ADVANCED STRATEGIES FOR AGRICULTURE

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PREFACE

Agriculture is the starting point of the food chain, which we define as basic production. Sustainable Agriculture includes systems and programs that will improve the production of sufficient and quality foodstuffs for appropriate growth and the protection of agricultural land, farmers, the environment and natural agriculture. In recent years, with globalization in the agricultural sector, it has regained importance and turned into a sector again, especially due to the decrease in the developing common weakness, food security, supply of input to the industry, foreign exchange supply and the impact of economic growth transactions. It is seen that developed industrial countries do not put agriculture in the background, on the contrary, they bring together different research and development studies, innovations in production, processing, marketing, systems and activities, and global agricultural activities.

Since agriculture is a branch of production dependent on natural conditions, it is the sector that has the most negative impact from climate changes. In addition, it is inevitable that sectors that obtain their raw materials from agriculture will also be harmed by this change. While product quantity, not product quality, is more important in the classical farming method, product quality is more important in organic farming. This environmentally friendly farming method provides long-term growth and growth for natural methods and increases the amount of product.

Developing innovation to solve options while anticipating tomorrow's challenges. It offers the necessary solutions and services to protect our resources through innovation, ensure sustainability and meet the needs of the food chain. Agricultural innovation is “new or improved inputs and methods used in the production process.

I hope that this book, which evaluates the issues that need to be taken into consideration in terms of Turkey not falling behind these developments and evaluating its agreement potential, will be useful to sensitive entrepreneurs and everyone else.

Assoc. Prof. Dr. Mehmet Fırat BARAN
Dr. Kevser KARAGÖZ SEZER

CHAPTER 1

EFFECTS OF AGRICULTURAL WASTES ON SOME SOIL PROPERTIES

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Introduction

To development management strategies which protect and develop soil became necessary caused by increasing concerns about sustainability and productivity of natural resources (Campbell et al., 1992). There is a growing awareness that soil is a critical component of the biosphere, not only for food production but also for maintaining environmental quality. Therefore, land degradation has been one of the main environmental concerns (Marcotea et al., 2001). Sustainable functioning of soils, which are the basic elements of agricultural production, can only be possible by preserving and even improving basic soil characteristics and genetic capacities.

The addition of organic wastes enhances soil organic and humic content, helping to build a fertile soil structure that makes better use of water and nutrients. Fageria (2012) reported that organic matter play an essential role in the sustainability of farming systems. The use of organic and green manures, compost and similar products, and animal and vegetable wastes added to the soil afterwards are beneficial for increasing the amount of both soil organic matter and soil microorganisms activities. Plant litter is the primary source of nutrients for saprophytic microbiota in soil, and its quantity and properties strongly influence the formation and hydration of soil organic matter in terrestrial ecosystems (Scholes et al. 1997; Kögel-Knabner 2002). Soil microbial biomass represents a significant fraction of terrestrial carbon, and its residues are important parent materials for humus formation (Haider 1992; Kögel-Knabner 2002). Additionally many researchers reported that use of organic amendments has been found efficient for improving soil physical and chemical properties such as aggregation, structure, moisture holding capacity of soils, and increasing soil microbial activity and cation exchange capacity, and finally crop yields (Albiach et al., 2000; Tejada et al., 2008; Candemir and Gülser, 2011).

Organic amendments help to desirable soil microbial, chemical, and physical properties, such as greater plant-available water-holding capacity and lower bulk density (Doran, 1995). Soil organic matter can strongly affect aggregation of soil particles and in turn is influenced by the types of plant residues or organic amendments used and by their decomposition rate and products. The impact of organic matter on soil aggregation depends on the soil's textural class, with the strongest effects generally being observed in coarse-textured soils (Bronick and Lal, 2005). Organic matter applications increase soil organic carbon content, and it results in increased water-holding capacity, porosity, infiltration capacity, hydraulic conductivity, and water-stable aggregation and decreased BD and surface crusting (Haynes and Naidu, 1998). In this review effects of agricultural plant wastes on some soil properties and yield parameters are discussed.

Effects of Agricultural Wastes on Some Physical Soil Properties

Soil physical parameters are not only indices for soil physical quality, determining the suitability and sustainability of soil for agricultural management (Rabot et al. 2018; Almendro Candel et al. 2018), but also they influence on several soil chemical and biological processes (Jat et al., 2018). A soil must create a favorable physical environment for root development to meet the plant's needs for nutrients and water to optimum growth conditions. Soil properties such as porosity (micro and macropores), pore size distribution, bulk density, hydraulic conductivity, aggregate size distribution, permeability, and infiltration are major physical indicators of soil structural stability and plant productivity (Almendro Candel et al 2018). Soil aggregates are the main units of soil structure, and organic matter contribute to the development of soil structure with a binding agent in the formation of aggregates (Bronick and Lal, 2005; Gülser, 2006; Gülser and Candemir, 2015). Hydraulic conductivity is an important soil physical property for determining soil hydrological processes and may change as water permeates and flows in a soil due to various chemical, physical and biological processes (Hillel, 1982).

Intensive farming generally causes to soil degradation due to loss of soil organic matter and decline of soil structure, and results of reduced macroporosity, infiltration rate and water-holding capacity of soils. Many studies revealed that organic wastes addition to soils decreases bulk density and increases total pore space (Candemir and Gülser, 2011; Gülser and Candemir 2012; Gülser 2021). The increase in water holding at field capacity by increasing soil OM can be attributed to greater macro aggregation and increased porosity. Organic matter content in soil increases the capacity of soils to retain water by direct absorption and by enhancing the formation and stabilization of aggregates containing an abundance of pores that retain water under moderate tension. Infiltration is a volume flux of water flowing into the soil profile per unit of soil surface area (Hillel1982). High infiltration rate describes the efficiency of use of irrigation or rainfall water in soil profile. Brown and Cotton (2011) reported that continuous application of compost to fields increased water infiltration over the control.

The effects of farmyard manure, hazelnut husk, tobacco waste and tea waste applications on some soil physical properties of fine and coarse textural soils were investigated by Candemir and Gülser (2011). Generally agricultural waste applications significantly increased aggregate stability (AS), moisture content at field capacity (FC) and total porosity with decreasing bulk density (BD) over the control treatments of both soils (Table 1).

Table 1. Effects of agricultural waste applications on some physical properties of different textural soils (Adapted by Candemir and Gülser, 2011).

Agricultural wastes	BD g (cm^{-3})	AS (%)	FC (%)
Clay soil			
C	1.125 a**	61.97 b	37.24 b
M	1.042 ab	57.08 c	38.43 ab
TOW	0.978 b	66.47 a	38.17 ab
HH	1.001 b	64.26 ab	40.55 a
TEW	0.948 b	66.97 a	39.91 a
Loamy sand soil			
C	1.497 a	24.35 c	10.88 c
M	1.281 b	34.94 b	12.61 ab
TOW	1.300 b	40.52 a	12.06 b
HH	1.159 c	43.72 a	12.95 ab
TEW	1.254 b	40.29 ab	13.36 a

** significant at 0.01 level. C: control, M: farmyard manure, TOW: tobacco waste, HH: hazelnut husk, TEW: tea waste.

Infiltration rate generally increases with increasing organic C content and aggregate stability of soils. Nnabude and Mbagwu (1999) reported that dry rice-mill waste treatment from 12.5 tons/ha to 50 tons/ha increased infiltration rate from 52.9 cm/h to 225.0 cm/h with 29% and 454% rate of increment over the control, respectively. Gülser et al. (2015) found that raw (HH) and composted (CMP) hazelnut husk treatments in a hazelnut orchard significantly reduced bulk density (BD) and penetration resistance (PR) and increased infiltration rate by 436% and 34% over the control, respectively (Figure 1). They found that infiltration rate had significant positive correlations with OC (0.869) and AS (0.832) at the 1% level. While the lowest IR (0.56 m/h) was determined in the control, the highest IR (3.02 m/h) was reported in HH treatment. HH due to its high C:N ratio had slow mineralization rate and higher aggregate stability, total porosity and infiltration rate.

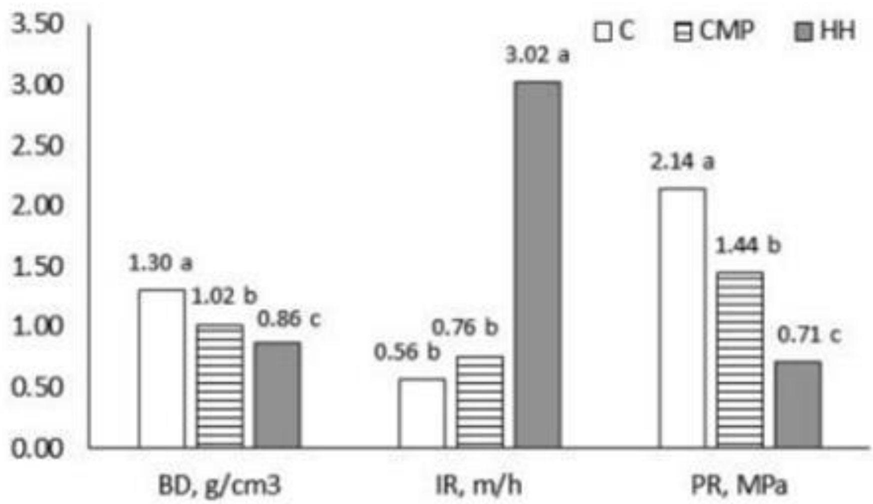

Figure 1. Effect of raw (HH) and composted (CMP) hazelnut husk treatments on bulk density (BD) infiltration rate (IR) and penetration resistance (PR) over the control (C) (Adapted by Gülser et al. 2015).

In another study, changes of soil quality indexes in a hazelnut orchard after hazelnut husk (HH) and compost (CMP) applications were investigated by Gülser et al. (2015). They reported that the slow decomposition rate of HH, due to having the highest C:N ratio, caused the highest increases in soil organic carbon, aggregate stability, total porosity, and infiltration rate, and the lowest bulk density and penetration resistance. They concluded that HH application was much more effective on improving the soil physical quality in hazelnut orchards than CMP application over the control treatment.

In a study, the effect of tea waste application on soil physical properties were investigated in a clay loam soil by Gülser et al. (2019). Organic waste amendment increased aggregate stability from 15.66% to 23.53%, total porosity and saturated hydraulic conductivity from 2.36 to 5.20 cm/h while it decreased soil bulk density from 1.20 to 1.01 g/cm^3 over the control treatment. They concluded that tea waste can be used as a soil conditioner to improve soil physical properties. In another study by Gülser (2021), effect of tobacco waste (TW) application on soil structural parameters and water holding capacity were determined in a clay field. After eight months, TW application significantly increased organic C contents and total porosity values while bulk density values decreased significantly in the clay soil. It was concluded that increasing air filled porosity by the TW application over the control is important for plant root respiration and microbial activity especially in clay textural soils. Tejeda and Gonzales (2007) found that cotton gin crushed compost (CC) and poultry manure (PM) applications increased aggregate stability by 21% and 17.8% respectively, reduced bulk density by 19.6% and 16.9% respectively, and soil loss under 140 mm/h rain by 29.2% and 25% respectively. They concluded that variability in the results may be due to different chemical composition of the organic wastes such as CC had higher humic acid-like concentration increased structural stability and decreased soil loss to a greater extent than PM which had a higher fulvic acid-like concentration.

Aggregation and stabilization of soil structure are significantly related to the decomposition of plant roots and particulate organic matter content in soil (Gale et al., 2000). Kushwaha et al. (2001) found that keeping plant residues in soil with reduced tillage practices increased mean weight diameter of aggregates by 71–98% over control because of increasing organic C in macroaggregates. Soil organic C content is strongly related with macroaggregates and macroaggregates has greater organic C than in microaggregates (Kushwaha et al., 2001). Effects of hazelnut husk (HH) and tobacco waste (TW) applications on soil moisture constants, aggregate stability and saturated hydraulic conductivity (Ks) of clay loam soil were investigated under greenhouse conditions by Gülser (2022). Application of HH and TW as organic matter sources significantly increased field capacity, permanent wilting point, aggregates stability and saturated hydraulic conductivity (Ks) over the control (Figure 2). In improving soil physical properties of clay loam soil, HH treatment was more effective on the soil moisture constants while TW treatment was more effective on aggregate stability and Ks. TW application which improved soil structure more than HH application with increasing aggregate stability of clay loam soil, had higher soil permeability. Cercioglu (2017) similarly reported that composted tobacco waste, chicken manure, and biohumus applications into a coarse textural soil increased total porosity, structural stability, moisture constants at field capacity, wilting point and available water content, and decreased bulk density over the control treatment. In another study by Gülser (2021), effect of tobacco waste on structural parameters and water holding capacity of a clay soil were investigated. Organic C contents, air filled porosity and water holding capacity significantly increased by increasing tobacco waste application while bulk density reduced significantly. Increasing air filled porosity is important for plant root respiration and microbial activity especially in clay textured soils (Gülser, 2021).

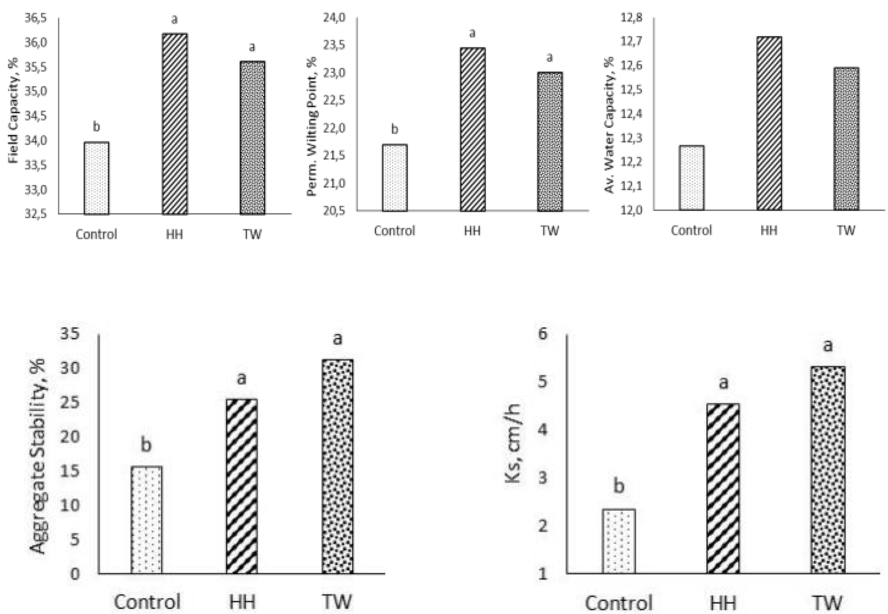

Figure 2. Effects of hazelnut husk (HH) and tobacco waste (TW) applications on soil moisture constants, aggregate stability and saturated hydraulic conductivity (Ks) of clay loam soil (Adapted by Gülser, 2022).

Soil compaction due to intensive agricultural practices reduces plant root growth due to decline of soil structure. Penetration resistance is widely used to assess soil compaction. In a study, penetration resistance (PR) values of a clay field significantly reduced from 1.72 MPa to 0.91 MPa, 0.84 MPa and 0.72 MPa after seven months of 2%, 4% and 6% of HH application, respectively agricultural waste applications over the control (Gülser and Candemir, 2012) (Figure 3). Percentage reduces in mean PR values over the control with agricultural waste application were reported in the following order; HH (52.10%) > TEW (42.07%) > TOW (30.73%) > M (25.17 %). They concluded that application of different agricultural wastes shoved different effects on PR due to changing soil structure depending on their different C:N ratios. Tejeda and Gonzales (2007) also reported that cotton gin crushed compost applications improved physical and biological properties of a coarse textural soil while fresh beet vinasse application reduced these properties due to their chemical composition.

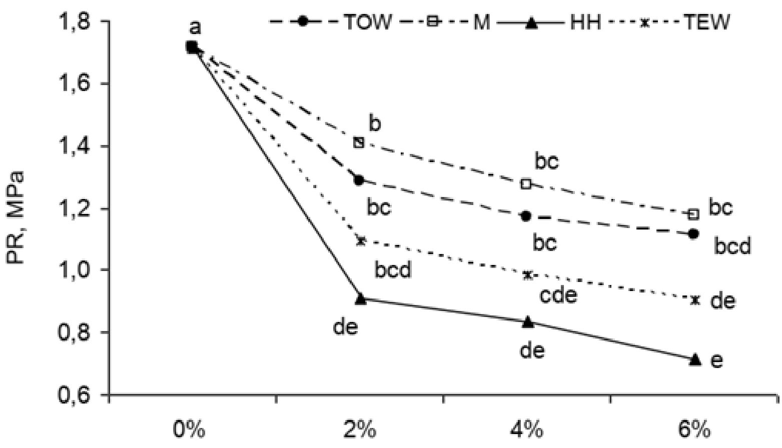

Figure 3. Effects of different application dosses of agricultural wastes on soil penetration resistance (PR) (HH:hazelnut husk, TW: tobacco waste, TEW: tea waste, M: manure) (Adapted by Gülser and Candemir, 2012).

In many studies, it is indicated that soil organic matter content increased by the agricultural waste applications had a significant negative relation with bulk density and significant positive relations with total porosity, field capacity, permanent wilting point, available water content, aggregate stability, infiltration ratio, saturated hydraulic conductivity (Candemir and Gülser, 2011;

Demir and Gülser 2015; Gülser et al., 2016, Gülser et al., 2020). According to many researches, it can be concluded that agricultural waste treatments to fields generally help to improve soil physical properties.

Effects of Agricultural Wastes on Some Chemical Soil Properties

Soil chemical properties generally are highly related to plant nutrients availability, toxicity of heavy metals, and pesticide mobility in soils, are soil organic matter, soil reaction, electrical conductivity, nitrate nitrogen, exchangeable cations and cation exchange capacity. Soil organic matter is readily turned over or decomposed organic residues including living organisms, plant roots, and humus (Hodges, 1991; Lampkin, 1992). Incorporated crop residues into soil and green manure applications are decomposed under favorable conditions and help to preserve soil organic matter content at a desired level and maintain soil organic matter status which influences microorganism activity and soil nutrient cycling processes in soils (Lampkin, 1992; Blake, 1994). Mineralization of organic matter in soil is not only important for availability of N but also important for other plant nutrients in soil and generally controlled by the chemical composition of organic matter such as total C and N contents, C:N ratio. Soil organic matter has a great specific surface area with a net negative surface charges causing high cation exchange capacity and retains many cations as plant nutrients such as Ca, Mg, K, NH_4.

