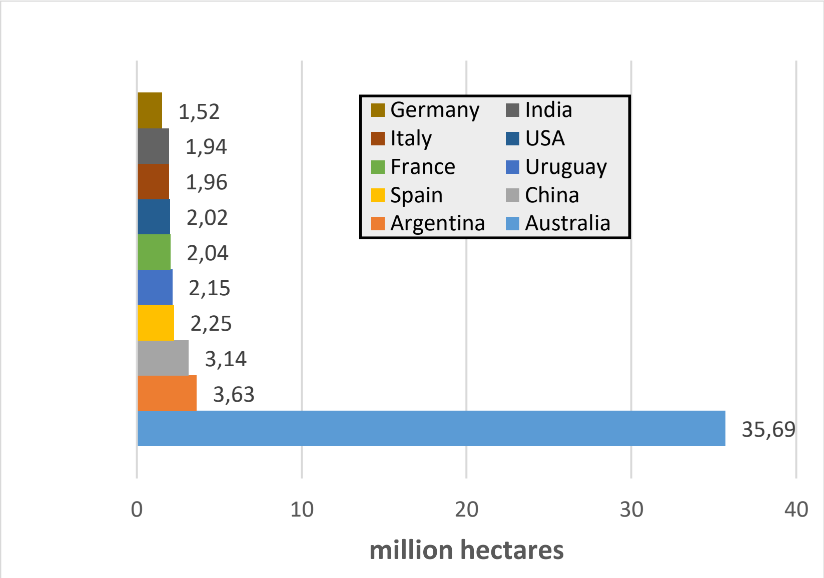

Figure 3. The ten countries with the largest areas of organic agricultural land
Source: *(FiBL,2020).*

11.8. Conclusion

All agricultural systems affect the environment to a greater or lesser extent. Organic farming is thought to have less harmful environmental impacts than conventional farming. However, scientific studies on this subject are not enough yet. Although there is conclusive evidence about the positive effects of organic agriculture on soil, air and water quality and biodiversity, its effects on energy use and land use efficiency are debatable. In the coming years, agricultural areas devoted to organic farming will increase as consumer demand continues. However, long-term field experiments are needed in major global farming regions to assess the environmental impacts of organic farming.

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CHAPTER 12

Determination of long-term toxic effects of licorice root (*Glycyrrhiza glabra*) plant in the model organism *Daphnia magna*

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12.1. Introduction

Daphnia magna, as a planktonic organism of the class *Phyllopoda*, is used to determine the toxicological effects of many drugs such as antibiotics, antidepressants, anti-inflammatory drugs, beta-blockers, lipid regulators and many different drugs (Ebert, 2005; Tkaczyk et al., 2021). *Daphnia magna* is frequently used as a model organism for toxicity testing, e.g., by the European Union (EU), the Organization for Cooperation and Economic Development (OECD), the American Society for Testing and Materials (ASTM), the International Organization for Standardization (ISO), and other organizations (Ferraz, 2021).

The oldest and most widely used licorice root (*Glycyrrhiza Glabra L.*) is one of the herbal remedies found in many Mediterranean and Asian countries, including Turkey, that can contribute to human health (Ding et al., 2022; Özüsağlam & Karakoca, 2014). It is used in the treatment of licorice root ulcers, asthma, pharyngitis, malaria, abdominal pain, insomnia and some infections with anti-inflammatory, antiviral, anti-allergic, antioxidant and anti-cancer properties (Charpe & Rathod, 2012).

As with many plants that can be used by humans for herbal medicine, few studies have been conducted on the toxicity of licorice extract. Therefore, this study attempted to evaluate the effects of acute and long-term subchronic toxicity on aquatic invertebrates *Daphnia magna*.

12.2. Methods

The study was conducted in the Fisheries Laboratory of Tekirdağ Namık Kemal University, Faculty of Arts and Science, Department of Biology. The aquatic invertebrate Daphnia magna used in the study has been cultured in our aquaculture laboratory since 2020 at an average water temperature of 24 °C and a light period of 16 hours and 8 hours of darkness.

2.1. Experimental organisms and chemicals

Daphnia magna kept in production aquaria is fed ad libitum twice weekly with unicellular green microalgae *Chlorella sorokiniana*. Newborn Daphnia fry removed from production aquaria for the study were placed in 30*20*15 cm plastic boxes and left in these boxes for one week for adaptation. During this one-week period, microalgae feeding was reduced and transition to the powdered feed used in the study was ensured. The amount of water in the boxes was kept constant at 4 liters.

The hot water method was used in the preparation of the licorice extract. In this method, the licorice root was ground into powder and the extract was collected in hot water. It was then cooled at room temperature (Tsuge et al., 2020). The product, which was stored in a closed, dark glass bottle at 4 °C, was added to water containing daphnia in the specified amounts.

12.2.2. Experimental setup

The study was designed as 3 replicates in 4 groups. each daphnia group received 4 liters of water, which was renewed daily and added with the extract from the licorice root plant used in the study. The doses added to the water were set as control (without the addition of licorice), 0.125 ml/L, 0.250 ml/L, 0.500 ml/L, 1 ml/L, 2 ml/L, and 3 ml/L.

A total of 420 asexual (parthenogenetic) offspring were randomly selected and an experimental order was established, and after adjustment, 20 animals were placed in each experimental group and the experiment was started. In the study, a diet of Inve O. Start-S 100-200 µ series was used to feed the daphnia, which contained 56% crude protein, 13% crude oil, 1% crude fiber, 1.2% Ca, 1.3 P and 10% ash. A single dose of food was administered daily by dissolving 1 gram of food in 1 liter of water, and licorice extract was added to the water during each daily water change. During the daily water change, the newborn pups were counted and separated from the main pens at the same time. In the study, the animals were kept at a water temperature of 24±1 ^{0}C, with 16 hours of light and 8 hours of darkness.

A total of 7 measurements were taken at 4-day intervals and the size, heart rate, number of eggs, number of offspring, and survival rates of *Daphnia* in 25 days were recorded.

12.2.3. Hearth rate

Daphnia, of which 7 measurements were taken over a 4-day period, were collected using a plastic pipette and placed on a slide (Figure 1). Images were captured for 6 seconds using a SOIF microscope, and heart rate was determined by slowing down the images using Windows Media Player.