The effects of farmyard manure, hazelnut husk, tobacco waste and tea waste applications on some soil chemical properties of clay and loamy sand soils were investigated by Candemir and Gülser (2011). Agricultural waste applications significantly increased organic C content (OC), electrical conductivity (EC) and nitrate nitrogen over the control treatments in both soils (Table 2). A critical level for soil organic C content is 2%, soil quality can be declined below this value (Loveland and Webb, 2003). Organic waste applications to different textural soils help to maintain soil OC content around 2% (Table 2). The effect of organic waste application on soil OC content is highly related with C/N ratio of waste material, soil texture, drainage, climate conditions. Preserving OC in coarse textural soils is lower than fine textural soils due to high aeration and rapid mineralization rate in coarse textural soils

(Shepherd et al., 2002). The low C/N ratios of organic materials results high mineralization rate and increases in available nitrogen content (Horwath, 2007). Candemir and Gülser (2011) reported that lower C/N ratios of manure (7.98), tea (21.77) and tobacco (19.46) wastes than hazelnut husk (51.31) caused higher nitrate contents and EC values in both soils due to high mineralization rate of these materials. The soil reaction (pH) generally reduces after the organic waste application due to transformation of ammonium to nitrate in nitrification processes and carbonic acid occurred by the reaction of water with CO_2 produced in microbial activity (Brady, 1974; Xua et al., 2005).

Table 2. Effects of agricultural waste applications on some chemical properties of different textural soils (Adapted by Candemir and Gülser, 2011).

Agricultural wastes	OC (%)	pH (1:1)	EC (dS m^{-1})	NO_3-N (ppm)	BSR ($mgCO_2/m^2d$)
Clay soil					
C	1.775 c **	6.87 b	0.501 c	39.32 b	4.59 d
M	2.611 b	7.16 a	0.689 b	77.65 a	7.86 c
TOW	2.563 b	7.10 a	0.903 a	90.14 a	8.81 bc
HH	2.164 bc	6.90 b	0.494 c	37.74 b	12.33 a
TEW	3.102 a	6.40 c	0.672 b	75.91 a	10.89 ab
Loamy sand soil					
C	1.097 d	7.35 ab	0.235 c	36.13 c	7.41 c
M	1.747 c	7.40 a	0.426 b	62.19 c	12.24 b
TOW	1.834 bc	7.25 bc	0.612 a	294.17 a	10.78 bc
HH	2.005 ab	7.29 ab	0.416 b	42.77 c	18.38 a
TEW	2.150 a	7.18 c	0.489 b	207.10 b	18.91 a

** significant at 0.01 level. C: control, M: farmyard manure, TOW: tobacco waste, HH: hazelnut husk, TEW: tea waste.

Changes in soil chemical properties along a clay soil profile after 20 months of surface application of agricultural wastes were investigated by Candemir et al. (2010). Application of manure (M), hazelnut husk (HH) into 15 cm surface layer of a clay soil increased electrical conductivity (EC) and nitrate nitrogen (NO_3) values throughout 80 cm soil profile. They concluded that higher mineralization rate in M treatment due to lower C:N ratio (8.0) in manure than C:N ratio (51.3) in HH caused high mineral matter and nitrate contents in all soil depths (Figure 4).

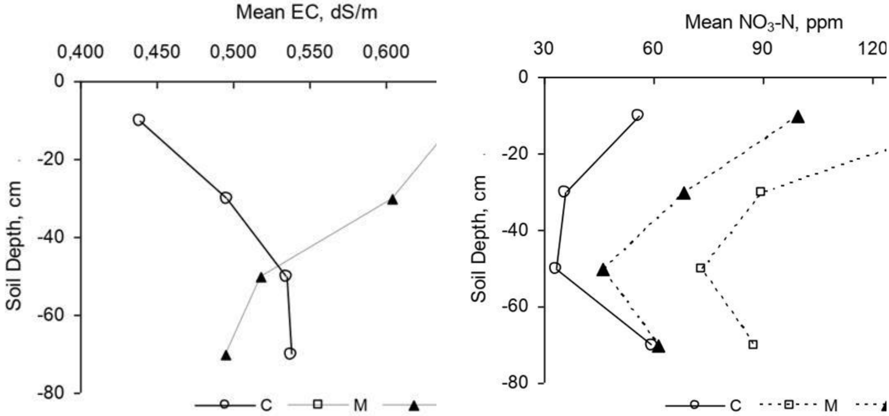

Figure 4. Changes in electrical conductivity (EC) and nitrate N (NO_3) content along a clay soil profile with manure (M) and hazelnut husk (HH) application over the control (C) (Adapted by Candemir et al., 2010).

The effect of rice husk compost (RHC) application on some soil chemical properties under greenhouse conditions was investigated by Demir and Gülser (2015). Increasing the application dosses of RHC from 3% to 9% increased soil organic matter (OM) content from 4,801% to 7,546% (Table 3). While electrical conductivity (EC), available P and exchangeable cations generally increased by increasing OM content, soil reaction decreased over the control treatment. They reported that rice husk compost treatment provides productivity and sustainability of soil under greenhouse conditions.

Table 3. Changes in some chemical soil properties by rice husk compost application doses over the control (K) (Adapted by Demir and Gülser, 2015).

	pH (1:1)	EC, dS/m	OM, %	P, ppm	Exchangeable cations, me/100 g K,	Ca	Mg	Na
K	7,82 a	0,930 b	3,628 c	63,757 b	3,399 b	37,490 a	12,217 c	0,925
3%	7,72 ab	1,106 a	4,801 b	80,053 ab	3,722 b	37,214 a	12,375bc	0,849
6%	7,74 ab	1,117 a	5,590 b	97,893 ab	3,883 ab	36,885 a	13,182ab	0,824
9%	7,66 b	1,164 a	7,546 a	110,257 a	4,261 a	35,201 b	13,324 a	0,756
LSD	0.112	0.154	0.870	24.350	0.528	1,568	0.923	ns

The effects of compost obtained from household waste, sewage sludge, pig manure and cow manure on soil chemical properties during four years were evaluated by Odlare et al. (2007). They found that compost application increased soil pH due to production of ammonia in the aerated soil and also available phosphorus and potassium contents increased in soil. In another study, applications of three different organic sources, sewage sludge, municipal solid waste compost, and garden waste compost in a highly acidic metal contaminated soil were evaluated for 25, 50 and 100 tons/ha application doses by Alverenga et al. (2009). They found that all treatments increased N, P and K contents and soil pH significantly over the control treatment and decreased the mobile fractions of Cu, Pb and Zn in soil. Ameziane et al. (2019) mixed the olive pomace with a coarse textured soil at different application rates (0, 10, 15, 25, 50, 75 and 100%) and investigated its effect on soil chemical properties for four months. They found that available P and exchangeable cations (Ca, Mg, K) increased significantly over the control due to increasing cation exchange capacity.

Effects of Agricultural Wastes on Some Biological Properties

Soil microorganism activity is influenced by the agricultural practices, such as cropping, soil cultivation, organic waste, compost, farmyard manure, fertilizer applications, and soil moisture level. Soil organic matter has an important effect on soil microorganisms with supplying carbon sources (Garbeva et al., 2004). When organic wastes are added in the soil, microorganism activity increase rapidly. Liang et al. (2007) investigated the effects of soybean leaf or maize stalk amendments on fungal and bacterial transformation processes in soil. Soil C/N ratios and organic C decreased over time after the addition of organic wastes. Accumulation of amino sugars produced by fungi and bacteria increased with increasing decomposition of organic residues in soil.

Basal soil respiration is the production of carbon dioxide by the microorganism activity in soil. The effect of tea waste application on soil properties were investigated in a clay loam soil by Gülser et al. (2019). Tea waste application significantly increased organic matter content from 0.77% to 3.55% and soil respiration rate from 1.01 to 3.22 gCO_2/m^2day (Figure 5).

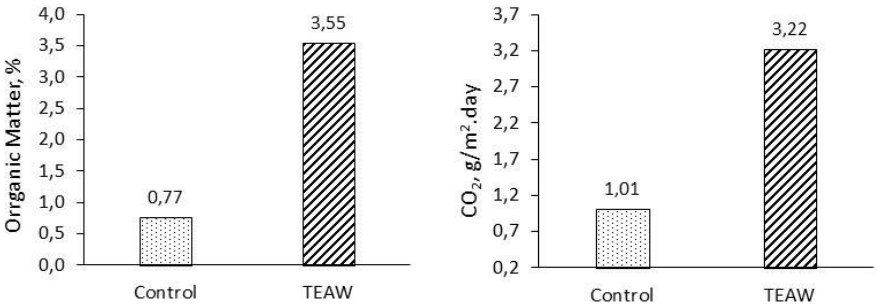

Figure 5. application of tea waste (TEAW) on soil organic matter and basal soil respiration (Adapted by Gülser et al., 2019)

Basal soil respiration is the production of carbon dioxide (CO2) by the microorganism activity in soil. The effects of different agricultural wastes amendment on properties of clay and loamy sand soils indicate that organic waste application increases soil organic matter content and basal soil respiration rate (Candemir and Gülser, 2011). The level of basal soil respiration in different textural soils over the control depends on C:N ratios of organic wastes added in soil (Table 2). The highest soil respiration rate in HH treatment of both soils was explained by high mineralization rate due to greatest C/N ratio in HH among the all organic wastes. Kızılkaya and Hepşen (2007) investigated the effects of different agricultural waste application on microbiological properties in earthworm cast and surrounding soil. They reported that the addition of wheat straw, tea waste, tobacco waste, manure and hazelnut husk increased microbial biomass, soil respiration, metabolic quotient, and dehydro-genase, catalase, b-glucosidase, urease, alkaline phosphatase, and arylsulphatase enzyme activities on earthworm cast and soil samples.

Conclusion

A large amount of organic waste is generated in agricultural areas in Türkiye. The amount of these wastes varies according to the product variety and climate characteristics. If the necessary precautions are not taken for dispose of these agricultural wastes, negative effects on the environment and human health reveal. These plant wastes have an important potential in terms of nutrients for soils with poor organic matter content. These wastes also have positive effects on the water holding capacity, salt content, electrical conductivity, pH value and aggregation of the soil, enabling both the prevention of soil erosion and the formation of a healthy plant growing media. With the using of these plant waste, both the organic matter content of our soils with low organic matter content will be increased and less chemical fertilizers will be used as they will be enriched in terms of plant nutrients. Knowing the properties such as salinity heavy metal contents pH value and nutrients status of the wastes used in the evaluation of plant wastes will increase the success rate in agricultural production.

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CHAPTER 2

DISTRIBUTION OF SOIL FRACTIONS AND TEXTURE CLASSES IN VAN LAKE BASIN SOILS

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Introduction

Knowledge of soil physical properties is essential to define or improve soil health to achieve optimum productivity for each soil/climate condition. There is a strong awareness that yield is limited by physical conditions rather than plant nutrient status in the soil. Unless the physical environment of the soil is kept at an optimum level, the genetic yield potential of a crop cannot be realized even if all other conditions are fulfilled. The yield potential of different crops can be significantly increased if soils are properly managed for good physical health. Soil physical management technologies are location specific and the benefits derived from their adoption are highly variable depending on the available crop/equipment system as well as rainfall intensity, slope and soil texture. Soil texture represents the relative proportion of soil particles of different sizes, which is a fundamental physical property of soils and is related to other soil properties. Textural classification of soils is based on particle size analyzes in many parts of the world. Most commonly, particle size distribution (PSD) is represented in a texture diagram based on the sand, silt, and clay content of the soil (Figure1) (Soil Survey Staff,1951).

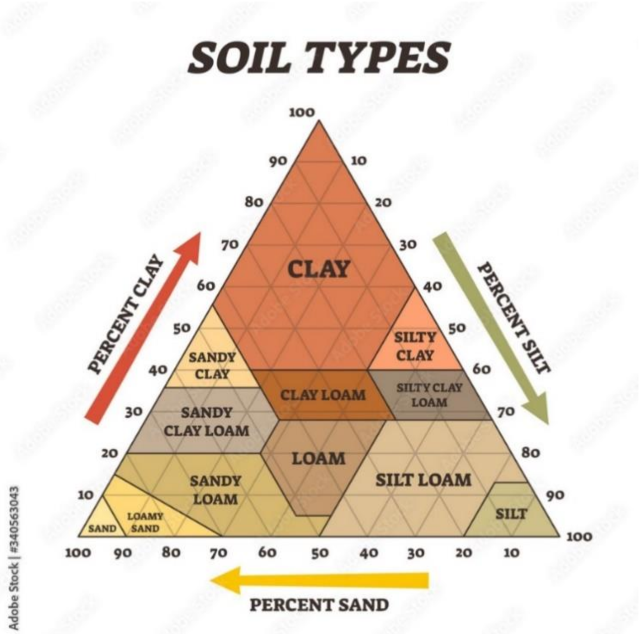

Figure 1. Textural classification systems according to USDA (Soil Survey Staff,1951).

In general, it is possible to separate soil particles into groups and characterize soil in terms of the relative proportions of particle size groups; these may differ from each other in both mineral composition and particle size (Hillel,1982). Soil a number of standards exist internationally for defining soil PSD and particle size classes. Most national systems follow one of the internationally accepted standards. FAO (1990) and USDA (Soil Survey Staff, 1951) define clay as the part with a particle size < 2 μm, silt as the part between 2 and 50 μm, and sand as the part between 50 and 2000 μm. Soil texture is of great importance for soil development. It can help us understand the age of the soil and the development process of the soil. Practically all properties of the soil and its productivity as a whole depend on it. Soil properties such as irregular water holding capacity, aeration, sensitivity to erosion, organic matter content, cation exchange capacity, pH buffering capacity, etc. It is affected by the texture (Dilkova, 1989).

In this study distribution of soil fractions and texture classes of soils in Van Lake Basin were investigated.

Materials and Methods

Van Lake Basin placed in eastern of Turkey among 37 55'-39 24' North and 42 05'44 22' east coordinates. This basin have 1797 643 ha area with lake surface. This area is equel 2.3% of total Turkey area. The mean altitude is 1600 2500 m in Van Lake Basin. The relief having sharp andsheer slopes and big differences on altitudes is generally mountainous (Figure 1). The soils have no drainage problem in this basin. The parent materials are volcanious in north, sedimanter and methamorphic in south and alluvial in west and sedimanter and methamorphic in east.Sedimanter parent materials are generally marn, shale, calcite and conglomera. The meadow is natural vegetation of Van Lake is Basin. The continental climate is shown in this basin. The mean temperature and precipitation are 9.4 0C and 387 mm respectively (Anonymous, 2019). There are eight big soil groups as chestnut, non- calcareous brown, non-calcareous brown forest, brown, regosol, alluvial, kolluvial and hydromorphic in this area. Sampling number of each big soil group were determined according to portion of covered area by them in basin. Soil samples taken from 0-20, 20-40, 40-60, 60-80 and 80-100 cm depth and total twenty five (6 samples in chestnut, 6 samples in non- calcareous brown, 4 samples in brown, 4 samples in regosol, 2 samples in alluvial, 1 samples in non- calcareous brown forest, 1 samples in kolluvial, 1 samples in hydromorphic) sampling points. The sampling places in study area were given in Figure 2. Particle size distribution of soil samples were analysed by Bouyocous hydrometer method as explain following (Gee and Bauder,1986).

Method of texture analysis: 50 g of soil was taken and transferred into a beaker. After the addition of pure water, dispersion and mixing processes were applied to the suspension. Then, the first and second hydrometer readings were made and the obtained sand %, silt % and clay % values were applied to the texture analysis triangle to determine the texture classes of the soil samples.

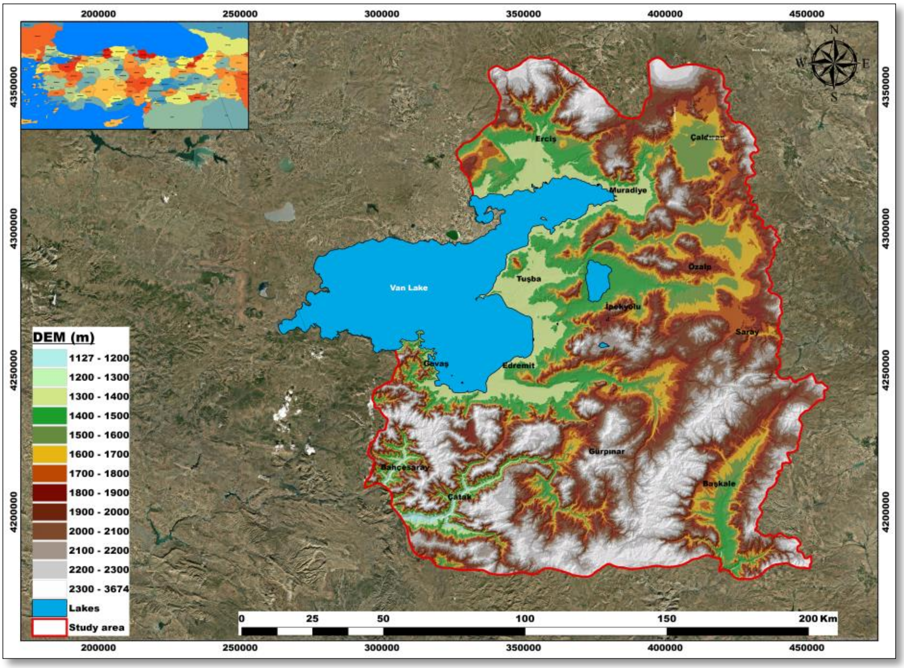

Figure 2. The study area

Results and Discussion

The particle size distribution of soil samples taken from 0-20 and 20-40cm depth in this study were given in Table 1.

Table 1. The particle size distribution of soil samples taken from 0-20, 20-40cm depth.

Big Soil Groups	Sand %		Silt %		Clay %	
	Min.	Max.	Min	Max	Min	Max
chestnut soils	38.56	65.84	6.16	20.88	27.28	55.28
non-calcareous brown soils	47.12	71.12	6.16	26.88	18.00	35.28
non-calcareous brown forest soils	43.12	51.12	30.00	32.00	16.88	26.88
brown soils	53.84	75.12	7.28	39.28	4.16	16.88
regosol soils	57.12	71.12	18.00	34.00	6.88	12.88
alluvial soils	36.56	46.56	40.56	58.56	4.88	18.88
colluvial soils	50.56	54.56	40.56	42.56	4.88	6.88
hydromorphic soils	30.56	56.56	27.28	33.28	10.16	42.16

As that shown in Table1, generally ratio of sand fractions of alluvial soils soil were lower than those in the other big soil groups. When compare with each other soil groups according to ratio of clay fractions the highest clay fraction ratio were determined in non-calcareous brown forest soils and alluvial soils. The highest silt ratio were found in alluvial and colluvial soils. Additionally ratio of soil fractions and sampling places for each one big soil group were given separately in Figure 3, 4, 5, 6, 7, 8, 9 and 10. Soil texture classes were determined for each one big soil group by applying of soil fractions rates given in Table 1 to the texture analysis triangle (Gee and Bauder,1986).

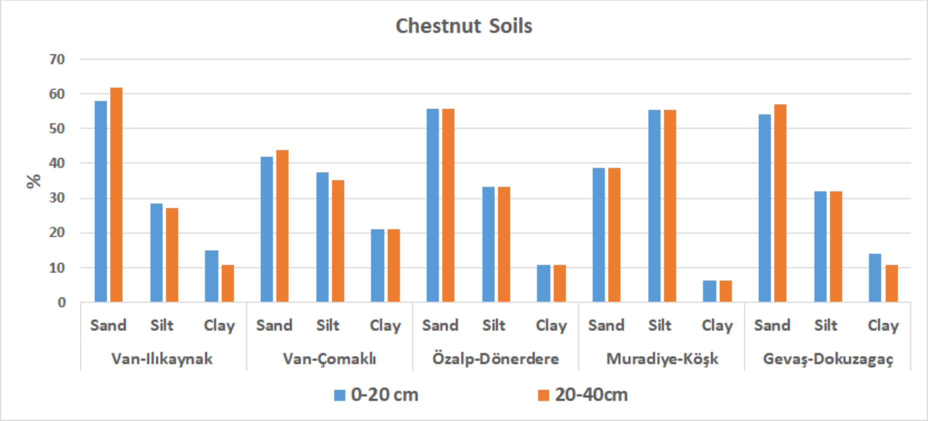

Figure 3. Ratio of soil fractions and sampling places for chestnut soils.

It was determined that chestnut soils had a sandy loam texture in Van - Ilıkaynak and Özalp- Dönerdere while texture classes were determined as loam, silty loam, sandy clay loam in Van- Çomaklı, Muradiye- Köşk and Gevaş-Dokuzagaç respectively. There were no differences among sampling depth in terms of texture classes (Figure 3).

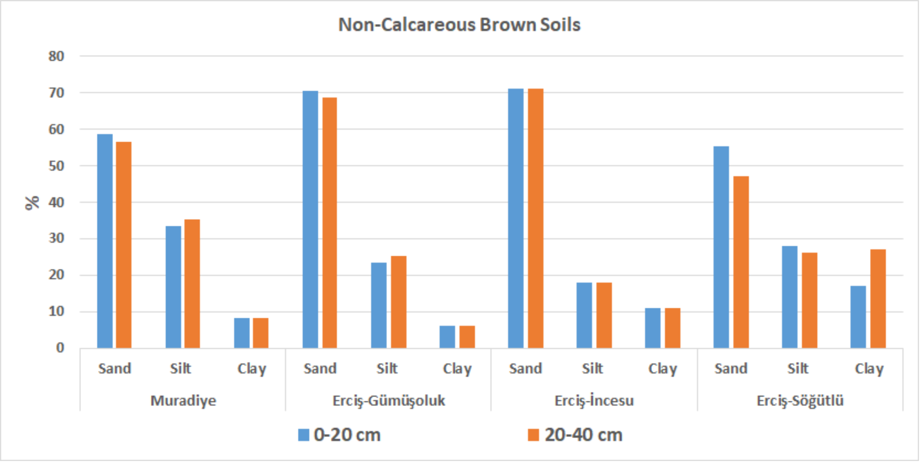

Figure 4. Ratio of soil fractions and sampling places for non-calcareous brown soils.

When investigate the Figure 4, it was determined that all of non-calcareous brown soils in both depth had sandy clay loam texture class except one soil sample taken from 20-40cmdepth in Muradiye which in a sandy loam texture class.

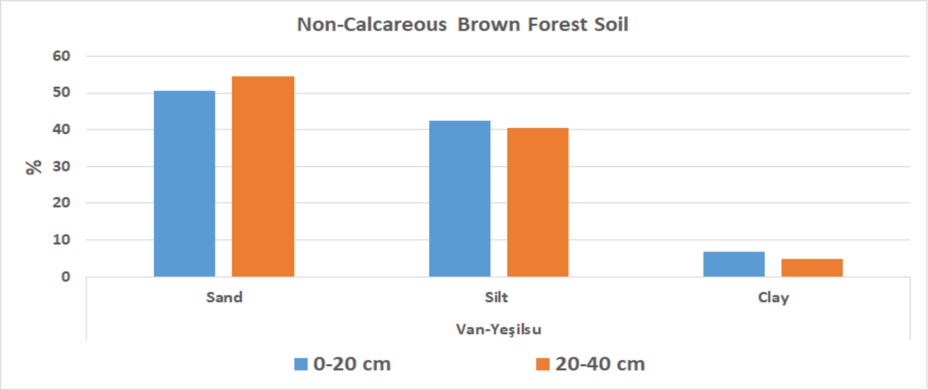

Figure 5. Ratio of soil fractions and sampling places for non-calcareous brown forest soils.

All of investigated non-calcareous brown forest soils had taken place in sandy loam texture class (Figure 5).

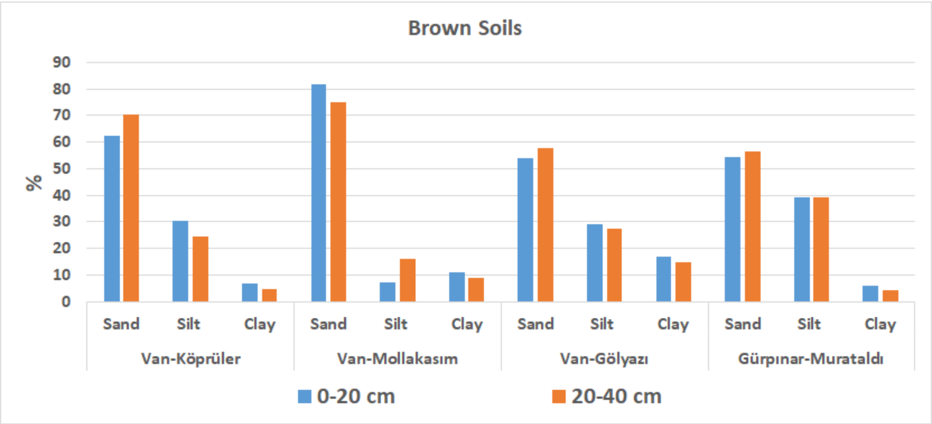

Figure 6. Ratio of soil fractions and sampling places for brown soils.

As that shown in Figure 6, all of brown soils had sandy loam texture except one soil sample taken from 0-20 cm depth in Van- Mollakasım which in a loamy sand texture class.

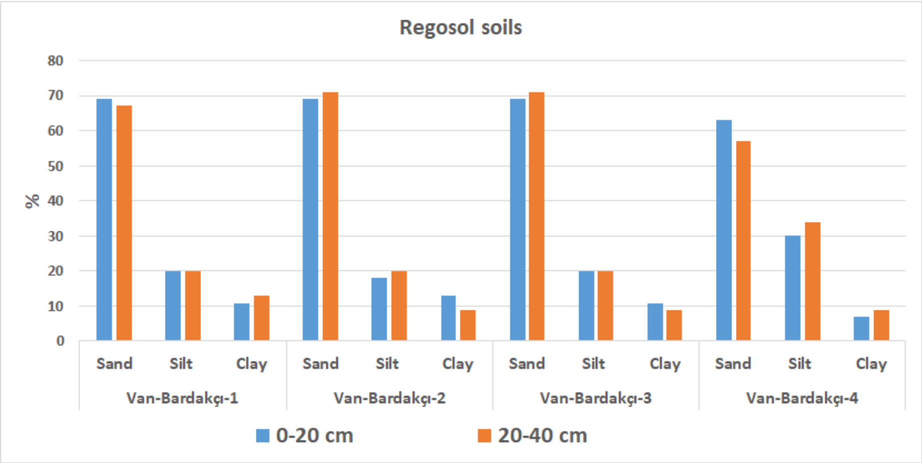

Figure 7. Ratio of soil fractions and sampling places for regosol soils.

It was determined that investigated all of regosol soils were in sandy loam texture class in both of sampling depths (Figure 7).

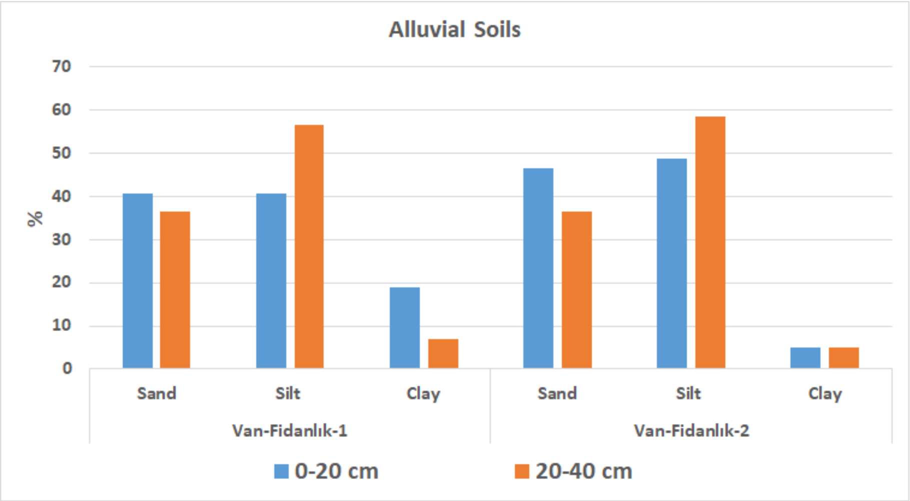

Figure 8. Ratio of soil fractions and sampling places for alluvial soils.

As regard for Figure 8, alluvial soil samples taken from 0-20 cm depth had in loam and sandy loam texture class in Van Fidanlık 1 and Van Fidanlık 2 sampling places while soil samples taken from 20-40 cm in silty loam texture class.

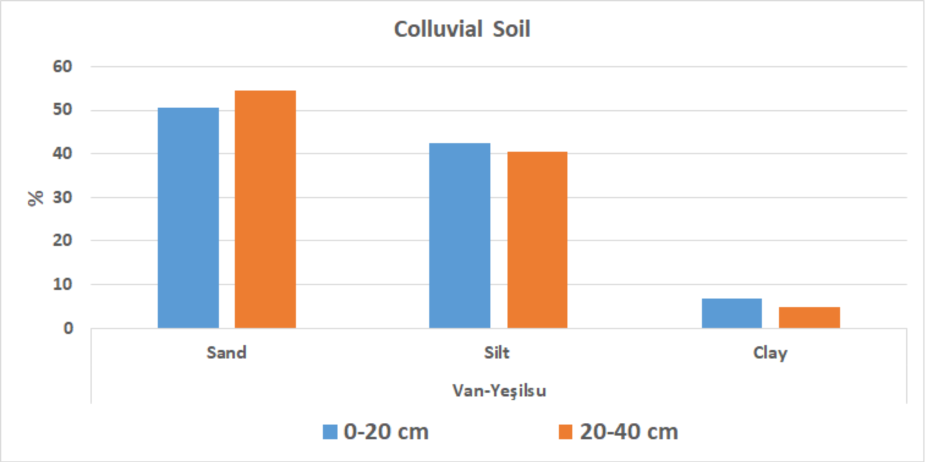

Figure 9. Ratio of soil fractions and sampling places for colluvial soils.

When investigated Figure 9, it was tetermined that all of investigated colluvial soils were in sandy loam texture class.

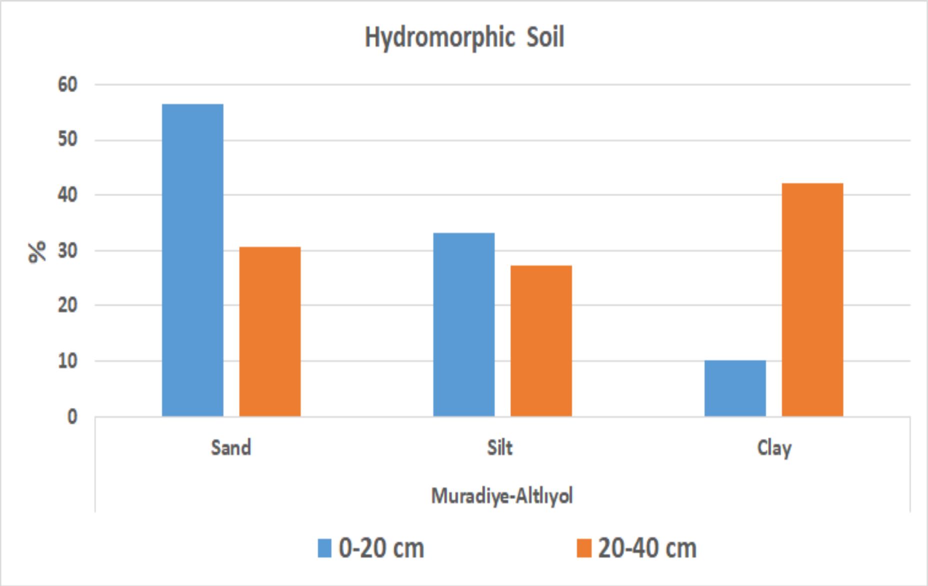

Figure 10. Ratio of soil fractions and sampling places for hydromorphic soils.

All of investigated hydromorphic soil samples were found as sandy loam in term of texture classification. At the study area distribution of texture classes of soil samples taken from 0-20 and 20-40cm depth were shown in Figure 3 and Figure 4 respectively.

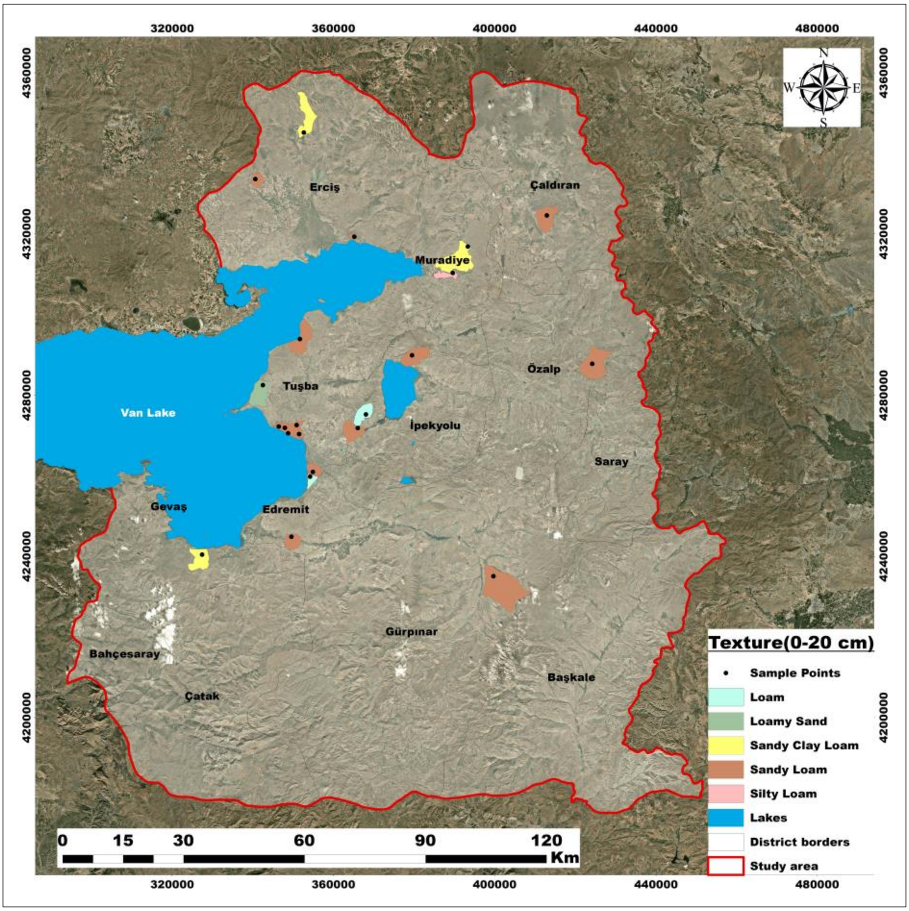

Figure 11. The sampling places and distribution of texture classes of soil samples taken from 0-20 cm depth.

In this study it was determined that texture classes of Van Lake Basin soils mostly had sandy loam texture class in both of sampling depth The second most common texture class in the study area is sandy clay loam (Figure 11 and Figure 12). Considering the literature information (Soil Survey Division Staff. 1993), sandy loam texture class was evaluated as moderately coarse-textured, and sandy clay loam texture class was evaluated as moderately fine-textured.

Soil texture, as an abiotic factor, is an important factor affecting the distribution of minerals, organic matter retention, microbial biomass and other soil properties (Scott and Robert, 2006). It was reported that soil texture influences microbial activity by directly affecting water content and soil temperature of soil (Sugihara et al., 2010, Chodak and Nikli'nska, 2010). The soil texture class plays an important role in the aggregation and porosity of the soil, as well as in the gas exchange between the soil and the atmosphere, which occurs as a result of the respiration of roots and microorganisms. Heavily textured soils in the same soil class have more microbial activity and carbon stock than lightly textured soils (Dieckow et al., 2009, Wei et al., 2014). Thus, studies of microbial and biochemical indicators and soil texture can lead to a better under-standing of the ecological processes and soil function. Therefore, studies on microbial and biochemical indicators and soil texture may be useful in better understanding ecological processes and soil function.