Figure 1. Measuring way of *Daphnia* under microscope

12.2.4. Number of eggs and offspring

Eggs collected in the brood sac on the dorsal side were counted at 4-day intervals and recorded under the microscope (Figure 2).

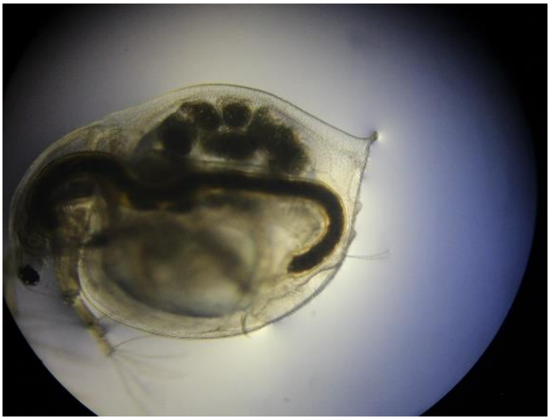


Figure 2. Asexual (parthenogenetic) reproduction, diploid eggs

12.2.5. Survival rates/Mortalities

Daphnia mortality rates were recorded daily as a function of licorice root extract added in the study.

2.6. Data analyses

Statistical analysis using the software package IBM SPSS Statistics 22.0, the repeated measures test ANOVA, and the Tukey post hoc test highlighted significant differences between groups in data marked with "*".

12. 3. Material and Method

The study determined the height, heart rate, egg count, population size, and mortality rates of daphnia from licorice extract added to water in various amounts and determined the effects of the doses used in the study.

12.3.1. Effects on body length

During the 25-day exposure of *D. magna* to licorice extract, differences in body length were observed in 7 measurements of each individual at different doses administered over 4 days (Table 1, Figure 3). It was found that the concentrations of licorice extract added to the water containing the daphnia reached lower heights than the control, the height values also decreased with the increase of the dose, and the data analyzed by repeated ANOVA showed statistically significant differences ($p<0.05$). As shown in Table 2, differences are marked with "*" and different colors.

Table 1. Length measurement values in groups

GROUPS		Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
KONTROL	1. measurement	1.896	.021	1.854	1.937
	2. measurement	1.990	.015	1.960	2.019
	3. measurement	2.183	.017	2.149	2.218
	4. measurement	2.413	.018	2.376	2.449
	5. measurement	2.597	.019	2.560	2.634
	6. measurement	2.823	.021	2.782	2.864
	7. measurement	3.131	.020	3.091	3.170
0.125 ml/L	1. measurement	1.883	.021	1.842	1.925
	2. measurement	1.950	.015	1.920	1.980
	3. measurement	2.136	.017	2.101	2.170
	4. measurement	2.277	.018	2.240	2.313
	5. measurement	2.424	.019	2.386	2.461
	6. measurement	2.738	.021	2.697	2.779
	7. measurement	3.034	.020	2.995	3.073
0.250 ml/L	1. measurement	1.881	.021	1.840	1.923
	2. measurement	1.952	.015	1.922	1.982
	3. measurement	2.100	.017	2.066	2.134
	4. measurement	2.270	.018	2.233	2.306
	5. measurement	2.417	.019	2.379	2.454
	6. measurement	2.731	.021	2.690	2.772
	7. measurement	3.006	.020	2.967	3.045
0.500 ml/L	1. measurement	1.898	.021	1.856	1.940
	2. measurement	1.948	.015	1.918	1.978
	3. measurement	2.108	.017	2.074	2.143
	4. measurement	2.251	.018	2.214	2.287
	5. measurement	2.396	.019	2.359	2.433
	6. measurement	2.719	.021	2.678	2.760
	7. measurement	2.997	.020	2.958	3.036

Table 2. Statistical differences between the groups (Length)

		Mean Difference (I-J)	Std. Error	Sig.
KONTROL	0.125 ml/L	.0844*	.01038	.000
	0.250 ml/L	.0964*	.01038	.000
	0.500 ml/L	.1022*	.01038	.000
0,125 ml/L	KONTROL	-.0844*	.01038	.000
	0.250 ml/L	.0119	.01038	.658
	0.500 ml/L	.0177	.01038	.322
0,250 ml/L	KONTROL	-.0964*	.01038	.000
	0.125 ml/L	-.0119	.01038	.658
	0.500 ml/L	.0058	.01038	.945
0,500 ml/L	KONTROL	-.1022*	.01038	.000
	0.125 ml/L	-.0177	.01038	.322
	0.250 ml/L	-.0058	.01038	.945

*The mean difference is significant at the .05 level.

At the same time, the height differences where different doses were applied are summarized graphically in Figure 3.

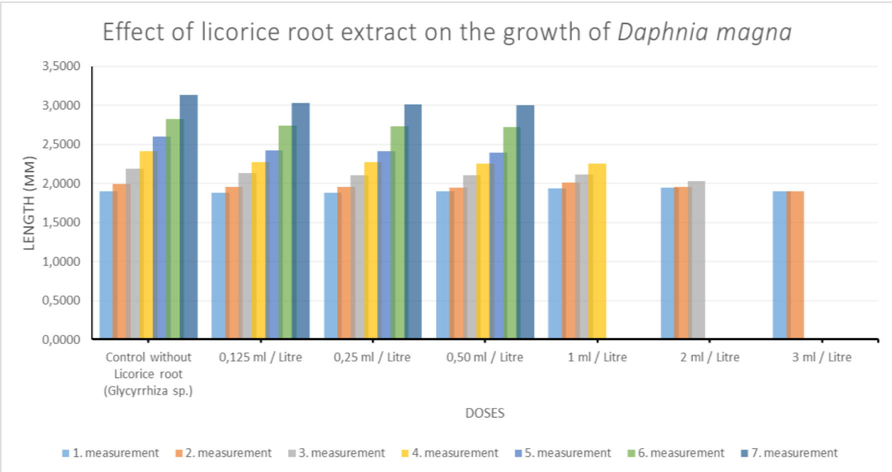


Figure 3. Effect of licorice root extract on the growth of *Daphnia magna*

12.3.2. Effects of hearth rate

The results obtained with the concentrations of licorice extract at different doses on heart rate are shown in Table 3. Accordingly, an increase was observed between the doses administered according to the heart rates of the animals in the control group, and higher values were obtained in the heart rates compared to the control group ($p<0.05$) (Table 4).