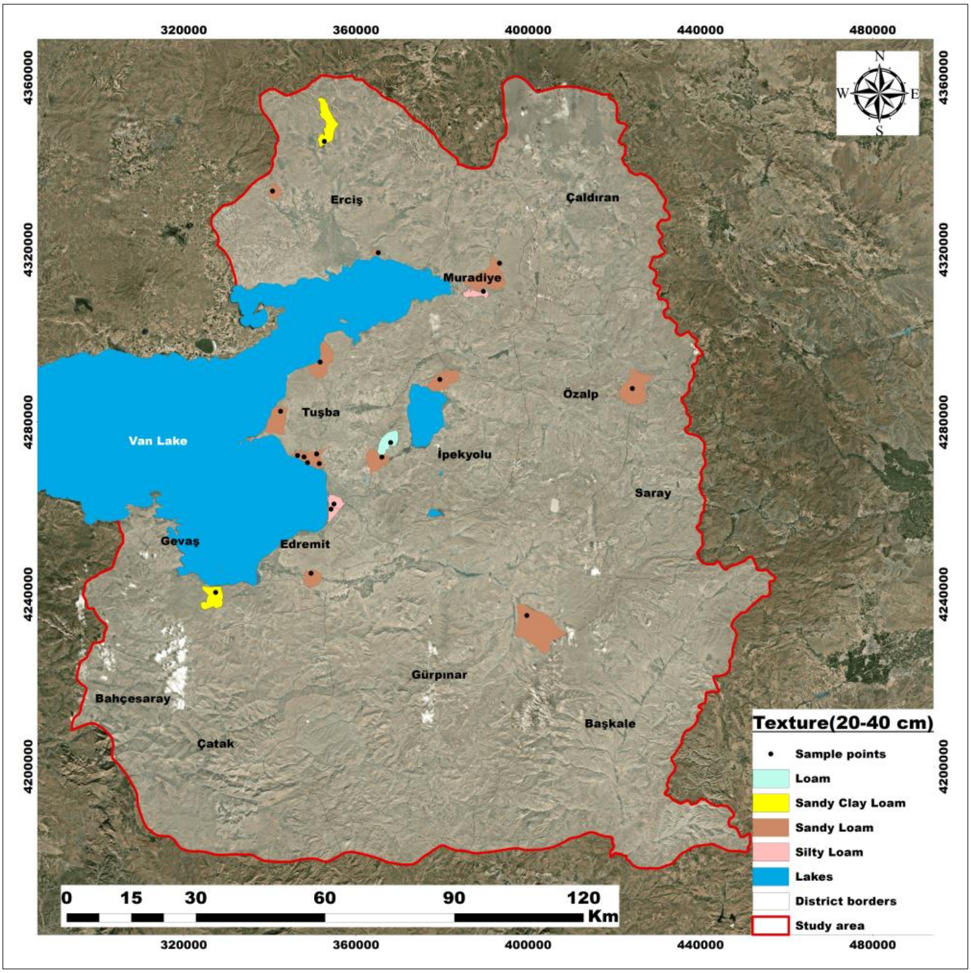

Figure12. The sampling places and distribution of texture classes of soil samples taken from 20-40 cm depth.

Vinhal-Freitase et al. (2017) reported that soil texture class plays a key role in changing microbial and biochemical indicators, and its characterization is very important in land use studies. Some studies have shown that climate and soil type are strong factors for biological and physico-chemical properties in agricultural soils, and land use intensity is secondary (Groffman et al., 1996, Boeddinghaus et al., 2015).

Conclusion

Soil texture, defined by granulometric fraction, affects soil function, which changes the intensity of ecological soil processes (Dieckow et al., 2009, Paul, 2007, Sugihara et al., 2010).Assessing changes in soil properties resulting from land use is important for addressing agricultural ecosystem transformation and sustainable land productivity issues (Yao et al., 2010). Sustainable land use systems are needed to prevent further soil degradation and maintain soil fertility. The fertility status of most soils, especially under low-input farming systems, largely depends on certain soil physicochemicals, such as texture, soil aggregates, hydraulic conductivity, and soil organic matter. Therefore knowing the soil texture classes and particle size distribution that affect soil properties such as irregular water retention capacity, aeration, sensitivity to erosion, organic matter content, cation exchange capacity, pH buffering capacity, etc. will enable the right implementation of sustainable agricultural practices.The findings regarding soil texture obtained in this study will be beneficial in terms of practices such as irrigation, fertilization, tillage and precautions that can be taken within the scope of sustainable agriculture in the Lake Van basin.

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CHAPTER 3

THE EFFECTS OF HUMIC ACID AND POTASSIUM APPLICATIONS ON THE YIELD, YIELD COMPONENTS AND NUTRIENT COMPOSITION IN CHICKPEA (*Cicer arietinum* L.)

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INTRODUCTION

Chickpea is an important crop because of its high protein content of seed and straw for human and animal nutrition. The effects of humic substances on plant growth, under conditions of adequate mineral nutrition, consistently show positive effects on plant biomass. Potassium have many vital metabolic, physiological and biochemical functions in plants. The yield and the quality increase under the effects and the functions of potassium in the crop plants. Potassium not only affects the enzyme activation, the rate of photosynthesis, the transport of water and nutrients and sugars, it also increases protein content of plants, maintains turgor, water loss and wilting.

Legumes have been and in some areas still is one of man's basic foodstuffs. From a nutritional point of view legumes are a good source of proteins, complex carbohydrates, some minerals and vitamins, and at the same time are poor in fats and sodium (Torija et al., 1999). Chickpea is a plant suitable for planting rotations with cereals in fallow lands, due to its resistance to low temperatures (-8 -10^{0}C) and its small vegetative component (Donder and Togay, 2021). Chickpea can benefit from the free nitrogen of the air since it is capable of living in symbiosis with rhizobium bacteria. Since the C/N ratio is very low in the root residues left in the soil after the harvest, the residues are broken down in a short time and turn into humus, thus leaving a more suitable soil for the next plants. This phenomenon, called symbiotic nitrogen fixation, occurs as a result of mutually beneficial interactions between Rhizobium spp bacteria and the host legume plant (Soysal and Erman, 2020). Humic acid (HA) is a relatively stable product of organic matter decomposition and thus accumulates in environmental systems. Humic acid might benefit plant growth by chelating unavailable nutrients and buffering pH. Humic substances (humic and fulvic acids) are the major components of soil organic matter and the term of "humus" is widely accepted as synonymous for the soil organic matter. The effects of humic substances on plant growth, under conditions of adequate mineral nutrition, consistently show positive effects on plant biomass (Chan and Aviad, 1990). Potassium increases root growth, improves drought and cold resistance, reduces lodging, affects the harvest time, improves the availability of nitrogen and helps to increase resistance to disease. By increasing protein content, potassium also increases the nutritive value of food and forage crops, and improves the quality of forage crops in pasture land. It helps earliest and uniform maturation of grain in corn and other grain crops. Potassium fertilization not only improves fruit color, size of fruit, thickness of rind, acid/sugar ratio, soluble solids and vitamin C contents of different fruits, but also benefits various aspects of marketability. These advantages result in a higher quality product and, therefore, greater return to the producers. This study was conducted in order to analyze the effect of different doses of potassium and humic acid applications on yield, some yield parameters and nutrient composition in chickpea.

MATERIALS AND METHODS

Morphological and grain characteristics of Yasa-05 chickpea cultivar used in the experiment: Plant Height: 30-45 cm, First Pod Length: 12-20 cm, Number of Plant Pods: 24-30 Number of Grains per Pod: 1.5, Plant Growth Type: Upright, hundred grain weight: 35-45 g. Grain Color: Cream and Grain Type: Sheep head.

An experiment was conducted to know the effect of different levels of humic acid and potassium on yield and yield attributes of chickpea during 2015 in Agricultural Faculty experiment field of Yuzuncu Yil University. The province of Van, where the research was conducted, is located in the Eastern Anatolia Region, in a basin surrounded by mountains, with Lake Van to the west. The altitude of the province is 1725 m, and it is located at 380 25' north latitude and 430 21' east longitude. The location of the research is located in the north-east of the Lake part of Van and approximately 2-3 km from the lake shore. In the study were investigated the plant height, branch number per plant, pod, seed number and per plant, biological yield, seed yield per unit, harvest index, 100-seed weight, N, P, K, Pb, Ni, Fe, Mn, Mg, Ca, Cu and Zn content in seed.

The climate data of the months covering the period of the study and the long-term average are given in Table .1. The average precipitation amount for the long years in the growing season of the area where the experiment was established is 301.6 mm, the average temperature is 17.0 °C, and the average relative humidity is 56.6%. The amount of precipitation falling in 2015 is 117.9 mm. Average temperature is 18.6 0C, average relative humidity is 52.8% (Table 1).

Table 1. Meteorological data for the growing seasons of 2015 and long-term averages in Van, Turkey

	Precipitation (mm)		Average tem (C^O)		Relative humidity (%)	
Months	2015	LTA	2015	LTA	2015	LTA
April	66.9	165.7	8.9	8.8	49.4	68.5
May	21.1	99.9	13.7	13.0	42.6	62.7
June	23.4	25.3	19.8	18.9	35.7	53.1
July	5.1	6.3	24	22.7	72.2	48.8
August	1.4	4.4	23.9	21.5	64.4	50.1
Total	117.9	301.6			52.8	
Average			18.6	17.0		56.6

According to the soil analysis, the soil samples taken from 0-20 cm of the research area are loamy textured, have strong alkaline reaction, low organic matter content, moderately calcareous in terms of lime content, unsalted, very low iron content, medium phosphorus content, potassium content. was found to be sufficient (Table 2).

Table 2. Some properties of the <2 mm fraction of the top 20 cm of soil used for site

Soil properties	2015
Texture	loam
pH[A]	8.88
Clay (%)[B]	40.8
$CaCO_3$ (%)[C]	6.6
Olsen soil test P (ppm)[D]	8,9
Fe (ppm)	0.2
Total Salt (%)[E]	0.01
Organic matter (%)[F]	1.89

[A] 1 : 2.5 soil : water, [B] Bouyoucos (1951), [C] lime by calcimetric methods, [D] Olsen et al. (1954), [E] Richard (1954), [F] Jackson (1962).

The experiment, consisting of 27 plots in total, was carried out according to the factorial experiment design in randomized blocks in 2015 and the number of replications was determined as 3. Each plot is 5 rows, the distance between the rows in the parcels is 30 cm. There is a 2 m gap between the parcel and the block. The parcel area is arranged as 1.5 meters x 5 meters = 7.5 square meters. The planting norm was adjusted to be 60 plants per square meter. Before sowing, seeds were inoculated into each plot using Rhizobium culture prepared at a density of 10^6 cells/g (Vincent, 1970). Bacterial culture was obtained from Ankara Soil Research Institute. Sugar water was used to ensure that the bacterial culture adhered to the seeds in inoculation (Akdağ and Şehirali, 1994). In the experiment, 3 humic acid doses (0, 300 and 600 kg /ha) and 3 potassium doses (0, 100 and 200 kg /ha) were used as fertilizer. Fertilizer was used as ammonium sulphate with 40 kg / ha of pure nitrogen and TSP with 60 kg/ha of pure phosphorus on the bottom. The trial was established on 28.03.2015. At harvest, the first and fifth rows in the plots, one row on each side, and the plants within fifty cm from the plot heads were excluded as edge effects (Ceylan and Sepetoğlu, 1979). Measurements and weighing's were made over an area of 0.9 meters' x 4 meters = 3.6 square meters. Sowing, harvesting and threshing were done by hand. Weed control in the study area was carried out by hand plucking and hoeing twice, before and after flowering. The trial was harvested on 08.08.2015. Measuring, counting and threshing processes of harvested plants were made and average values were taken. Grain yields per unit area were also found by threshing with the condition that the plants were dried and crushed. Since the experiment was conducted in dry conditions, irrigation was not done.

RESULTS AND DISCUSSION

In the determination of the difference between different potassium and humic acid applications in the chickpea tested in the study in terms of yield and yield components, factorial trial design variance analysis method was used in random blocks, and in the determination of different groups, the Multiple Comparison Test (Düzgüneş et al., 1987) used.

Table 3. Effects of potassium and humic acid applications on yield, some yield parameters and nutrient composition of chickpea.

Treatments	Plant height (cm)	Number of (Branches plant^{-1})	Pods/plant (number plant^{-1})	Seeds/plant (number plant^{-1})	Seed yield (kg ha^{-1})	Harvest index (%)	100 seed weight (g)	N (%)	P (mg kg^{-1})	K (%)
Humic acid Levels (kg ha^{-1})										
0	37.8 b	2.4 c	20.3 b	21.0 c	1509 b	26.1 b	36.3 b	3.776 c	6232. 3 b	1.186 c
300	38.5 b	2.7 b	21.5 a	22.6 b	1531 ab	26.6 a	36.6 a	3.840 b	6463.1 a	1.194 b
600	39.3 a	3.0 a	21.8 a	23.4 a	1553 a	26.7 a	36.9 a	3.872 a	6465.6 a	1.207 a
K_2O levels (kg ha^{-1})										
0	35.9 c	2.1 c	19.6 c	19.9 c	1417 c	25.2 c	35.1 c	3.728 c	6209.2 c	1.188 b
10	37.9 b	2.8 b	21.5 b	23.1 b	1524 b	26.6 b	36.6 b	3.792 b	6409.6 b	1.198.a
20	41.8 a	3.3 a	22.6 a	24.0 a	1652 a	27.5 a	38.1 a	3.968 a	6542.2 a	1.200 a
Treatments	**Pb (mg kg^{-1})**	**Ni (mg kg^{-1})**	**Cd (mg kg^{-1})**	**Fe (mg kg^{-1})**	**Mn (mg kg^{-1})**	**Mg (mg kg^{-1})**	**Ca (mg kg^{-1})**	**Cu (mg kg^{-1})**	**Zn (mg kg^{-1})**	
Humic acid Levels (kg ha^{-1})										
0	5.168 a	3.852	0.8977 b	74.40 b	24.86	1113.0 b	2876.7	20.79	53.90	
300	4.493 b	3.461	0.7801 b	77.05 a	24.01	1124.1 b	3020.4	22.19	54.71	
600	3.788 c	3.913	1.0878 a	79.11 a	24.16	1159.8 a	3173.1	20.00	54.23	
K_2O levels (kg ha^{-1})										
0	5.205 a	3.214	0.6869 c	69.42 b	23.93	1125.2 b	2894.0	19.79 b	51.88 c	
10	4.232 b	3.560	0.9555 b	77.39 a	24.75	1099.3 b	3000.1	19.46 b	53.73 b	
20	5.205 b	3.452	1.1211 a	78.74 a	24.85	1172.4 a	2894.7	23.73 a	57.23 a	

Values in a column with different letters are significantly different from each other (Duncan's multiple range tests, < 0.05)

The average plant height of chickpea with different doses of potassium fertilizer applications varied between 35.9-41.8 cm. Donder and Togay (2021) Boulbaba et al. (2005) stated that high amounts of K application caused a depressive effect on the growth of chickpeas, while Asghar et al. (2007) stated that the effect of increasing potassium doses on growth is important. When the effect of humic acid doses on plant height in chickpea was examined, the highest plant height was 39.3 cm, obtained from 600 kg ha^{-1} humic acid application, and the lowest plant height was 37.5 cm, from 0 kg ha^{-1} humic acid application (Table 3). Kahraman et al. (2017) reported that humic acid applications increased plant height.

In potassium applications, the average number of branches in the plant varied between 42.1-3.3. The average number of branches per plant of humic acid doses was between 2.4-3.0, the highest value was 53.0 at the 600 kg ha^{-1} humic acid dose, and the lowest value was 2.4 in the control plots where humic acid was not applied. Elkatmış and Toğay (2017) stated that humic acid applications increased the number of branches in the plant.

When the effect of potassium doses on the number of pods per plant in chickpea is examined, it is seen that the highest value is obtained from the 200 kg ha^{-1} potassium dose with 22.6 units, and the lowest number of pods per plant is obtained from the 0 kg ha^{-1} potassium dose applications with 19.6 units. Erman et al. (2012) reported that potassium fertilization increased all examined traits, and Asghar et al. (2007) stated that the effect of increasing potassium doses on growth is important, but the difference between the control application and 250 kg ha^{-1} potassium application in the number of pods in the plant is insignificant. When the effect of humic acid applications on the number of pods on the plant was examined, the highest number of pods on the plant was 21.8 from the 600 kg ha^{-1} humic acid dose, and the lowest number of pods on the plant was 20.3 from the control plot. Unsal (2007), Saadati and Baghi (2014) and Kahraman (2017) report that humic acid application in chickpeas increases the number of pods.

When the effect of potassium doses on the number of grains per plant in chickpea was examined, the highest value was obtained in the amount of 200 kg ha^{-1} potassium with 24.0 number/plant, and the lowest number of grains in the plant was obtained from the parcels where potassium was not applied, with

19.9 number/plant (Table 3). Number of grains in the plant; It is affected by both variety characteristics and agricultural practices. It is understood from the results obtained that potassium applications increase the number of grains in the plant in parallel with the number of pods in the plant. When the effect of humic acid doses on the number of grains in the plant was examined, the highest value was obtained with 23.4 number/plant in the amount of 600 kg ha^{-1} humic acid dose, and the lowest value in the number of grains in the plant with 21.0 number/plant was obtained from the control plots in which humic acid was not applied. Unsal (2007) and Elkatmış and Toğay (2017) reported that humic acid applications had a positive effect on the number of grains per plant in chickpea.

As can be seen in Table 3, the average grain yield per unit area of different potassium fertilizer applications varied between 1417-1652 kg ha^{-1}, and the minimum value was determined from 0 kg/ha potassium (control) application. Singh et al. (1994), Tomar et al. (2001), Asghar et al. (2007) and Erman et al. (2012) knew that potassium fertilizer applications increased grain yield. Additionally, Asghar et al. (2007) stated that the highest benefit in potassium fertilizer doses applied to chickpeas was obtained from the application of 150 kg ha^{-1} of potassium. The results recorded in the trial are consistent with the results of the researchers. When the yield effect per decare of different doses of humic acid fertilizer applied to chickpeas was examined, the highest value was obtained from 1553 kg ha^{-1} and 600 kg ha^{-1} humic acid dose, while the lowest value was determined from 1509 kg ha^{-1} and 0 kg ha^{-1} humic acid application. Unsal (2007), Saadati and Baghi (2014) and Kahraman (2017) stated that humic acid application increased grain yield per unit area.

When the data in Table 3 is examined in terms of potassium doses, the maximum harvest index average was obtained with 27.5% at 200 kg ha^{-1} potassium application, and the minimum harvest index average was obtained with 25.2% at 0 kg ha^{-1} potassium application. Erman et al. (2012) reported that potassium fertilizer applications increased the harvest index compared to the control. When the effect of humic acid doses in terms of harvest index was examined, the highest value was found to be 26.7% from the 600 kg ha^{-1} humic acid dose amount, while the lowest value was 16.1%, obtained from parcels where humic acid was not applied.

As can be seen from Table 3, the average weight of 100 grains obtained from potassium doses was between 25.2-27.5 g. While the highest 100 grain weight value was obtained from the 200 kg ha^{-1} potassium application, the lowest 100 grain weight was determined from the parcels where potassium was not applied. Tomar et al. (2001) and Kumar et al. (2005) stated that increasing doses of potassium significantly increased the 100-grain weight. While the average 100 grain weight of different humic acid doses varied between 26.1-26.7 g, the highest value was obtained from the 600 kg ha^{-1} humic acid dose, but the difference between the 300 kg ha^{-1} humic acid application was found to be insignificant. The lowest value was obtained from 0 kg ha^{-1} humic acid application.

Due to the increase in humic acid applications, significant increases were achieved in nitrogen, phosphorus, potassium, magnesium, iron and cadmium contents. The highest values were determined as 3.872%, 6466 mg kg^{-1}, 1.207%, 1160 mg kg-1, 79.11 mg kg^{-1}, and 1.0878 mg kg^{-1}, respectively, in the 600 kg ha^{-1} application. Similarly, Yıldırım et al. (2009) reported in their study that humic acid applications provided significant increases in nutrient element content. This may be due to the improvements in the physical, chemical and biological properties of the soil with humic acid applications (Mayhew, 2005; Yılmaz et al., 2008; Baş Odabaş, 2019). It may also be due to the fact that humic acid facilitates the uptake of nutrients by increasing the permeability of the root cell membranes of plants (Tipping, 2002; Akıncı, 2011). Lead content decreased due to humic acid applications and the highest value was determined as 5.168 mg kg^{-1} in the control, while the lowest value was determined as 3.788 mg kg^{-1} in the 600 kg ha^{-1} humic acid application. This may be due to the fact that the functional groups contained in humic acid form metal-organic complexes with metal ions, metal oxides, metal hydroxides and minerals (Kerndorff and Schnitzer, 1980; Livens, 1991; Apak and Hızal, 2012; Kıran et al., 2014).

With increasing potassium applications, an increase was determined in the N, P, K, Cd, Fe, Mg, Cu and Zn contents of the plant compared to the control. While the lowest values were determined in control plants, the highest values were 3.968%, 6542 mg kg^{-1}, 1.200%, 1.1211 mg kg^{-1}, 78.74 mg kg^{-1}, 1172 mg kg^{-1}, 23.73 mg kg^{-1}, respectively, in 20 kg K ha^{-1} applications. It was determined as 57.23 mg kg^{-1}. This is due to the fact that potassium has vital metabolic, physiological and biochemical functions in plants. These functions arise from activities in enzyme activity, photosynthesis, transport of plant nutrients and photosynthesis products, increasing protein content, regulating turgor, and preventing water loss and wilting in plants (Kacar and Katkat, 2017). A decrease in Lead content was determined with the increase in potassium application dose. The lead content, which was 5.205 mg kg^{-1} in the control plants, was determined as 4.232 mg kg^{-1} with the application of 10 kg K ha^{-1}.

CONCLUSION

This study was carried out to determine the effects of different potassium and humic acid dose applications on unit area grain yield, some yield criteria and nutrient composition on chickpea plants in Van conditions.

In the study were investigated the plant height, branch number per plant, pod, seed number and per plant, biological yield, seed yield per unit, harvest index, 100-seed weight, N, P, K, Pb, Ni, Fe, Mn, Mg, Ca, Cu and Zn content in seed. The results of the study indicated that humic acid and potassium applications increased significantly the seed yield and yield components. Whereas the highest seed yield was obtained from 200 kg potassium ha^{-1} with 1651 kg ha^{-1} and 600 kg humic acid ha^{-1} application with 1553 kg ha^{-1} in 2015.

As a result, it can be recommended to apply a dose of 200 kg ha^{-1} of potassium + 60 kg of humic acid ha^{-1} in chickpeas in Van and its surroundings.

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CHAPTER 4

COMPONENTS OF INTEGRATED WEED MANAGEMENT

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INTRODUCTION

Weeds, which are named plants found at undesirable places and/or times, compete with the crop for light, water, mineral matter and space, causing loss of production and quality. Although there are numerous strategies to manage weeds, farmers typically opt to use herbicides since they are affordable and practical. Excessive and unthinking use of herbicides badly affects the environment and its health and raises the chance of resistance to herbicides in weeds. Therefore, weed management using pesticides alone is neither sustainable and ecological. Adopting a suitable Integrated Weed Management (IWM) approach not only reduces weed populations below economic threshold levels but also slows the development of resistance in weeds. IWM is an ecologically sound and holistic management principles-based approach to limit weed populations. It focuses on both preventative and therapy strategies to tackle agroecologies' recurrent weed issues. IWM stresses the redesign, reshaping and restructuring of natural ecologies in response to weed shifts and weed dynamics in light of climate change and agricultural developments. The combination of diverse non-chemical, cultural and preventative weed management strategies and the use of controlled herbicides when required also minimizes the selection pressure for the evolution of herbicide resistance in weeds. A sophisticated mix of integrated techniques has the ability to tackle the weed threat in the long run. A successful and acceptable IWM strategy may be produced by using effective strategies such as staggered planting, plowing, increased seed rates and competitive cultivars. Despite the multiple hurdles in pursuing IWM, i.e. sluggish action, laborious, unpredictable reaction, less predictive and greater expense, it may give a long-term sustainable solution to the weed menace.

STRATEGIES OF INTEGRATED WEED MANAGEMENT (IWM)

Integrated Weed Management (IWM) is a multi-tactical method to controlling weeds (Menalled et al., 2016). IWM aims to use a variety of techniques throughout the growing season to provide farmers the greatest opportunity to manage weeds that are causing them problems (Moss, 2019). To maximize control over a specific weed issue, Integrated Weed Management (IWM) refers to the integration of several weed control strategies into a single weed management program (Harker & O'Donovan, 2013). Simplified weed management methods that largely depend on a few well-known herbicides have been prevalent during the last several decades (Scavo & Mauromicale, 2020). However, farmers now need to use other weed control techniques due to the quick proliferation of weeds resistant to herbicides (Shaner & Beckie, 2014). Even if a lot of farmers are using various herbicides, this will probably only be effective in the near future (Duke, 2012). Long-term effectiveness requires the use of several, effective areas of action in conjunction with non-herbicide techniques (Loddo et al., 2021).

It would be best to start by talking about the reasons weed management is required. Weeds interfere with many agricultural production procedures, have a detrimental effect on crop yields, and may contaminate grain with weed seeds (MacLaren et al., 2020). Out of the complete global flora only a very tiny proportion (fewer than 250 species) are recognized as important weeds. About 80 weed species are considered to be responsible for 90% of agricultural losses attributed to weeds (Adkins, 2023). The primary method of weed management is the use of herbicides (Chikowo et al., 2009). Herbicide-resistant weeds have emerged as a result of reliance on this one technique (Gage et al., 2019). Herbicide resistance is rising quickly in the world, and the number of herbicides that may be used is restricted (Chikowo et al., 2009). Herbicides thus need additional assistance in order to maintain sufficient weed control. IWM strategies include a broad spectrum of possibilities and intricacy. While some IWM strategies may be implemented with little to no alteration to present management systems, others need for more thorough preparation and execution. More involved choices include crop rotation, cover crops, tillage methods, harvest time weed seed management, and more. Some of the simpler options include equipment cleaning, timely scouting, and modifying herbicide tank mixtures.

IWM seeks to control weeds by combining several weed management techniques into one cohesive effort (MacLaren et al., 2020). Similar to how repeatedly applying the same herbicide may result in resistance, relying too much on any one of the following techniques over time might lessen its effectiveness against weeds. When creating an IWM strategy, there are two main things to take into account: The target weed species; and the time, resources, and capabilities required to carry out these techniques. Although it makes sense to utilize herbicide technology responsibly, IWM necessitates the adoption of strategies other than herbicides, such as tank mixes or pre and post herbicide treatments. IWM might include, for instance, using these herbicide application techniques in conjunction with harvest weed seed control (HWSC) and preventative techniques or a winter cover crop. General weed management strategies are given in Figure 1.

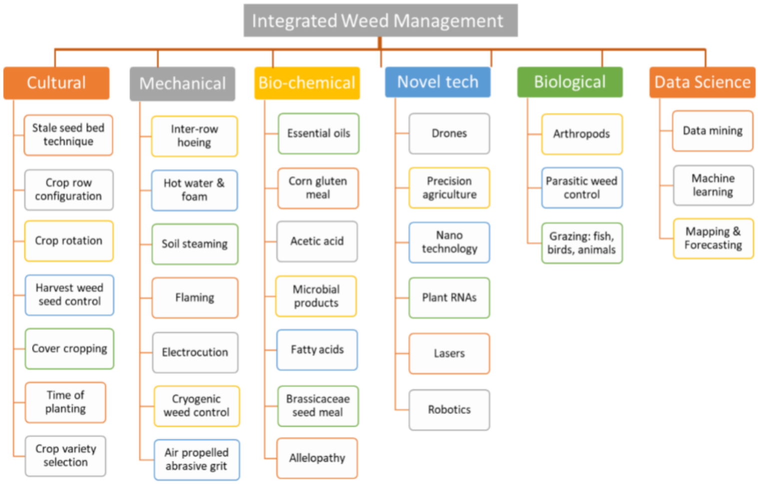

Figure 1. Integrated weed management strategies (Dhakal, 2023)

Among the strategies in Figure 1, prevention, cultural, mechanical, chemical and biological weed management, which have wider application areas in practice, are given below.

1. Prevention

Preventative weed control refers to any management approach that tries to prevent weeds from being developed in a cultivated areas (Christoffoleti et al., 2007). Examples of preventive weed management would include utilizing certified weed free seed, only shipping hay that is weed free, making sure agricultural equipment is cleaned before moving from one area to another, and screening irrigation water to prevent weed seeds from migrating down irrigation ditches (Walker, 2017).

One of the first stages in managing weeds is prevention (Scavo & Mauromicale, 2020). In contrast to the other categories, this one concentrates on preventing weeds from entering or proliferating inside fields (Monaco et al., 2002). Growers may use these strategies. Steer clear of inputs like manure, crop seed, and other inputs that are tainted with weed seeds (McDonald & Copeland, 2012; Monaco et al., 2002). Equipment for cleaning, such as combines (combine cleaning technique), that may move weed seeds from one field to another. Keeping weeds from seeding not just in the field but also in neighboring non-crop areas like ditches and fencerows. Timely weed-scouting expedition. Using leased land or buying old agricultural equipment should be done carefully. Shortly, choosing weed-free areas for agricultural operations, recording the current situation, preventing new infections, knowing the biology and ecology of weeds, and correct diagnosis are important in determining the weed control technique to be chosen.

2. Cultural

Cultural weed management refers to any strategy that includes managing field conditions so that weeds are less likely to get established and/or grow in quantity (Blackshaw et al., 2007). Examples of cultural weed management would include crop rotation, preventing overgrazing of pastures or rangeland, utilizing well-adapted competitive forage species, and keeping adequate soil fertility.

The greatest weed control is a robust, healthy crop (Harker & O'Donovan, 2013). The purpose of cultural practices is to provide the crop an edge against weeds in the marketplace (Bastiaans et al., 2008). Growers may use these strategies. Decreased row spacing to enable the crop to cover weeds more rapidly by reaching the canopy (Bàrberi, 2002). Rotate your crops to prevent weeds from becoming resistant to the weed-control strategies used often in a given crop (Liebman & Dyck, 1993). Nutrient management helps prevent weeds from accessing nutrients and enable maximum crop absorption (Kumar et al., 2010). To force weeds to give up space, sunshine, nutrients, and water in favor of cover crops. Changed the planting date to allow for a controlled weed germination flush before to planting or to give the crop an early start. Choose your crop varieties carefully to give your crops the best possible edge against weeds. The key to cultural weed control is crop rotation and competitive crop selection.

3. Mechanical

Mechanical weed control refers to any approach that includes the use of agricultural machinery to manage weeds (Harker & O'Donovan, 2013). The two mechanical control methods most typically utilized are tillage and mowing.

The mechanical weed control is one of the oldest weed management strategies that entail the physical removal of weeds by mechanical equipment before planting the primary crops or during the crop growth season (Buhler et al., 1992). One of the most essential variables in mechanical control of weeds is the management of soil cultivation activities. Physical methods that prevent germination and damage plant tissue are the main focus of mechanical weed control. Growers may use these strategies.

- Hand-pulling
- Tillage
- Burning
- Mowing
- Robotic weeding machines

Harvest weed seed control, by eliminating or destroying the seeds that remain on the weeds after harvest, harvest weed seed management lowers the amount of weed seeds that are added to the soil seedbank.

4. Chemical

Herbicides are and will be an essential component of the majority of weed control schemes, including IWM initiatives (Moss, 2019). When using herbicides, good management techniques include the following tactics. Prompt reconnaissance, ccurate plant identification and knowledge of local herbicide-resistant weeds, appropriate herbicide application refers to using the proper product at the suitable rate and moment, maximized variety by cycling herbicides whenever feasible throughout the season and by using tank mixtures of herbicides with many, efficient sites of action (SOA) or mode of action (MOA). To prevent applying herbicides with the same SOA or MOA again, plan ahead throughout the seasons. Common herbicides are listed below (Antonious, 2023).

- 2,4-D amine, MOA 4
- Alachlor, MOA 15
- Atrazine, MOA 5
- Bensulide, MOA 8
- Bentazon, MOA 6
- Benefiin, MOA 3

- Bicyclopyrone, MOA 27
- Capric acid and caprylic acid
- Carfentrazone-ethyl, MOA 14
- Clethodim, MOA 1
- Clomazone, MOA 13
- Clopyralid, MOA 4
- Cycloate, MOA 3
- Cyclohexylethylthiocarbamate, MOA 3
- DCPA, MOA 3
- Dimethenamid, MOA 15
- EPTC, MOA 8
- Ethalfluralin, MOA 3
- Ethofumesate, MOA 8
- Fluazifop, MOA 1
- Flumioxazin, MOA 14
- Fluthiacet-methyl, MOA 14
- Fomesafen, MOA 14
- Glyphosate, MOA 9
- Halosulfuron-methyl, MOA 2
- Imazethapyr, MOA 2
- Imazosulfuron, MOA 2
- Linuron, MOA 7
- Mesotrione, MOA 27
- Metolachlor, MOA 15
- Metribuzin, MOA 5
- Napropamide, MOA 15
- Nicosulfuron, MOA 2
- Norflurazon, MOA 12
- Oxyfluorfen, MOA 14
- Paraquat, MOA 22
- Pelargonic acid, MOA 27
- Pendimethalin, MOA 3
- Phenmedipham, MOA 6
- Prometryn, MOA 5
- Pronamide, MOA 3
- Pyraflufen-ethyl, MOA 14
- Pyroxasulfone, MOA 15
- Quizalofop p-ethyl, MOA 1
- Rimsulfuron, MOA 2
- Saflufenacil, MOA 14
- Sethoxydim, MOA 1
- Simazine, MOA 5
- S-metolachlor, MOA 15
- Sulfentrazone, MOA 14
- Tembotrione, MOA 27
- Terbacil, MOA 5
- Topramezone, MOA 27
- Trifloxyfulfuron-sodium, MOA 2
- Trifluralin, MOA 3
- Triflusulfuron, MOA 2

This list represents the mechanisms of action of these herbicides as well as the compounds outlined in the chemical weed control document. For detailed information about these herbicides, see the Plant Protection Product (PPP) database of the Ministry of Agriculture and Forestry. Be sure to read the labels of herbicides regarding the application principles and consult the company and agricultural technical staff. The right herbicide must be used at the right time, in the right dose, with the right tools and by competent operators. It is necessary to report wrong and erroneous practices to the poison hotline or the nearest phytosanitary institution.

5. Biological

Biological weed control refers to any strategy that includes the employment of natural enemies of weed plants to restrict the germination of weed seeds or the spread of mature plants (Thill et al., 1991). This is a fast increasing topic of weed management with numerous examples (Scheepens et al., 2001). Examples of biological weed management include sheep to control tansy ragwort or leafy spurge, cinnabar moth and the tansy flea beetle to control tansy ragwort, the chrysolira beetle to control St. John's Wort, and the employment of goats to remove brush on rangeland (Brock, 1988). The important natural enemies used in biological control of weeds are listed in Table 1 (USDA, 2023).