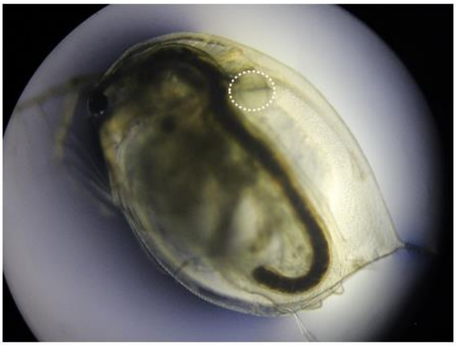


Figure 4. The heart of *Daphia magna*

Table 3. Hearth rate measurement values in groups

GROUPS		Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
KONTROL	1. measurement	368.533	1.604	365.374	371.693
	2. measurement	366.333	1.691	363.002	369.665
	3. measurement	366.733	1.566	363.648	369.819
	4. measurement	371.267	1.644	368.027	374.506
	5. measurement	370.998	1.748	367.553	374.443
	6. measurement	370.513	1.560	367.441	373.586
	7. measurement	371.149	1.498	368.198	374.100
0.125 ml/L	1. measurement	370.400	1.604	367.241	373.559
	2. measurement	369.667	1.691	366.335	372.998
	3. measurement	370.305	1.566	367.220	373.391
	4. measurement	373.068	1.644	369.829	376.308
	5. measurement	375.529	1.748	372.085	378.974
	6. measurement	378.560	1.560	375.488	381.633
	7. measurement	378.498	1.498	375.547	381.450
0.250 ml/L	1. measurement	369.067	1.604	365.907	372.226
	2. measurement	369.267	1.691	365.935	372.598
	3. measurement	371.867	1.566	368.781	374.952
	4. measurement	374.368	1.644	371.128	377.607
	5. measurement	377.594	1.748	374.149	381.039
	6. measurement	378.427	1.560	375.354	381.500
	7. measurement	379.514	1.498	376.563	382.465
0.500 ml/L	1. measurement	361.800	1.604	358.641	364.959
	2. measurement	370.000	1.691	366.668	373.332
	3. measurement	372.372	1.566	369.286	375.458
	4. measurement	377.503	1.644	374.263	380.742
	5. measurement	379.394	1.748	375.949	382.839
	6. measurement	382.117	1.560	379.044	385.190
	7. measurement	384.740	1.498	381.788	387.691

It was observed that with increasing dose, heart rate increased. Among the doses administered, the dose of 0.500 ml/L reached the highest heart rate. Statistically, significant differences were observed in the doses administered compared with the control group ($p<0.05$) (Table 4). Many reviews and studies have reported that the use of licorice extract can cause hypertension, especially in mice and humans (DiPietro & Mondie, 2021; Ferraz, 2021; Husain et al, 2021; Omar et al, 2012). In our study, it was observed that the doses administered resulted in a significant increase in the heart rate of *Daphnia*.

Table 4. Statistical differences between the groups (Hearth rate)

		Mean Difference (I-J)	Std. Error	Sig.
KONTROL	0.125 ml/L	-4.3573*	.84567	.000
	0.250 ml/L	-4.9393*	.84567	.000
	0.500 ml/L	-6.0568*	.84567	.000
0.125 ml/L	KONTROL	4.3573*	.84567	.000
	0.250 ml/L	-.5820	.84567	.902
	0.500 ml/L	-1.6995	.84567	.187
0.250 ml/L	KONTROL	4.9393*	.84567	.000
	0.125 ml/L	.5820	.84567	.902
	0.500 ml/L	-1.1175	.84567	.550
0.500 ml/L	KONTROL	6.0568*	.84567	.000
	0.125 ml/L	1.6995	.84567	.187
	0.250 ml/L	1.1175	.84567	.550

*The mean difference is significant at the .05 level.

12.3.3. Effects on reproduction

It was found that the number of eggs and fry, determined individually in each measurement period, was lower in the group treated with licorice extract than in the control group (Table 5, Figure 5). After the fifth measurement period, there was a significant difference in egg numbers compared to the other doses in the control group, and it was found that the number of eggs decreased with the increase of doses ($p<0.05$) (Table 6). Figure 5 shows that the applied doses negatively affect the number of eggs.

Table 5. The difference between the egg numbers between the groups

GROUPS		Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
KONTROL	1. measurement	.283	.102	.082	.485
	2. measurement	1.350	.111	1.132	1.568
	3. measurement	1.667	.127	1.417	1.916
	4. measurement	2.717	.186	2.351	3.082
	5. measurement	3.948	.387	3.186	4.710
	6. measurement	5.093	.262	4.577	5.609
	7. measurement	4.475	.230	4.021	4.929
0.125 ml/L	1. measurement	.317	.102	.115	.518
	2. measurement	.817	.111	.599	1.035
	3. measurement	1.052	.127	.803	1.302
	4. measurement	2.133	.186	1.768	2.499
	5. measurement	2.879	.387	2.117	3.641
	6. measurement	3.786	.262	3.270	4.302
	7. measurement	3.967	.230	3.513	4.421
0.250 ml/L	1. measurement	.267	.102	.065	.468
	2. measurement	.700	.111	.482	.918
	3. measurement	.950	.127	.700	1.200
	4. measurement	1.767	.186	1.401	2.132
	5. measurement	2.410	.387	1.649	3.172
	6. measurement	3.703	.262	3.187	4.219
	7. measurement	3.859	.230	3.405	4.313
0.500 ml/L	1. measurement	.250	.102	.048	.452
	2. measurement	.633	.111	.415	.851
	3. measurement	.886	.127	.636	1.135
	4. measurement	1.367	.186	1.001	1.732
	5. measurement	2.260	.387	1.499	3.022
	6. measurement	2.600	.262	2.084	3.116
	7. measurement	2.730	.230	2.276	3.184

Table 6. Statistical differences between the groups (Egg numbers)

		Mean Difference (I-J)	Std. Error	Sig.
KONTROL	**0.125 ml/L**	.6545*	.11877	.000
	0.250 ml/L	.8396*	.11877	.000
	0.500 ml/L	1.2582*	.11877	.000
0.125 ml/L	**KONTROL**	-.6545*	.11877	.000
	0.250 ml/L	.1851	.11877	.404
	0.500 ml/L	.6037*	.11877	.000
0.250 ml/L	**KONTROL**	-.8396*	.11877	.000
	0.125 ml/L	-.1851	.11877	.404
	0.500 ml/L	.4186*	.11877	.003
0.500 ml/L	**KONTROL**	-1.2582*	.11877	.000
	0.125 ml/L	-.6037*	.11877	.000
	0.250 ml/L	-.4186*	.11877	.003

*The mean difference is significant at the .05 level.

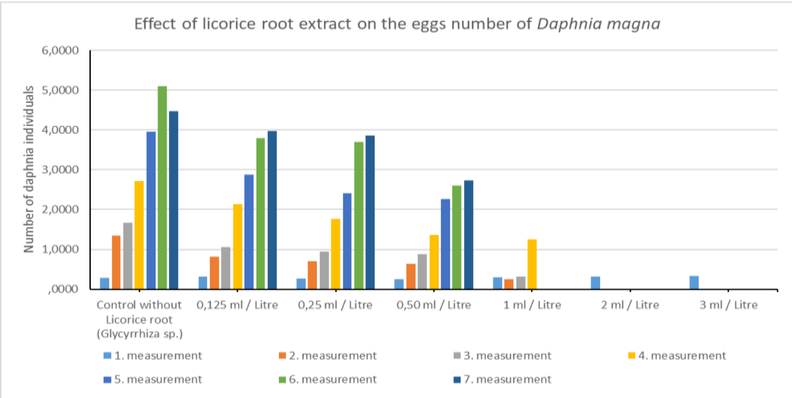


Figure 5. Effect of licorice root extract on the eggs number of *Daphnia magna*

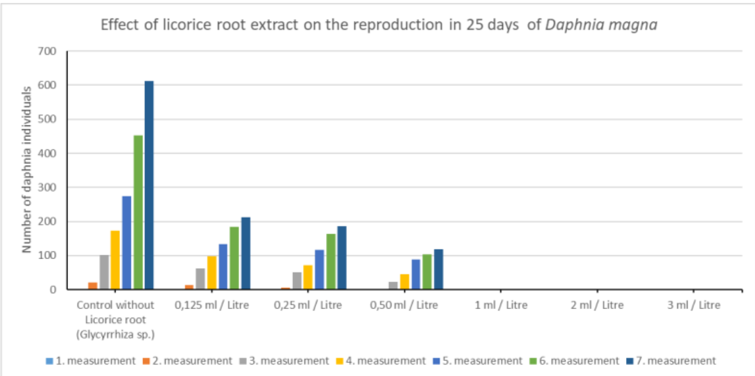
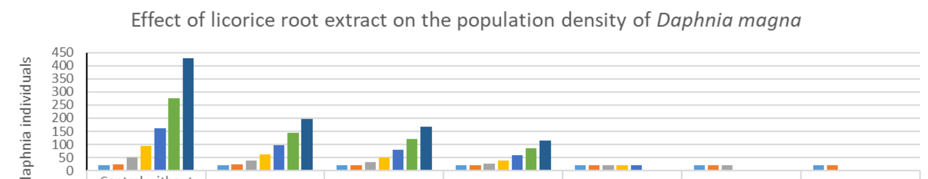


Figure 6. Effect of licorice root extract on the reproduction in 25 days of *Daphnia magna*

Looking at the graph showing the newborn offspring hatched in 7 measurement periods, it is clear that the control group achieved a higher number of offspring compared to the doses administered (Figure 6). It was found that the doses of licorice root administered had a negative effect on the number of offspring.

12.3.4. Effects of population density



	Control without Licorice root (Glycyrrhiza sp.)	0,125 ml / Litre	0,25 ml / Litre	0,50 ml / Litre	1 ml / Litre	2 ml / Litre	3 ml / Litre
1. Day	20	20	20	20	20	20	20
5. Day	25	23,5	21,25	20,75	20,25	20	20
9. Day	50,25	39,25	34	26,25	20,5	20	
13. Day	93,5	63,5	52	37,75	21		
17. Day	162	97	81,25	60	21		
21. Day	275	143,25	122	85,75			
25. Day	428,25	196,5	168,75	115,25			

1. Day 5. Day 9. Day 13. Day 17. Day 21. Day 25. Day

Figure 7. Effect of licorice root extract on the population density of *Daphnia magna*

The number of populations per liter in our study, in which three replicates were applied for each dose, is shown in Figure 7. Accordingly, the total population number at the end of the 25-day study in the control group was 428.5 individuals, with a higher number of individuals compared to the other groups.

12.3.5. Effects of survival

In our study, the survival effects of licorice root extract on D. magna were determined by determining the number of viable Daphnia in each measurement period. The licorice root extract dose of 3 ml per liter in the second measurement period, the dose of 2 ml in the third measurement period, and the dose of 1 ml in the fourth measurement period showed very low survival performance. There was no significant difference between the other doses administered compared to the control group until the end of the study (Figure 8).

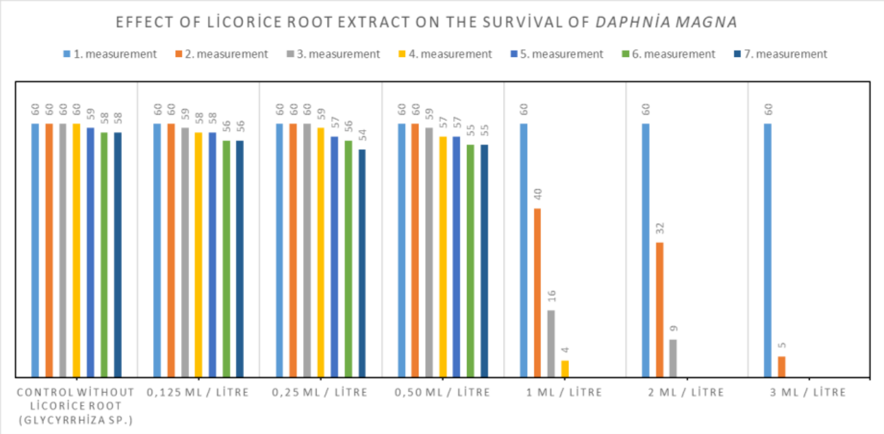


Figure 8. Effect of licorice root extract on the survival of *Daphnia magna*

12.4. Conclusion

Plants have been used by people since ancient times as products that can be used in many fields such as medicine, cosmetics and food. It is shown that licorice root, the herbal product we used in our study, has a decreasing effect on growth, egg and offspring formation compared to the control group, and heart rate increases with increasing dose. Especially nowadays, when herbal products are becoming more and more popular, consumers need to know the risk factors involved in using these products and they should follow the recommended doses when using these products.