Table 1. Biological weed control agents

Biological Control Agent	Common Name	Target Weed
Agapeta zoegana	Knapweed	*Centaurea stoebe*
Agasicles hygrophila	Alligator Weed	*Alternanthera philoxeroides*
Agonopterix alstroemeriana	Poison Hemlock	*Conium maculatum*
Amynothrips andersoni	Alligator Weed	*Alternanthera philoxeroides*
Aphthona cyparissiae	Leafy Spurge	*Euphorbia esula*
Aphthona czwalinae	Leafy Spurge	*Euphorbia esula*
Aphthona flava	Leafy Spurge	*Euphorbia esula*
Aphthona lacertosa	Leafy Spurge	*Euphorbia esula*
Aphthona nigriscutis	Leafy Spurge	*Euphorbia esula*
Arcola malloi	Alligator Weed	*Alternanthera philoxeroides*
Bangasternus fausti	Knapweed	
Bangasternus orientalis	Yellow starthistle	*Centaurea solstitialis*
Boreioglycaspis melaleucae	Paperbark tree, Melaleuca	*Melaleuca quinquenervia*
Botanophila seneciella	Tansy ragwort	*Senecio jacobaea*
Bruchidius villosus	Genista monspessulana,	*Cytisus scoparius*
Calophasia lunula	Toadflax	*Linaria genistifolia, Linaria vulgaris*

Coleophora parthenica	Russian thistle, Salsola tragus	*Salsola tragus*
Cyphocleonus achates	Knapweed	*Centaurea stoebe micranthos*
Cyrtobagous salviniae	Giant salvinia/ Water spangles	*Salvinia molesta/Salvinia minima*
Cystiphora schmidti	Rush skeletonweed	*Chondrilla juncea*
Eriophyes chondrillae	Rush skeletonweed	*Chondrilla juncea*
Eteobalea intermediella	Toadflax	*Linaria dalmatica/ L. vulgaris*
Eustenopus villosus	Yellow starthistle	*Centaurea solstitialis*
Exapion (=Apion) fuscirostre	Brooms	*Genista monspessulana*
Exapion (=Apion) ulicis	Gorse	*Ulex europaeus*
Fergusonina turneri	Melaleuca	*Melaleuca quinquenervia*
Galerucella calmariensis	Purple Loosestrife	*Lythrum salicaria*
Galerucella pusilla	Purple Loosestrife	*Lythrum salicaria*
Gratiana boliviana	Tropical soda apple	*Solanum viarum*
Hydrellia balciunasi	Hydrilla	*Hydrilla verticillata*
Hydrellia pakistanae	Hydrilla	*Hydrilla verticillata*
Jaapiella ivannikova	Knapweed	*Acroptilon repens*
Larinus minutus	Knapweed	
Larinus obtusus	Knapweed	
Leucoptera spartifoliella	Brooms	*Genista monspessulana, Cytisus scoparius*
Lilioceris cheni	Air potato	*Dioscorea bulbifera*
Longitarsus jacobaeae	Tansy ragwort	*Senecio jacobaea*
Mecinus janthiniformis	Toadflax	*Linaria genistifolia*
Mecinus janthinus	Toadflax	*Linaria vulgaris*
Megamelus scutellaris	Water hyacinth	*Eichhornia crassipes*
Metzneria paucipunctella	Knapweed	
Microlarinus lareynii	Puncturevine	
Microlarinus lypriformis	Puncturevine	*Tribulus terrestris*
Nanophyes marmoratus	Purple Loosestrife	*Lythrum salicaria*
Neochetina bruchi	Waterhyacinth	*Eichornia crassipes*
Neochetina eichhorniae	Waterhyacinth	*Eichornia crassipes*
Neohydronomus affinis	Waterlettuce	*Pistia stratiotes*
Neomusotima conspurcatalis	Old world climbing fern	*Lygodium microphyllum*
Niphograpta albiguttalis	Waterhyacinth	*Eichornia crassipes*
Oberea erythrocephala	Leafy Spurge	*Euphorbia esula*
Oxyops vitiosa	Melaleuca	*Melaleuca quinquenervia*
Phrydiuchus tau	Mediterranean sage	*Salvia aethiopis*
Psylloides chalcomera	Plumeless thistles	*Carduus spp.*

Puccinia jaceae var. solstitialis	Yellow starthistle	*Centaurea solstitialis*
Rhinoncomimus latipes	Mile-a-minute weed	*Persicaria perfoliata*
Rhinusa antirrhini	Toadflax	*Linaria genistifolia, Linaria vulgaris*
Rhinusa linariae	Toadflax	*Linaria genistifolia, Linaria vulgaris*
Sphenoptera jugoslavica	Knapweed	
Spurgia esulae	Leafy Spurge	*Euphorbia esula*
Terellia virens	Knapweed	
Tetramesa romana	Giant arundo	*Arundo donax*
Tetranychus lintearius	Gorse	*Ulex europaeus*
Tyta luctuosa	Field bindweed	*Convolvulus arvensis, Calystegia sepium*
Urophora affinis	Knapweed	*Centuarea diffusa, C. maculosa*
Urophora cardui	Canada thistle	
Urophora quadrifasciata	Knapweed	
Urophora sirunaseva	Yellow starthistle	*Centaurea solstitialis*
Urophora stylata	Bull thistle	

Biological control is the purposeful use of a weed's "natural enemies" to reduce its proliferation. A weed's natural enemies may include arthropods (insects, mites and their relatives), bacteria or fungus. Examples of biological control agents include, but are not limited to: arthropods (insects and mites), plant pathogens (fungi, bacteria, viruses, and nematodes), fish, birds, and other animals. These "control agents" feed upon or induce illness in the weed, so reducing its growth, reproduction and dissemination. This strategy targets weeds using live organisms such as fungus, bacteria, or insects that are attracted to a particular variety of weed (Harding & Raizada, 2015). Though it is perhaps the least utilized strategy overall, there has been a lot of study done on it. One strategy for biological control is the use of cover crops.

CONCLUSION

Strategies that can be included in integrated weed management can be summarized as follows.

- Prevention: Quarantine, sanitation, certified seed
- Cultural: Crop rotation, competitive crop variety, cleaning equipment, scouting, cover croping, stale seed bed, time of planting, crop row, harvest weed seed control

- Mechanical: Tillage, Moving, Hand Pulling, Hoeing, Streaming, Hot Water And Foam, Flaming, Flooding, Cryogenic, Air-Propelled Abrasive Grit, Mulching, Solarization, Laser, Electrucution
- Chemical: Herbicide
- Biological: Pests, grazing
- Bio-chemical: Biopesticides (390 registered biopesticide, essential oils, corn gluten meal, acetic acid, microbial products, fatty acids, Brassicaceae seed meal), allelopathy
- Bio-technological: Herbicide tolerance crops (IMI tolerance, clearfield), genetically modified varieties (GM)
- Artificial intelligence (AI) tecnologies: Precision, robotic, drone

IWM can be achieved by combining the appropriate ones from the above weed management tactics. IWM is a system that uses all available weed control methods as harmoniously as possible and keeps the weed population below the economic damage threshold. Therefore, in order to successfully implement IWM programs, farmers must be trained in IWM. When it comes to IWM, growers who are aware of the possibility of weed infestation use a four-tiered approach: 1) set an economic threshold when it signals the need for weed control action; 2) monitor and accurately identify weeds so that appropriate control decisions can be made in conjunction with action thresholds; 3) use cultural practices to keep weeds from becoming a threat; and 4) once the third approach is no longer available and the first two approaches indicate the need for weed control, an effective and less risky control strategy must be selected.

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CHAPTER 5

2030 FORECAST OF AGRICULTURAL MACHINERY UTILIZATION OF MARDIN PROVINCE WITH DATA FROM THE PAST YEARS (2012-2022)

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INTRODUCTION

Agriculture is at the center of food production, which has been a basic need since the existence of humanity. However, in the modern world, challenges such as increasing population, changing climate conditions and limited use of resources reveal the need to make the agricultural sector more efficient and sustainable. At this point, making an assessment of how important a role the agricultural machinery park plays in a region is of critical importance for both the future of agriculture and economic development.

The agricultural machinery park offers a wide range of technological opportunities to farmers and agricultural enterprises. These technological tools, ranging from tractors to combine harvesters, irrigation systems to tillage machines, have the potential to optimize agricultural processes and make them more effective. At this point, widespread and effective use of agricultural machinery parks in a region brings with it a number of important advantages.

Elements such as obtaining more products by increasing productivity, modernizing labor-based agricultural methods, and using water and land resources in a sustainable manner are just some of the main factors that determine the importance of an agricultural machinery park in a region.

The most important sector of the Southeast Anatolia Region is agriculture. In the region 3.2 million ha of the 7.5 million ha area is suitable for agricultural activities (Kuzu et al., 2021). Irrigation is the most important part of GAP. It is one of the important infrastructure investments. Approximately 2.1 million ha gross area has irrigation potential. This area corresponds to 20% of Turkey's economically irrigable land (Anonymous, 2023a).

The Southeastern Anatolia Project is a large-scale, multi-sectoral development project aimed at promoting economic and social development in the southeastern part of Turkey. It encompasses various sectors such as agriculture, energy, infrastructure, and social services. The GAP region includes the provinces of Adıyaman, Batman, Diyarbakır, Gaziantep, Mardin, Siirt, Şanlıurfa, and Şırnak. It has an area of 75 358 km2, which corresponds to 9.7% of Turkey's surface area (Sessiz et al., 2006; Gürsoy et al., 2013; Anonymous, 2023b). Mardin city is called "Mardin-Midyat Threshold" in Southeastern Anatolia region is located to the south of the high mass sandwiched between the north Diyarbakır-Siirt Pliocene basin and Syria-

Arabia plains (Arslan and Karadoğan, 2007). In this study, it is aimed to determine the agricultural mechanization projection of Mardin province until 2030 and these values will guide the mechanization plans in the region.

MATERIAL AND METHOD

Mardin, a border province in the Southeastern Anatolia Region, has a surface area of 8891 km².

It constitutes 1.1% of Turkey's territory. Mardin lies between 36°55 - 38°51 north latitude and 39°56 - 42°54 east longitude. Şanlıurfa is located in the west of the province, and Diyarbakır is located in the north. Batman, Şırnak and Siirt are located in the east of the province, and Syria is in the south. The provincial center is approximately 1083 meters above sea level (Mercan and Arpağ, 2020; Anonymous, 2023c). Mardin is the 3rd city of the Southeast Anatolia Region in crop production in terms quantity after Diyarbakır and Şanlıurfa province.

Mardin has an important place in agricultural production with its total agricultural land of 3261656 ha (Anonymous, 2023a). In recent years, the presence of irrigable agricultural land has increased throughout the province. This increase allowed a change in the crop pattern in the province and more than one crop per year from the existing lands. The agricultural area of Mardin province yields cereals and other herbal products on 350964 ha, fruits, beverage and spice crops on 47497 ha, vegetables on 11228 ha in the year 2022 (Anonymous, 2023d).

The material of the study consisted of the agricultural machinery data of the Turkish Statistical Institute for the years 2012-2022 for the province of Mardin (Anonymous 2023e). This data is used to determine the percentage ratios, either an increase or a decrease, for every agricultural tools and machinery by analyzing the covering years. After that, taking into account the 10-year usage amounts of agricultural machines, the percentage rates of increase and decrease in their numbers were calculated, and the average coefficients of these percentage rates were determined. By using the coefficients determined based on the data of previous years, the projections of agricultural tools and machines widely used in Mardin until 2030 are calculated using the same method in cited studies (Demir and Kuş 2016;

Akbaş, 2019; Baran et al., 2019; Baran 2021; Ertop et al., 2021; Baran and Kaya, 2021).

RESULTS AND DISCUSSIONS

In Mardin province, where conventional tillage is widely practiced, the increase in the number of rotary tillers is noteworthy. At the same time, the increase in the number of cultivators can be interpreted as the transition to conservation tillage practices in provincial agriculture. In the last year, the number of cultivators in enterprises has exceeded the number of moldboard plows. As seen in Table 1, the highest projection coefficient with positive percent of 58.46 value is occurred in case of rotary tiller among those taken into consideration. Subsoiler, rotary cultivator, stubble plough (moldboard type), disc harrow, cultivator, moldboard type tractor plough, disc type tractor plough, disc type stubble plough (one way) and land roller are followed rotary tiller with positive projection coefficient value of 10.09%, 9.50%, 8.74%, 7.53%, 2.89%, 2.30%, 1.91%, 1.14% and 1.06% respectively. Furthermore, arc opening plow has negative projection coefficient with a percent of 1.06.

Table 1. Projection of Some Soil Tillage Tools and Machines Widely Used in Mardin Province

Years	Moldboard type tractor plough	Stubble plough (moldboard type)	Disc type tractor plough	Disc type stubble plough (one way)	Arc opening plow	Cultivator	Disc harrows	Rotary Tiller	Rotary cultivator	Subsoiler	Land roller
2012	3241	57	1058	327	511	3173	521	16	115	69	698
2013	3313	58	1059	332	522	3253	556	16	132	74	686
2014	3407	68	1113	337	499	3302	652	86	140	75	699
2015	3685	89	1139	344	505	3359	743	108	148	97	694
2016	3795	94	1185	350	488	3514	761	112	152	97	725
2017	3844	110	1242	347	491	3645	752	125	149	101	757
2018	3879	109	1241	350	470	3788	781	196	149	135	778
2019	3894	118	1279	363	481	3826	800	213	150	148	783
2020	3942	119	1262	364	473	3932	813	269	152	150	782
2021	4083	120	1272	366	474	3993	1035	281	250	165	772
2022	4059	127	1275	366	458	4215	1044	309	253	172	774
Years	**PERCENTAGE CHANGE**										

2012-2013	2.22	1.75	0.09	1.53	2.15	2.52	6.72	0.00	14.78	7.25	-1.72
2013-2014	2.84	17.24	5.10	1.51	-4.41	1.51	17.27	437.50	6.06	1.35	1.90
2014-2015	8.16	30.88	2.34	2.08	1.20	1.73	13.96	25.58	5.71	29.33	-0.72
2015-2016	2.99	5.62	4.04	1.74	-3.37	4.61	2.42	3.70	2.70	0.00	4.47
2016-2017	1.29	17.02	4.81	-0.86	0.61	3.73	-1.18	11.61	-1.97	4.12	4.41
2017-2018	0.91	-0.91	-0.08	0.86	-4.28	3.92	3.86	56.80	0.00	33.66	2.77
2018-2019	0.39	8.26	3.06	3.71	2.34	1.00	2.43	8.67	0.67	9.63	0.64
2019-2020	1.23	0.85	-1.33	0.28	-1.66	2.77	1.63	26.29	1.33	1.35	-0.13
2020-2021	3.58	0.84	0.79	0.55	0.21	1.55	27.31	4.46	64.47	10.00	-1.28
2021-2022	-0.59	5.83	0.24	0.00	-3.38	5.56	0.87	9.96	1.20	4.24	0.26
Projection Coefficient	**2.30**	**8.74**	**1.91**	**1.14**	**-1.06**	**2.89**	**7.53**	**58.46**	**9.50**	**10.09**	**1.06**
Years	**PROJECTIONS**										
2023	4099	122	1313	370	453	4337	1123	490	277	189	782
2024	4140	118	1351	375	448	4462	1207	776	303	208	791
2025	4181	114	1391	379	444	4591	1298	1229	332	230	799
2026	4222	110	1432	383	439	4724	1396	1948	364	253	807
2027	4264	106	1474	388	451	4860	1501	3087	398	278	817
2028	4306	102	1518	392	464	5001	1614	4892	436	306	825
2029	4349	98	1563	397	476	5145	1735	7751	477	337	835
2030	4392	95	1609	401	489	5294	1866	12282	523	371	844

Mardin province is divided into 2 Sub-Agro-Ecological regions. Differences in climate, topography and soil characteristics in the sub-regions have also caused differences in the methods applied in agricultural production. It has been observed that machine planting in sub-region I is more developed than sub-region II. Therefore, although the percentage increase is not high, the largest number of chemical fertilizer spreaders are available in farms. As seen in Table 2, the highest projection coefficient with positive percent of 19.83 value is occurred in case of manure spreading machinery among those taken into consideration. Stubble drill, pneumatic precision drill, chemical fertilizer spreader, combined seed drill, are followed stubble drill with positive projection coefficient value of 19.59%, 10.39%, 5.13%, 2.70% respectively. Tractor-drawn seed drill and universal seed drill has negative projection coefficient with a percent of 3.84 and 0.96 respectively. In the province, the broadcast sowing method is being replaced by machine sowing. Farmers in the province prefer to use stubble drill and pneumatic precision drill, especially in the cultivation of wheat and corn. In the 2030 projection, it is predicted that the largest number of chemical fertilizer spreaders will be in the province. The negative economic conditions that emerged in 2018 and the rapidly increasing prices of chemical fertilizers forced farmers to use organic fertilizers. This situation has also increased the demand for manure spreading machinery in the province after the year 2019.

Table 2. Projection of Some Sowing-Planting Fertilizer Machines Widely Used in Mardin Province

Years	**Tractor-drawn seed drill**	**Combined seed drill**	**Pneumatic precision drill**	**Stubble drill**	**Universal seed drill**	**Manure spreading machinery**	**Chemical Fertilizer Spreader**
2012	1732	1673	184	5	17	4	2501
2013	1757	1715	208	10	17	4	2515
2014	1809	1823	223	11	17	5	2552
2015	1657	2010	238	14	17	6	2717
2016	1669	2083	248	15	18	6	2799
2017	1595	2186	291	19	19	6	2884
2018	1312	2243	318	19	15	10	3180
2019	1374	2511	331	21	15	10	3259
2020	1381	2582	352	21	15	15	3401
2021	1157	2660	451	24	15	18	3137
2022	1134	2746	485	24	15	21	3236
Years	**PERCENTAGE CHANGE**						
2012-2013	1.44	2.51	13.04	100.00	0.00	0.00	0.56
2013-2014	2.96	6.30	7.21	10.00	0.00	25.00	1.47
2014-2015	-8.40	10.26	6.73	27.27	0.00	20.00	6.47
2015-2016	0.72	3.63	4.20	7.14	5.88	0.00	3.02
2016-2017	-4.43	4.94	17.34	26.67	5.56	0.00	3.04
2017-2018	-17.74	2.61	9.28	0.00	-21.05	66.67	10.26
2018-2019	4.73	11.95	4.09	10.53	0.00	0.00	2.48
2019-2020	0.51	2.83	6.34	0.00	0.00	50.00	4.36
2020-2021	-16.22	3.02	28.13	14.29	0.00	20.00	-7.76
2021-2022	-1.99	3.23	7.54	0.00	0.00	16.67	3.16
Projection Coefficient	**-3.84**	**5.13**	**10.39**	**19.59**	**-0.96**	**19.83**	**2.70**
Years	**PROJECTIONS**						
2023	1090	2887	535	29	15	25	3324
2024	1049	3035	609	38	14	25	3440

2025	1085	3177	693	49	13	25	3561
2026	1122	3326	788	65	13	25	3686
2027	1161	3481	896	85	12	25	3815
2028	1201	3644	1020	111	12	26	3949
2029	1243	3815	1160	146	11	26	4088
2030	1286	3993	1319	191	10	26	4231

Especially viticulture and olive cultivation have an important place in Mardin province. Especially knapsack sprayer is widely used in these areas. It is seen that knapsack sprayers appear to be the most abundant. On the other hand, it is seen that engine driven sprayer increased more than knapsack sprayers (4.51%) with a rate of 9.70%. These are followed by atomizers and engine driven sprayers, respectively, with positive percentage coefficients. Considering the negative projection coefficients, it is estimated that there will be a decrease in the number of Barrow dusters and combine sprayers and dusters in 2030 (Table 3).

Table 3. Projection of Spraying Machines Widely Used in Mardin Province

Years	**Knapsack sprayer**	**Barrow duster and combine sprayer**	**PTO driven sprayer**	**Engine driven sprayer**	**Atomizer**	**Duster**
2012	2540	67	773	92	46	7
2013	2545	67	832	91	48	8
2014	2614	69	853	156	49	8
2015	2626	64	965	152	51	8
2016	2706	64	1038	178	53	8
2017	2890	65	1158	188	53	8
2018	3442	54	1474	186	53	8
2019	3560	54	1514	198	53	8
2020	3653	54	1563	204	51	7
2021	3710	54	1580	201	68	6
2022	3902	54	1607	200	71	6
Years	**PERCENTAGE CHANGE**					
2012-2013	0.20	0.00	7.63	-1.09	4.35	14.29
2013-2014	2.71	2.99	2.52	71.43	2.08	0.00
2014-2015	0.46	-7.25	13.13	-2.56	4.08	0.00
2015-2016	3.05	0.00	7.56	17.11	3.92	0.00

2016-2017	6.80	1.56	11.56	5.62	0.00	0.00
2017-2018	19.10	-16.92	27.29	-1.06	0.00	0.00
2018-2019	3.43	0.00	2.71	6.45	0.00	0.00
2019-2020	2.61	0.00	3.24	3.03	-3.77	-12.50
2020-2021	1.56	0.00	1.09	-1.47	33.33	-14.29
2021-2022	5.18	0.00	1.71	-0.50	4.41	0.00
Projection Coefficient	**4.51**	**-1.96**	**7.84**	**9.70**	**4.84**	**-1.25**
Years	**PROJECTIONS**					
2023	4078	53	1733	219	74	6
2024	4262	52	1869	241	78	6
2025	4469	52	1956	241	79	6
2026	4685	52	2047	241	80	6
2027	4912	52	2142	242	81	5
2028	5151	51	2242	242	82	5
2029	5401	51	2346	243	83	5
2030	5662	51	2455	243	84	5

Harvesting machines commonly used in Mardin province are given in Table 4. It can be observed that a positive projection coefficient of 45.00% for the baler, 10.72% straw conveyor and unloader machine, 8.22% for the combine harvester, 6.95% for the corn forage harvester, 0.01% for the thresher. Cotton picker, tractor drawn mower and straw machine have negative projection coefficient with a percent of 3.70, 1.75 and 0.46 respectively. Especially combine harvesters with straw chopping and hay making units are very popular in the region. Therefore, the demand for straw machines throughout the province will decrease over time. This decrease will also be reflected in the numbers in a similar study to be conducted two or three years from now.

Table 4. Projection of Harvest-Threshing Machines Widely Used in Mardin Province

Years	Combine harvester	Thresher	Cotton picker	Straw conveyor and unloader	Straw machine	Corn forage harvester	Baler	Tractor drawn mower
2012	94	709	39	12	138	8	6	180
2013	96	700	38	12	77	9	23	174
2014	102	749	44	12	82	10	34	181
2015	105	751	43	14	86	13	40	179
2016	108	772	44	14	90	13	45	168
2017	128	783	37	15	92	15	60	165
2018	130	719	29	16	99	14	64	152
2019	132	726	29	17	102	15	71	154
2020	145	747	24	18	105	15	76	153
2021	182	712	26	29	115	15	97	150
2022	202	704	25	30	113	15	100	150
Years	**PERCENTAGE CHANGE**							
2012-2013	2.13	-1.27	-2.56	0.00	-44.20	12.50	283.33	-3.33
2013-2014	6.25	7.00	15.79	0.00	6.49	11.11	47.83	4.02
2014-2015	2.94	0.27	-2.27	16.67	4.88	30.00	17.65	-1.10
2015-2016	2.86	2.80	2.33	0.00	4.65	0.00	12.50	-6.15
2016-2017	18.52	1.42	-15.91	7.14	2.22	15.38	33.33	-1.79
2017-2018	1.56	-8.17	-21.62	6.67	7.61	-6.67	6.67	-7.88
2018-2019	1.54	0.97	0.00	6.25	3.03	7.14	10.94	1.32
2019-2020	9.85	2.89	-17.24	5.88	2.94	0.00	7.04	-0.65
2020-2021	25.52	-4.69	8.33	61.11	9.52	0.00	27.63	-1.96
2021-2022	10.99	-1.12	-3.85	3.45	-1.74	0.00	3.09	0.00
Projection Coefficient	**8.22**	**0.01**	**-3.70**	**10.72**	**-0.46**	**6.95**	**45.00**	**-1.75**
Years	**PROJECTIONS**							
2023	219	704	24	33	112	16	145	147
2024	237	704	23	37	112	17	210	145
2025	265	695	25	44	117	19	242	142
2026	297	686	27	52	122	20	279	140
2027	333	677	29	62	128	22	321	137
2028	372	668	32	73	134	24	369	135
2029	417	660	34	87	140	27	425	133
2030	467	651	37	104	146	29	490	130

CONCLUSIONS

The importance of the distribution of agricultural mechanization across regions cannot be overstated. It is a catalyst for increased productivity, economic sustainability, and rural development. As we continue to embrace technological advancements, ensuring that the benefits of mechanization reach every corner of our regions is crucial for the cultivation of a sustainable and prosperous future.

Based on the calculated projection coefficient for Mardin, it is estimated that, there will be an increase of more than 10% in 7 agricultural machines by 2030. In addition, 17 agricultural machineries will also increase by certain percentages. All 8 machines with a negative projection coefficient are projected to decline in use by 2030. It is very important to consider the regional conditions in the design and selection of agricultural machinery to be used in the province.

Mardin's agricultural structure is a testament to the resilience of its people and their ability to adapt to changing circumstances while preserving their cultural heritage. The region's agricultural practices, rooted in history, continue to evolve with the integration of modern technologies and sustainable approaches. As Mardin looks towards the future, its agricultural sector remains a vital part of the region's identity, sustaining communities and contributing to the rich tapestry of this ancient city.

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CHAPTER 6

PROJECTION OF AGRICULTURAL MACHINERY USAGE IN DIYARBAKIR PROVINCE

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INTRODUCTION

Agriculture has been the backbone of human civilization for millennia, providing sustenance and livelihoods to billions of people worldwide. The advancement of agricultural mechanization has revolutionized the way we cultivate, harvest, and process crops and livestock. Agricultural mechanization refers to the integration of various machinery and technologies into farming practices to streamline and optimize agricultural processes. It encompasses a wide range of equipment, from tractors and harvesters to irrigation systems and drones (Altıkat et al., 2015). The adoption of agricultural mechanization has become increasingly crucial to meet the growing global demand for food while addressing challenges related to labor shortages, environmental concerns, and climate change. Achieving profitability in agricultural production is possible by creating a machinery park suitable for climate, soil structure, farm size and crop pattern. Inappropriate machine selection and mechanization planning will increase the expenses of the business and reduce profitability (Demir and Kuş, 2016; Akbaş, 2019; Baran et al., 2019; Ertop et al., 2021).

The Southeastern Anatolia Project is a large-scale, multi-sectoral development project aimed at promoting economic and social development in the southeastern part of Turkey. It encompasses various sectors such as agriculture, energy, infrastructure, and social services (Sessiz, 2020). The GAP region includes the provinces of Adıyaman, Batman, Diyarbakır, Gaziantep, Mardin, Siirt, Şanlıurfa, and Şırnak. It has an area of 75 358 km^2, which corresponds to 9.7% of Turkey's surface area (Sessiz et al., 2006; Gürsoy et al., 2013; Çakmak and Yaviç, 2022).

Diyarbakır province, which is within the scope of GAP, has a significant potential in agricultural production with its large lands. It is thought that the availability of agricultural tools and machinery in the region will increase as larger areas are opened to irrigated agriculture within the scope of GAP (Baran et al., 2021). In this study, it is aimed to determine the agricultural mechanization projection of Diyarbakır province until 2030 and these values will guide the mechanization plans in the region.

MATERIAL AND METHOD

Diyarbakır province is located in the Southeast of Turkey, between 37°30' and 38°43' northern latitudes and 40°37' and 41°20' eastern longitudes. Diyarbakır province, with a surface area of 15 355 km^2, is surrounded by Siirt and Muş in the east, Şanlıurfa, Adıyaman and Malatya in the west, Mardin in the south, and Elazığ and Bingöl in the north. The outer ranges of the Southeastern Taurus Mountains in the north, Batman Stream in the east, Mardin threshold in the south, and Karacadağ and the Euphrates River in the west constitute the natural borders of the province. The altitude of the city center above sea level is 670 m. The territory of the province is covered by the Tigris River and its tributaries, and the waters of a small area at the western end are covered by the Euphrates River (Sessiz, 2020; Çakmak and Yaviç, 2022; GAP BKİ, 2023).

Diyarbakır has an important place in agricultural production with its total agricultural land of 575847 ha (Anonymous, 2023a). Diyarbakır ranks first in red lentil production, third in wheat production, and fourth in seed cotton and watermelon production in Turkey (Anonymous, 2015). In recent years, the presence of irrigable agricultural land has increased throughout the province. This increase allowed a change in the crop pattern in the province and more than one crop per year from the existing lands. The agricultural area of Diyarbakır province yields cereals and other herbal products on 534913 ha, fruits, beverage and spice crops on 21292 ha, vegetables on 10637 ha and fallow area is 9006 ha (Anonymous, 2023a).

The material of the study consisted of the agricultural machinery data of the Turkish Statistical Institute for the years 2012-2022 for the province of Diyarbakır (Anonymous 2023b). This data is used to determine the percentage ratios, either an increase or a decrease, for every agricultural tools and machinery by analyzing the covering years. After that, taking into account the 10-year usage amounts of agricultural machines, the percentage rates of increase and decrease in their numbers were calculated, and the average coefficients of these percentage rates were determined. By using the coefficients determined based on the data of previous years, the projections of agricultural tools and machines widely used in Diyarbakır until 2030 are calculated using the same method in cited studies (Demir and Kuş 2016; Baran et al. 2019; Baran 2021; Ertop et al., 2021; Baran and Kaya, 2021).

RESULTS AND DISCUSSIONS

In Diyarbakır province, where intensive agricultural practices are widely applied, conventional tillage practices still hold an important place. As an indicator of this situation, the presence of moldboard plows in enterprises stands out. However, it is noteworthy that in recent years, due to increasing environmental awareness, changing climate conditions and increasing fuel prices, farmers have turned to conservative tillage equipments. In the last 5 years, the number of cultivators in enterprises has exceeded the number of moldboard plows. As seen in Table 1, the highest projection coefficient with positive percent of 19.74 value is occurred in case of rotary tiller among those taken into consideration. Subsoiler, disc harrow, disc type tractor plough, cultivator, arc opening plow, land roller, disc type stubble plough (one way) and moldboard type tractor plough are followed rotary tiller with positive projection coefficient value of 19.74%, 17.18%, 5.49%, 2.95%, 2.81%, 2.76%, 1.89%, 1.16% and 0.99% respectively. It has been calculated that there has been no change in the number of rotary cultivators in the 10-year period. Furthermore, stubble plough (moldboard type) has negative projection coefficient with a percent of 3.61.

Table 1. Projection of Some Soil Tillage Tools and Machines Widely Used in Diyarbakır Province

Years	Moldboard type tractor plough	Stubble plough (moldboard type)	Disc type tractor plough	Disc type stubble plough (one way)	Arc opening plow	Cultivator	Disc harrows	Rotary Tiller	Rotary cultivator	Subsoiler	Land roller
2012	9656	2498	924	795	914	9672	1625	62	208	58	1683
2013	9669	2509	938	796	917	9714	1763	62	210	64	1685
2014	9896	2615	1083	856	1047	9771	1817	63	220	105	1714
2015	9554	2617	1085	848	1061	9544	1848	59	214	103	1715
2016	9600	2616	1097	848	1064	9598	1868	59	213	104	1681
2017	9922	2620	1144	850	1061	9814	1997	64	201	123	1723
2018	8796	1422	1170	857	1068	9916	2031	26	196	126	1722
2019	8860	1419	1139	887	1058	10080	2023	32	197	160	1736
2020	9137	1436	1139	838	1076	10785	2050	36	198	180	1676
2021	10073	1487	1209	877	1156	12158	2606	113	198	242	1970

2022	10507	1491	1223	887	1190	12662	2707	117	207	251	2003
Years	**PERCENTAGE CHANGE**										
2012-2013	0.13	0.44	1.52	0.13	0.33	0.43	8.49	0.00	0.96	10.34	0.12
2013-2014	2.35	4.22	15.46	7.54	14.18	0.59	3.06	1.61	4.76	64.06	1.72
2014-2015	-3.46	0.08	0.18	-0.93	1.34	-2.32	1.71	-6.35	-2.73	-1.90	0.06
2015-2016	0.48	-0.04	1.11	0.00	0.28	0.57	1.08	0.00	-0.47	0.97	-1.98
2016-2017	3.35	0.15	4.28	0.24	-0.28	2.25	6.91	8.47	-5.63	18.27	2.50
2017-2018	-11.35	-45.73	2.27	0.82	0.66	1.04	1.70	-59.38	-2.49	2.44	-0.06
2018-2019	0.73	-0.21	-2.65	3.50	-0.94	1.65	-0.39	23.08	0.51	26.98	0.81
2019-2020	3.13	1.20	0.00	-5.52	1.70	6.99	1.33	12.50	0.51	12.50	-3.46
2020-2021	10.24	3.55	6.15	4.65	7.43	12.73	27.12	213.89	0.00	34.44	17.54
2021-2022	4.31	0.27	1.16	1.14	2.94	4.15	3.88	3.54	4.55	3.72	1.68
Projection Coefficient	**0.99**	**-3.61**	**2.95**	**1.16**	**2.76**	**2.81**	**5.49**	**19.74**	**0.00**	**17.18**	**1.89**
Years	**PROJECTIONS**										
2023	10611	1437	1259	897	1223	13018	2856	140	207	294	2041
2024	10716	1385	1296	908	1257	13383	3012	168	207	345	2080
2025	10822	1335	1334	918	1291	13759	3178	201	207	404	2119
2026	10929	1287	1374	929	1327	14145	3352	240	207	473	2159
2027	11037	1241	1414	940	1364	14542	3536	288	207	555	2184
2028	11147	1196	1456	951	1401	14951	3730	345	207	650	2225
2029	11257	1153	1499	962	1440	15370	3935	413	207	762	2251
2030	11369	1111	1543	973	1480	15802	4151	494	207	892	2294

Diyarbakır province is divided into 4 Sub-Agro-Ecological regions (Anonymous, 2015). Differences in climate, topography and soil characteristics in the sub-regions have also caused differences in the methods applied in agricultural production. It has been observed that machine planting in sub-region I is more developed than other sub-regions. In other sub-regions, farmers with small, stony and rugged lands use the broadcast sowing method. Therefore, although the percentage increase is not high, the largest number of chemical fertilizer spreaders are available in farms. As seen in Table 2, the highest projection coefficient with positive percent of 31.07 value is occurred in case of stubble drill among those taken into consideration. Pneumatic precision drill, combined seed drill, chemical fertilizer spreader, tractor-drawn seed drill and manure spreading machinery are followed stubble drill with positive projection coefficient value of 31.07%, 13.75%, 4.68%, 3.51%, 3.46%, 0.30% respectively. Universal seed drill has negative projection coefficient with a percent of 4.92. Farmers in the province prefer to use the broadcast sowing method, especially in the cultivation of wheat and lentils. For this reason, the table shows the presence of a significant number of chemical fertilizer spreaders. In the 2030 projection, it is predicted that the largest number of chemical fertilizer spreaders will be in the province.

Table 2. Projection of Some Sowing-Planting Fertilizer Machines Widely Used in Diyarbakır Province

Years	**Tractor-drawn seed drill**	**Combined seed drill**	**Pneumatic precision drill**	**Stubble drill**	**Universal seed drill**	**Manure spreading machinery**	**Chemical Fertilizer Spreader**
2012	2758	3125	136	1	263	64	4038
2013	2806	3228	187	1	186	65	4065
2014	2898	3342	233	3	173	69	4170
2015	2919	3398	253	4	175	79	4299
2016	2929	3434	265	4	174	79	4336
2017	3062	3640	284	7	176	83	4557
2018	3093	3691	294	6	174	44	4614
2019	3167	3751	364	7	156	46	4623
2020	3307	3820	378	7	155	46	4891
2021	3698	4715	421	7	154	56	5259
2022	3858	4853	473	7	151	54	5681
Years	**PERCENTAGE CHANGE**						
2012-2013	1.74	3.30	37.50	0.00	-29.28	1.56	0.67
2013-2014	3.28	3.53	24.60	200.00	-6.99	6.15	2.58
2014-2015	0.72	1.68	8.58	33.33	1.16	14.49	3.09
2015-2016	0.34	1.06	4.74	0.00	-0.57	0.00	0.86
2016-2017	4.54	6.00	7.17	75.00	1.15	5.06	5.10
2017-2018	1.01	1.40	3.52	-14.29	-1.14	-46.99	1.25
2018-2019	2.39	1.63	23.81	16.67	-10.34	4.55	0.20
2019-2020	4.42	1.84	3.85	0.00	-0.64	0.00	5.80
2020-2021	11.82	23.43	11.38	0.00	-0.65	21.74	7.52
2021-2022	4.33	2.93	12.35	0.00	-1.95	-3.57	8.02
Projection Coefficient	**3.46**	**4.68**	**13.75**	**31.07**	**-4.92**	**0.30**	**3.51**
Years	**PROJECTIONS**						
2023	3991	5080	538	9	144	54	5880
2024	4130	5318	612	12	137	54	6087
2025	4272	5567	696	16	130	54	6300
2026	4420	5827	792	21	123	55	6522

2027	4573	6100	901	27	117	55	6750
2028	4732	6385	1025	35	112	55	6987
2029	4895	6684	1166	47	106	55	7233
2030	5065	6997	1326	61	101	55	7487

In Diyarbakır province, fruit and viticulture production areas constitute 3.69% of the total agricultural area (Anonymous, 2023a). Especially knapsack sprayer is widely used in these areas. It is seen that knapsack sprayers are the second largest number after PTO driven sprayers in agricultural enterprises in the province. When looking at the increase rates, it is seen that knapsack sprayers increased more than PTO driven sprayers (4.65%) with a rate of 4.85%. These are followed by atomizers and engine driven sprayers, respectively, with positive percentage coefficients. Considering the negative projection coefficients, it is estimated that there will be a decrease in the number of Dusters and Barrow dusters and combine sprayers in 2030 (Table 3).