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Brief Curriculum Vitae

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In 2002, I graduated from İstanbul University, Faculty of Aquaculture, Department of Breeding and Disease. In 2005, I completed my Master's Education with the thesis titled "Up to the 3-4 month growth phase of mirror carp that have completed the purse period a study of weight gain and feed intake at different temperatures" at Trakya University Faculty of Agriculture. In 2012, I completed my PhD education with the thesis on "Effects of plant carotenoids (red pepper, crude palm oil, carrot) on pigmentation and growth of Japanese fish" at Tekirdağ Namık Kemal University Faculty of Agriculture. In 2011, I started to work as a lecturer at Tekirdağ Namık Kemal University, Vocational College of Technical Sciences. I am working at Tekirdağ Namık Kemal University, The Faculty of Arts and Sciences Departments of Biology with the assignment in February 2023.

CHAPTER 13

THE EFFECT OF BIOCHAR APPLICATIONS, SATURATED WITH BIOGAS PLANT WASTEWATER, ON THE PLANT NUTRITIONAL CONTENT OF MAIZE (*Zea mays* L.)

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13.1. Introduction

Biochar is a very rich carbon source obtained from biomass by thermal combustion in an oxygen-limited environment (Yaashikaa et al., 2020). Biochar is used for agricultural purposes to increase soil fertility and reduce environmental pollution. It increases soil fertility by reducing leakages caused by leaching on one hand, and it increases the water holding capacity of the soil and cation exchange, and reduces soil acidity on the other hand (Hamidzadeh et al., 2023). Due to its properties including high organic carbon content, high specific surface area, high porosity etc., it is used for many treatments in agriculture and environment (Liu et al., 2023). Therefore, many researchers are turning to biochar as a solution to the challenges of modern agriculture and to deal with environmental pollution.

Biochar consists of essential components such as moisture, stable carbon and unstable carbon. The ratio of these elements is closely related to the temperature and duration of the pyrolysis process and the type of raw material used. Therefore, the content and physical composition of the biochars to be produced will be different from each other. For this reason, each biochar production is unique and have different properties compared to the others (McLaughlin et al., 2009; Spokas, 2010).

The high surface area and charge density of biochars allow ions to be adsorbed through cation exchange. This high surface area, internal porosity, and both polar and non-polar surface regions allow nutrients to be adsorbed. In addition, it provides a suitable nutrient environment for the benefit of plants by containing essential plant nutrients in its structure. Therefore, biochar has an important role in plant nutrition strategies and can potentially increase agricultural productivity (Laird et al., 2010; Hale et al., 2013).

Studies show that pyrolysis conditions (heating temperature, heating time and raw material) affect the properties of biochar significantly. Changes in the properties of biochar are due to thermal degradation of the biomass, which is controlled by the pyrolysis temperature. A loss of moisture takes place in the first stage of pyrolysis, and then with the increase in temperature, the pyrolytic volatiles start to be released from the biomass. With the loss of volatile organic compounds, mineral matter is enriched in C-rich ash and a biochar rich in P, K, Ca and Mg content is obtained (Figueiredo et al., 2018).

In a study conducted in Indonesia, Nurida (2021) evaluated the effect of biochar addition with urea/urine on soil chemical properties and maize yield. The experiment included the treatments of 1- urea, 2-biochar+urea, 3-

biochar+dissolved urea and 4- biochar+urine. The results showed that the addition of biochar had a positive effect on the chemical properties of the soil. In the experiment including the growth of maize plant, the highest dry grain weight was measured in the treatment of biochar + urea (7.49 tons ha^{-1}). 15 tons ha^{-1} biochar treatment applied together with urea/urine had a positive effect on the chemical properties of the soil compared to the groups without biochar addition. Total nitrogen was %40 higher in the groups where biochar and urea were applied together.

Majeed et al. (2018), conducted a research study to investigate how different biochar types (pine, poplar, and oak), biochar doses (0%, 1%, 2%, and 4%), and nitrogen doses (0 mg kg^{-1}, 70 mg kg^{-1}, 140 mg kg^{-1}, and 210 mg kg^{-1}) affect soil quality, antioxidant enzyme activities and maize plant growth. The study also examined how nutrient uptake and antioxidant enzyme activity were affected by these factors. The study was carried out as a pot experiment under greenhouse conditions and maize (*Zea mays* L.) was chosen as the test plant. Type of biochar significantly affected soil and plant parameters. As the biochar treatment dose increased, the pH, EC and organic matter increased, but the lime content as well as the P, K, Na and Zn uptake by the plant decreased. Increases in plant dry matter were also detected with biochar treatments. Leaf N content increased with nitrogen treatments, and the highest leaf dry matter weight was achieved with a nitrogen dose of 210 mg kg^{-1}. Based on the amount of leaf dry matter, the best interaction happened to be the combination of %2 biochar treatment and 140 mg kg^{-1} N treatment obtained from poplar.

In the study carried out by Ali et al. (2017) as a three-factor, biochar (0-, 25- and 50-tons ha^{-1}), farm manure (5- and 10-tons ha^{-1}) and nitrogen (75 and 150 kg ha^{-1}) and a two-year field experiment with the growth of maize (*Zea mays* L.), biochar treatment increased the maize oil content (%12, %29). In the plots with biochar treatment, the protein content increased by %27 compared to the control, but there was a decrease of %11 in starch content compared to the control.

Kara (2016) obtained biochar from four different organic materials: eucalyptus (*Eucalyptus deglupta*), poplar pruning waste, cotton harvest waste and olive pomace. Produced biochars were applied to maize (*Zea mays* L.) cultivated soils at four different doses (0 t/ha, 10 t/ha, 20 t/ha, 40 t/ha). As a result of the experiment, it was determined that the treatments increased the organic matter contents and the available macro element contents of the soils.

It was determined that the treatments did not cause a significant change in the dry matter percent values of the plants and increased the plant height and the number of leaves. The treatments did not have any significant effect on the morphological features of the plants. The aim of this study is to determine the effect of saturated and unsaturated biochar applications on the macro and micro nutrient content of maize.

13.2. Methods

13.2.1. Biochar production

Biogas plant solid wastes were used to obtain biochar. Biochar was obtained by carbonizing (pyrolysis) the solid organic waste from the separator outlet from the plant at 650°C for 6 hours without oxygen. In biochar production, the temperature of the muffle furnace is set at 10°C per minute (Kambo & Dutta, 2015). Analysis results of biochar are given in Table 1. The obtained biochar materials were sieved through 2 mm sieves and made ready for treatment.

Table 1. Physical and chemical properties of biochar

Parameter	*Unit*	*Value*
pH	-	9.82
EC	$dS\ m^{-1}$	3.32
CEC	$meq.100g^{-1}$	25.90
Total N	%	0.13
Total P	%	2.73
Total K	%	2.34
Total Na	%	3.34
Total Ca	%	8.46
Total Mg	%	2.32

13.2.2. Saturation of biochar

In the study, waste water (BPW), which is formed as a result of the biogas process of the same biogas plant and cannot be treated due to its high organic load, was used for saturation of biochars with nitrogen and phosphorus. Table 2 includes the analysis results of waste water.

Saturation of biochar was carried out under laboratory conditions. Cylindrical columns with dimensions of 280 x 80 mm were used in the saturation process. Coarse gravels and fine gravels are placed respectively at the bottom of the column where infiltration will take place. Hoses are attached to the end of the columns and fixed with clamps. In addition, the water flow was controlled by the tap placed at the end of the hoses (Figure 1).

Table 2. Biogas Plant Wastewater (BPW) and manure chemical properties

Parameter	*Unit*	*BPW*	*Manure*
pH	-	8.08	7.98
EC	dS m^{-1}	2.31	2.91
Organic matter	%	28.84	51.32
Org-C	%	16.72	29.77
C:N ratio	-	16,24	23.08
Total N	%	1.03	1.29
Total P_2O_5	%	0.30	2.16
Total K_2O	%	0.12	1.89
Total Ca	mg kg^{-1}	5800	15947
Total Mg	mg kg^{-1}	1400	6310
Total Na	mg kg^{-1}	764	1934

Biochar was weighed to 450 g and placed in saturation columns. The amount of water that the biomass can hold was calculated, and the amount of liquid manure to be washed daily was decided. The same biogas plant waste water was used for the daily saturation process. Every day 150 ml of waste water was added to the columns regularly. In order for the adsorption process to take place in a fixed time, the taps were kept closed for 16 hours. Afterwards, the taps were opened and the filtrates were obtained for daily analysis. At this stage, the washing process was continued until the biochar reached the maximum saturation level.

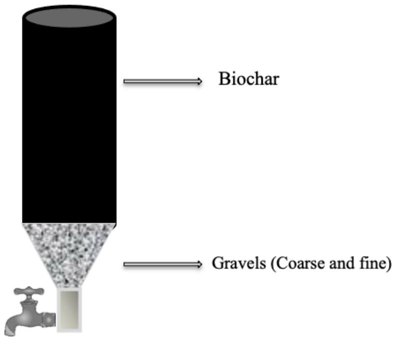

Figure 1. Saturation Column

13.2.3. Greenhouse experiment

A total of 24 pots were used for the experiment set in the greenhouses of Aydın Adnan Menderes University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition. The study was carried out in 3 replications and 12 kg of soil was used in each pot. The analysis results of the soil used are given in Table 3. Except for the control group, manure (Table 2) was applied at a rate of 1 ton da^{-1} with 50% reduced treatment of optimum N-P-K manure. Saturated and unsaturated biochar doses, which are the main subjects of the study, were applied to each pot as given in Table 4. The pots were moistened to the field capacity, and 4 silage maize seeds of the PR31G98 type were planted in each pot. It was diluted to 2 plants after plant emergence was observed. The plants were harvested at the end of the 90th day. After the biomass weight of the leaves was determined, the plants were washed 2 times with tap water and 2 times with distilled water. After dehumidifying the washed samples, they were dried in a furnace at 65°C and ground in the mill to make them ready for analysis. At the end of the study, the nutrient elements of the leaves were determined and the element concentrations were calculated on dry matter.

Table 3. Physical and chemical properties of soil

Parameter	*Unit*	*Value*
pH	-	7.75
EC	dS m^{-1}	0.22
Salt Content	%	0.01
Total Carbonate	%	2.86
Texture	-	SL
Organic matter	%	1.46
CEC	meq.$100g^{-1}$	5.60
Total N	%	0.09
Soluble B.	mg kg^{-1}	0.42
Exchangeable P	mg kg^{-1}	6.60
Exchangeable K	mg kg^{-1}	121.00
Exchangeable Na	mg kg^{-1}	64.00
Exchangeable Ca	mg kg^{-1}	1570
Exchangeable Mg	mg kg^{-1}	62.00

Table 4. Experimental design and biochar application rates

<table>
<tr><td colspan="2">CONTROL</td></tr>
<tr><td colspan="2">Optimum NPK (%50) + 1 ton da^{-1} Manure</td></tr>
<tr><td rowspan="3">SATURATED BIOCHAR</td><td>1 ton da^{-1} Biochar + Opt. NPK (%50) + 1 ton da^{-1} Manure</td></tr>
<tr><td>2 ton da^{-1} Biochar + Opt. NPK (%50) + 1 ton da^{-1} Manure</td></tr>
<tr><td>3 ton da^{-1} Biochar + Opt. NPK (%50) + 1 ton da^{-1} Manure</td></tr>
<tr><td rowspan="3">UNSATURADED BIOCHAR</td><td>1 ton da^{-1} Biochar + Opt. NPK (%50) + 1 ton da^{-1} Manure</td></tr>
<tr><td>2 ton da^{-1} Biochar + Opt. NPK (%50) + 1 ton da^{-1} Manure</td></tr>
<tr><td>3 ton da^{-1} Biochar + Opt. NPK (%50) + 1 ton da^{-1} Manure</td></tr>
</table>

13.2.4. Soil analysis methods

Texture: The texture of the soils were determined using the hydrometer method to the texture analysis triangle (Bouyoucos, 1962). Salt Content (%): It was determined by the method based on the electrical resistance measurement with the Conductivity Bridge Device in the soil paste saturated with distilled water (Richards, 1954). Total Carbonate (%): Measured with scheibler calcimeter, %10 HCl is used for reaction (Kacar, 2012). Soil Reaction (pH): The pH value was determined in the suspension obtained by shaking the soil with distilled water at a ratio of 1:2,5. After the mixture obtained was shaken for 5 minutes in a horizontal shaker, the pH was measured in the supernatant by using pH meter (Kacar, 1996).

Organic matter: By using the Walkey-Black method, the organic matter was oxidized with potassium dichromate, and then the amount of ammonium ferrosulphate spent in titration and the organic matter content were found using the formulas (Walkey & Black, 1934).

Available phosphorus: As a result of the reaction of the soil with 0.5 M sodium bicarbonate, the plant available phosphorus was determined (Jakson 1973). Extractable potassium, calcium, sodium, magnesium: The amount of K, Na, Ca, which passed into the solution by shaking the soil with 1 N ammonium acetate (pH=7) in a horizontal shaker for 30 minutes at 160 rpm, was determined in a flame photometer. Mg was determined in an Atomic Absorption Spectrophotometer (Richards, 1954). Total nitrogen (%):

It was done with Kjeldahl method, samples were digested, distilled and then analyzed by titration (Kacar, 1996).

Cation exchange capacity (CEC): Soil samples were first saturated with Na by shaking with 1N sodium acetate, then washed with %95 ethyl alcohol and shaken with 1 N ammonium acetate to replace the sodium adsorbed by the soil with ammonium (Jackson, 1958).

Hot water-soluble boron: It was determined colorimetrically by the Dianthrimid method in soil samples extracted by boiling with a soil-water ratio of 1:2 (Riehm, 1957).

13.2.5. Biochar and Manure Analysis Methods

Total nitrogen: Digestion was made with the modified Kjeldahl method, then distilled and the total nitrogen content was determined in percent (%) with titration (Kacar, 1996), pH: The suspension was obtained by mixing the sample with distilled water at a ratio of 1:20. The resulting mixture was obtained after shaking in a horizontal shaker for 30 minutes and reading it with a pH meter (Kacar, 1996).

EC: Sample-water suspension in a ratio of 1:20 was obtained and electrical resistance was measured with the electrical conductivity meter (Richards, 1954). Total Phosphorus content: Total P in wet-digested samples with a mixture of HNO_3 + $HClO_4$. Total P content was determined by the vanadomolybdophosphoric method (Kacar & Kovancı, 1982). Total macro element content: In manure samples wet-digestined with HNO_3 + $HClO_4$ acid mixture, potassium (K), calcium (Ca), sodium (Na) flamephotometer and magnesium (Mg) was determined by atomic adsorption spectrophotometer (AAS) (Kacar & İnal, 2008). Organic matter: Calculated from combustion loss according to dry digestion (70°C – 550°C) method. (AOAC, 1990).

13.2.6. Plant analysis methods

The plant samples harvested after the greenhouse experiment were brought to the laboratory and passed through tap water twice and distilled water twice. After that, they were dehumidified with coarse blotting paper and dried in an air-circulated furnace at 65°C until they reached a constant weight. After drying, the plant samples were ground with a special herb grinder and made ready for analysis.

The amount of dry sample needed for analysis was measured using a precision balance, and the weight of the sample was 0.25 grams. Wet digesting was carried out in the fume hood by adding acid as 4 parts nitric acid and 2 parts perchloric acid ($HNO_3/HClO_4$). Afterwards, the extracts were washed 5-6 times with hot water and filtered through blue banded filter papers and transferred to balloon flasks (Kacar & İnal, 2008).

Dry matter (%): Dry matter content was determined by using gravimetric analysis method (Kacar & İnal, 2008).

Total nitrogen: Total N was determined by using digestion, distillation and titration stages, according to the Kjeldahl method (Bremner, 1965).

Phosohorus determined by spectrophotometrically, vanadomolybdo phosphoric yellow colour method (Lott et al., 1956), while K, Ca and Na was determined with flame photometer and Mg, Fe, Zn, Mn and Cu was determined by measuring in Atomic Absorption Spectrophotometer (Kacar & İnal, 2008).

13.2.7. Statistical analysis

The effects of treatment doses and saturation factor on macro and micro element content of plant leaves were determined by variance analysis using statistical software 'SPSS 22.0' (Yurtsever, 1984). Statistically significant groups were determined by applying the $LSD_{0.01}$ test.

13.3. Result and Discussion

13.3.1. Effect on macronutrient content

When the effects of the treatment doses on the %N content of the plant samples were examin90ed, the difference between the doses was found to be statistically significant at the level of $p<0.01$. When the effects of treatment doses on dry matter, P, K, Ca (%) contents were examined, the difference between the doses was found to be statistically significant at the level of $p<0.01$. The effect of the treatments on the % Mg content was found to be statistically significant at the level of $p<0.05$. The effect of saturation using liquid manure to enrich the biochar with nitrogen and phosphorus on the N, P, K, Mg (%) contents of the plants was found to be statistically significant at the level of $p<0.05$. It was determined that the saturation process was not statistically significant in the Ca content of the maize plant (Table 5).

Compared to the control group, the greatest increase in N content was observed in the saturated biochar treatment of 3 ton da^{-1}, and this increase was determined to be %15.4. It was stated in previous studies that the addition of biochar to the soil can increase the plant nitrogen content. Lehmann et al. (2003) reported that the nitrogen content of maize grown in biochar-treated soils was %59 higher than that of plants grown in non-biochar-treated soils. Our results are parallel with the literature.

The saturation process increased the nitrogen content in the plants. These results were attributed to the highly porous structure and large surface area of biochar. Due to its large surface area, it is thought that biochar holds the nitrogen in the liquid manure, increasing the amount of N in plants due to more N entry into the soil (Hossain et al., 2020).

Table 5. Effect of biochar applications on the macro element and dry matter content of the maize (%).

Application		*N*	*P*	*K*	*Ca*	*Mg*	*Dry Matter*
Control		2.21 D	0.13 E	1.09 F	0.11 D	0.26	17.14 CD
Opt.NPK(%50)		2.27 CD	0.15 E	1.51 E	0.11 D	0.27	17.91 AB
SATURATED	***1 ton da^{-1}***	2.42 B	0.20 C	2.15 D	0.14 C	0.28	17.43 CD
	2 ton da^{-1}	2.31 BCD	0.25 B	2.23 BC	0.17 ABC	0.29	18.14 A
	3 ton da^{-1}	2.55 A	0.28 A	2.19 CD	0.19 A	0.28	18.25 A
UNSATURATED	***1 ton da^{-1}***	2.31 BCD	0.17 D	2.35 A	0.16 BC	0.27	16.99 D
	2 ton da^{-1}	2.32 BCD	0,20 C	2.31 D	0.16 BC	0.28	17.06 A
	3 ton da^{-1}	2.38 BC	0.20 C	2.11 D	0.18 AB	0.26	18.25 A
Apps. Effect		**	**	**	**	*	**
Saturation Effect		*	**	**	**ns**	*	**

***:** *p<0.05,**: p<0.01, ns: no significant*

With the increase in the treatment doses of biochar, the P (%) content of the plants increased and this increase was found to be statistically significant at the level of $p<0.01$. Compared to the control group, the greatest increase in N content was observed in the saturated biochar treatment of 3 ton da^{-1}, and this increase was determined to be %115. It was stated in previous studies that the treatment of biochar to the soil can increase the plant phosphorus content. Atkinson et al. (2010) stated that the treatment of biochar to soil increased the phosphorus content by up to %43 compared to grass grown in non-biochar treated soil. Jeffery et al. (2011) determined that biochar treatments increased the phosphorus content of beans by up to %80. The findings are parallel with these previous studies.

According to Major et al. (2010), the application of biochar resulted in increased availability of potassium (K), calcium (Ca), and magnesium (Mg) in the soil. Biochar treatment increased K, Ca concentrations of bean and maize plants (İnal et al., 2015). Dry matter content and plant nutrients such as N, P, K, Ca increased. Due to the low density of biochar (<0.9 cm^3), it is thought that it improves the physical conditions of the soil, prevents the leaching of plant nutrients thanks to its functional groups and high CEC, and acts as a storage for plant nutrients (Panwar et al. 2019; Bolan et al., 2022; Liu et al., 2020). Van Zwieten et al. (2010) suggest that N treatment together with biochar has a positive effect on plant growth. Syuhada et al., 2016 reported that, biochar treatments increased the N and K uptake of maize plant, but the same was not true for Ca and Mg.

13.3.2. Effect on micronutrient content

When the effects of the treatment doses on the Fe, Zn, Mn contents of the plant samples were examined, the difference between the doses was found to be statistically significant at the level of $p<0.01$. When the effects of treatment doses on Cu contents were examined, the difference between the doses was found to be statistically significant at the level of $p<0.05$ (Table 6).

Table 6. Effect of biochar applications on the micro element content of the maize (mg kg^{-1}).

Application		*Fe*	*Zn*	*Mn*	*Cu*
Control		142.20 D	20.37 C	123.63 D	12.34 B
Opt. NPK(%50)		153.10 C	22.33 G	132.13 C	12.51 B
SATURATED	***1 ton da^{-1}***	130.47 E	30.70 AB	111.02 E	13.13 AB
	2 ton da^{-1}	171.12 A	29.90 AB	151.53 A	13.49 A
	3 ton da^{-1}	132.07 E	26.45 BC	111.87 E	13.50 A
UNSATURATED	***1 ton da^{-1}***	162.20 B	34.69 A	141.43 B	13.57 A
	2 ton da^{-1}	148.50 CD	30.97 AB	128.42 CD	13.53 A
	3 ton da^{-1}	148,00 CD	32.27 AB	127.40 CD	13.52 A
Apps. Effect		**	**	**	*
Saturation Effect		ns	**	ns	ns

*: $p<0.05$,**: $p<0.01$, ns: no significant*

Although there are studies in the literature reporting that the microelement content of plants increases with biochar treatment, the changes in the microelement contents may not directly increase according to the biochar doses (Brantley et al., 2016; Noyce et al., 2017; Li and Shangguan 2018). The changes in micro element contents in the present study do not display an increase in parallel with biochar doses. The reason for this is thought to be the chemical properties of the soil and biochar used and the biochar treatment doses. In this context, it was considered that negative effects may take place on high uptake of Ca and Mg, particulary of Fe and Zn, depending on the increase in the amount of biochar treatment.

13.4. Conclusion

An increase in the application doses of biochar was found to result in a statistically significant increase in the N, P, K, Ca, Mg, Fe, Zn, Mn, and Cu content of maize plants, with the greatest increase observed in the application of 3 tons da^{-1} of saturated biochar. It was also found that the application of biochar saturated with biogas plant wastewater resulted in an increase in the dry matter, N, P, Mg, and Zn content of maize plants, with the most significant effect observed in the application of 3 tons da^{-1} of saturated biochar.

Annotation

This book chapter has been prepared from a part of Özlem Üstündağ's PhD thesis.

Titled: "*Investigation of Adsorbent Properties of Biochar in the Treatment of Wastewater from Biogas Production and its Usage Possibilities in Agriculture*"

* This thesis carried out in the Department of Soil Science and Plant Nutrition of Aydın Adnan Menderes University, Institute of Natural and Applied Sciences. 2022-DR-001, Supervisor; Assist. Prof. Dr. Selçuk GÖÇMEZ.

This study was presented as an oral presentation at the "International Conference on Global Practice of Multidisciplinary Scientific Studies-III Turkish Republic of Northern Cyprus, November 15-17, 2022" and its abstract was published under the title "*Effects of Biochars Aplications Which Were Saturated with Biogas Plant Wastewater on Plant Nutrient of Maize (Zea mays L.)*"

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