Table 3. Projection of Spraying Machines Widely Used in Diyarbakır Province

Years	**Knapsack sprayer**	**Barrow duster and combine sprayer**	**PTO driven sprayer**	**Engine driven sprayer**	**Atomizer**	**Duster**
2012	2706	195	3821	746	536	69
2013	2760	197	4120	753	511	69
2014	2988	191	4383	780	529	69
2015	3687	190	4437	789	525	73
2016	3691	185	4474	785	533	68
2017	3466	170	4852	799	548	54
2018	3590	164	4915	784	555	53
2019	3692	161	5060	790	550	53
2020	3728	154	5122	792	546	53
2021	4015	178	5803	728	561	53
2022	4245	187	5980	755	608	53
Years	**PERCENTAGE CHANGE**					
2012-2013	2.00	1.03	7.83	0.94	-4.66	0.00
2013-2014	8.26	-3.05	6.38	3.59	3.52	0.00
2014-2015	23.39	-0.52	1.23	1.15	-0.76	5.80

2015-2016	0.11	-2.63	0.83	-0.51	1.52	-6.85
2016-2017	-6.10	-8.11	8.45	1.78	2.81	-20.59
2017-2018	3.58	-3.53	1.30	-1.88	1.28	-1.85
2018-2019	2.84	-1.83	2.95	0.77	-0.90	0.00
2019-2020	0.98	-4.35	1.23	0.25	-0.73	0.00
2020-2021	7.70	15.58	13.30	-8.08	2.75	0.00
2021-2022	5.73	5.06	3.05	3.71	8.38	0.00
Projection Coefficient	**4.85**	**-0.23**	**4.65**	**0.17**	**1.32**	**-2.35**
Years	**PROJECTIONS**					
2023	4451	187	6258	756	616	52
2024	4667	186	6550	758	624	51
2025	4893	186	6854	759	632	49
2026	5130	185	7173	760	641	48
2027	5379	185	7506	761	649	47
2028	5640	184	7855	763	658	46
2029	5913	184	8221	764	666	45
2030	6200	184	8603	765	675	44

Harvesting machines commonly used in Diyarbakır province are given in Table 4. It can be observed that a positive projection coefficient of 18.90% for the straw conveyor and unloader machine, 15.13% for the baler, 12.02% for the combine harvester, 9.23% for the corn forage harvester, 8.18% for the cotton picking machinery, 4.56% for the straw machine, 0.55% for the tractor drawn mower are in hand. Thresher has negative projection coefficient with a percent of 1.30. Although it is in third place in terms of projection coefficient increase, it is seen that there will be the largest number of combine harvesters in 2030. Especially combine harvesters with straw chopping and hay making units are very popular in the region. Therefore, the demand for straw machines throughout the province will decrease over time. This decrease will also be reflected in the numbers in a similar study to be conducted two or three years from now.

Table 4. Projection of Harvest-Threshing Machines Widely Used in Diyarbakır Province

Years	Combine harvester	Thresher	Cotton picker	Straw conveyor and unloader	Straw machine	Corn forage harvester	Baler	Tractor drawn mower
2012	355	2109	110	54	292	54	25	555
2013	417	2136	114	66	315	62	41	573
2014	432	2165	131	67	347	63	46	593
2015	484	2229	138	68	351	75	48	605
2016	491	2209	138	66	354	73	49	604
2017	547	2242	144	86	388	76	59	640
2018	553	2237	149	88	392	76	62	641
2019	560	1896	155	104	409	83	71	602
2020	577	1810	154	191	440	102	74	580
2021	863	1778	216	231	439	117	87	540
2022	1029	1824	230	257	453	127	93	580
Years	**PERCENTAGE CHANGE**							
2012-2013	17.46	1.28	3.64	22.22	7.88	14.81	64.00	3.24
2013-2014	3.60	1.36	14.91	1.52	10.16	1.61	12.20	3.49
2014-2015	12.04	2.96	5.34	1.49	1.15	19.05	4.35	2.02
2015-2016	1.45	-0.90	0.00	-2.94	0.85	-2.67	2.08	-0.17
2016-2017	11.41	1.49	4.35	30.30	9.60	4.11	20.41	5.96
2017-2018	1.10	-0.22	3.47	2.33	1.03	0.00	5.08	0.16
2018-2019	1.27	-15.24	4.03	18.18	4.34	9.21	14.52	-6.08
2019-2020	3.04	-4.54	-0.65	83.65	7.58	22.89	4.23	-3.65
2020-2021	49.57	-1.77	40.26	20.94	-0.23	14.71	17.57	-6.90
2021-2022	19.24	2.59	6.48	11.26	3.19	8.55	6.90	7.41
Projection Coefficient	**12.02**	**-1.30**	**8.18**	**18.90**	**4.56**	**9.23**	**15.13**	**0.55**
Years	**PROJECTIONS**							
2023	1153	1800	249	306	474	139	107	583
2024	1291	1777	269	363	495	152	123	586
2025	1446	1754	291	432	518	166	142	590
2026	1620	1731	315	514	541	181	163	593
2027	1815	1709	341	611	566	197	188	596
2028	2033	1686	369	726	592	216	217	599
2029	2277	1664	399	863	619	236	249	603
2030	2551	1643	431	1026	647	257	287	606

CONCLUSIONS

Agricultural mechanization is pivotal for the modernization and sustainability of agriculture. It addresses challenges related to labor shortages, resource scarcity, and climate change while fostering increased production and economic viability for farmers. As technological advancements continue, the importance of embracing and adapting to agricultural mechanization will likely grow to ensure the resilience and productivity of the global farming sector.

Based on the calculated projection coefficient for Diyarbakır, it is estimated that, there will be an increase of more than 10% in 7 agricultural machines by 2030. In addition, 19 agricultural machineries will also increase by certain percentages. All 5 machines with a negative projection coefficient are projected to decline in use by 2030.

As important as the number of agricultural machinery in the province is, it is also crucial to expand agricultural mechanization and create a more inclusive, sustainable and productive agricultural sector. By ensuring that modern agricultural technologies reach a wide range of farmers, they can promote economic development, reduce poverty, improve food security and contribute to the overall well-being of rural communities.

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CHAPTER 7

THE IMPACT OF CLIMATE CHANGE ON WEEDS AND WEED MANAGEMENT

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INTRODUCTION

Ensuring the sustainability of agricultural production is of paramount importance for the healthy nourishment of the increasing global population. Considering the potential effects of climate change, the imperative utilization of natural resources becomes a necessity for the continuity of agricultural production (Anonymous, 2020). Given that approximately 90% of the biological mass constituting living organisms is of plant origin, the continuity of life on Earth is almost entirely dependent on plants. The essential development of plants, crucial for the future of humanity, relies on four fundamental elements (sources): sunlight, water, essential nutrients, and carbon dioxide. However, the reckless and excessive exploitation of nature by humanity, disregarding the ongoing balance in nature, has led to global warming, resulting in a climate change affecting the entire planet. While global warming leads to a direct impact on the growth of plants through increased temperature and carbon dioxide (CO_2) levels, irregularities in precipitation amount and patterns have emerged. Consequently, climate change, which profoundly affects the ecosystem as a whole, will inevitably influence primary producers, namely plants.

As a consequence of global warming, the perceived notion suggests that the increased temperature and CO_2 levels would generally enhance vegetative growth. However, this assumption is reversed by the presence of weeds in agricultural fields, which, when not adequately controlled, lead to significant yield and quality losses. Cultivated crops are anticipated to be more affected by the variations arising from global warming compared to weeds. Moreover, the declining efficacy of herbicides, among the most effective means of weed control, as a consequence of climate change (Ziska and Goins, 2006), will exacerbate the challenge posed by weeds. Additionally, the potential impact of environmental stress conditions on cultivated crops is likely to render them more susceptible to diseases, pests, and weed competition (Patterson, 1995), resulting in cultivated crops being more adversely affected by the environmental changes induced by global climate change. This highlights the escalated significance of weed management issues in agricultural fields due to climate change.

1. GLOBAL CLIMATE CHANGE

Since the 1750s due to increased use of fossil fuels, deforestation, and erroneous agricultural practices, has resulted in heightened levels of carbon dioxide, methane, nitrous oxide gases, ozone, and water vapor in the atmosphere. These emitted gases create a natural cover over the Earth's surface, creating an analogy of a greenhouse effect wherein the Earth and troposphere resemble a greenhouse that absorbs solar radiation but inhibits the release of internal heat. Hence, this phenomenon is termed the greenhouse effect. The escalating human consumption patterns and population growth have led to increased destruction of nature and a surge in the emission of these greenhouse gases (Booker et al., 2009).

Discrepancies in radiation received from the sun contribute to global temperature rise, while solar ultraviolet radiation also affects the ozone layer. The warming resulting from solar radiation and natural occurrences like volcanic eruptions mainly predating the 1950s and do not account for the global warming observed today (Anonymous, 2023). Although these natural events contribute to temperature changes, approximately 90% of global warming stems from human-induced erroneous practices on Earth. The escalated global warming leads to significant disparities in climate, resulting in notable climate variations or changes (Anonymous, 2009).

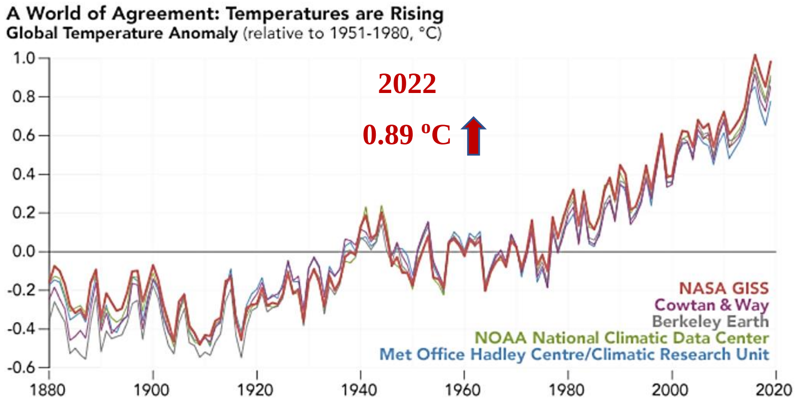

Figure 1. Global Temperature Anomaly (Anonymous, 2023)

Temperature records have been meticulously documented since approximately 1880 due to the limited coverage of observations across the globe before this period. Illustrated in the line plot are the yearly temperature anomalies spanning from 1880 to 2020, collated by multiple reputable sources including NASA, NOAA, the Berkeley Earth research group, the Met Office Hadley Centre from the UK, and the Cowtan and Way analysis. Despite slight year-to-year fluctuations, all five datasets exhibit coherent peaks and troughs, showing a consistent pattern. Each dataset highlights a marked trend of rapid warming particularly in recent decades, uniformly indicating that the most recent decade stands out as the warmest period on record (Anonymous, 2023).

2. IMPACTS OF CLIMATE CHANGE ON AGRICULTURE AND CROP PLANTS

Approximately one-third of the world's landmass is utilized for agricultural purposes to provide food for humanity. Since climate is a fundamental factor in agricultural production, any changes in climate will significantly affect agriculture (Perez Escamilla, 2017). The formation, characteristics, and fertility of the soil—the foundational element for agricultural production—are primarily influenced by climatic conditions. Climate elements, especially temperature and rainfall, play crucial roles in shaping soil properties. Increasing temperatures accelerate chemical, biological, and physical processes in the soil. Temperature fluctuations exert a profound impact on soil formation and properties (Durak and Ece, 2007). For instance, a rise of 10°C in air temperature can double or triple the speed of chemical processes occurring in the soil (Dinç et al., 1987). The pattern and amount of rainfall influence physical, chemical, and biological reactions in the soil, leading to the washing away of decomposition by-products as a result of fragmentation. Excessive rainfall causing prolonged saturation decreases oxygen levels in the soil, adversely affecting plant growth and leading to a decrease in soil pH, causing it to acquire acidic properties. This condition negatively impacts the activity of saprophytic microorganisms in the soil (Durak and Ece, 2007). Conversely, the reduction of beneficial antagonists in the soil leads to an increase in harmful fungal activities. Consequently, an increase in plant diseases may be observed in agricultural fields due to climate change.

Furthermore, climate change-induced extreme weather events can lead to soil erosion, increased salinity due to elevated temperatures and evaporation, and large-scale wildfires. Therefore, climate change resulting from global warming holds significant importance for soil and, consequently, for plants. These events lead to rapid changes in soil properties, consequently affecting agricultural production, yield, product quality, and production patterns. Climate change affects natural ecosystems similar to its impact on agricultural ecosystems. The influence on primary producers, which form the base of the food chain in ecosystems, will have a comprehensive effect on these systems. Plants play a vital role in the energy and carbon flow within ecosystems. Given that approximately 90% of living matter is of plant origin, their existence is indispensable for life itself. Factors affecting plant growth, such as sunlight, rainfall, nutrients, temperature, and carbon dioxide, are crucial elements influenced by climate change (Ziska, 2008). However, alongside the adverse effects of climate change, beneficial changes are also expected. Therefore, while global climate change is anticipated to bring about numerous negatives, it might enhance the physical quality of soils in certain regions and result in a relative increase in soil productivity due to the rise in atmospheric CO_2 levels (Durak and Ece, 2007). The increasing carbon dioxide levels will not only escalate the population density of invasive species in pastures and grasslands but also adversely affect the nitrogen and protein content in plants, consequently compromising feed quality. Elevated temperatures, diseases, and extreme weather events will also impact the productivity of domesticated animals (Anonymous, 2009). Despite humans having domesticated as many as 7000 plant species throughout history, only 15 plant species and 8 animal species currently contribute to fulfilling 90% of our food requirements (Anonymous, 2009). Consequently, the wild forms of these species hold significant importance for us and are considered as biological diversity. However, regrettably, as a consequence of global warming, many wild species are currently under threat. For instance, nearly a quarter of wild potatoes, which could have significant potential for breeders, have vanished in the last 50 years. Concerns arise that climate change might exacerbate the disappearance of wild forms of cultivated plants, which are of utmost importance in agriculture and might even hold solutions to certain problems. Climate changes will bring alterations in the vegetation period and variations in day-night temperature differences. These changes will impact certain plants positively while adversely affecting others. Elevated temperatures will allow for faster growth in plants such as cereals; however, rapid growth often means less time for grain formation, resulting in reduced yield. Increased temperatures will also lead to heightened competition for water in the absence of sufficient moisture. Shorter winters and prolonged vegetation periods will particularly enhance the activity of harmful insects.

3. THE IMPACT OF CLIMATE CHANGE ON WEEDS

The impact of climate change on weeds is critical for sustaining agricultural production amid the rapidly growing global population. The inevitable impact of increased CO_2 concentration and shifting rainfall patterns, quantities, and regimes due to global warming will collectively affect plant species **(**Early et al., 2016).

Indeed, various researchers have highlighted the differential impacts of climate change and increased CO_2 concentration on plant development. Increased carbon dioxide levels generally have a positive effect on the growth of crop plants, while rising temperatures and ozone tend to have negative effects, as identified by different researchers (Ainsworth and Long, 2005; Morgan et al., 2006; Ainsworth, 2008). Studies have found that C3 plants respond better to increased CO_2 levels compared to C4 plants (Heyman and Sadras, 2010; Broadbent et al., 2018). However, the extent of this increase varies significantly depending on the plant species. From this perspective, it might be assumed that changes favoring C3 plants, except for economically significant crops such as sorghum, maize, and sugarcane, would provide advantages to crop plants due to these alterations, consequently minimizing the problem of weeds. Moreover, the fact that many problematic weeds worldwide are generally C4 plants supports this argument. An overlooked aspect is the abundance of species encountered in agricultural fields (including numerous C3 plants) and the reality that under favorable conditions, these secondary weeds could replace others that cause lesser damage. Weed survey studies conducted on different crop plants, both globally and within our country, clearly highlight this fact (Özer et al., 2001).

As every farmer knows, each crop plant harbors its specific weeds, generally consisting of species adapted to the production process of that crop.

In other words, crop plants and weeds typically favor similar conditions and sometimes even comprise related species. Examples such as wild oat in wheat fields, barnyard grass in sugar beet fields, and barnyard millet in rice fields illustrate this situation. Additionally, research comparing crop plants and weeds following the same photosynthesis pathway reveals that the positive effects of increased CO_2 levels favor weeds. Moreover, weeds can rapidly adapt to disturbed habitats, often found in early successional stages within ecosystems. Thanks to these characteristics, they manage to adapt to agricultural ecosystems and can become harmful. In short, in the new environmental conditions caused by global warming, both C4 and C3 weeds will continue to rapidly adapt in cultivation areas. Although the effectiveness of C4 weeds may diminish in agricultural fields due to increased temperatures and CO_2 levels, it is highly probable that C3 weeds will immediately occupy their space (Özer et al., 2001).

3.1. The Impact of Climate Change on the Phenology and Physiology of Weeds

Pest control measures will be affected by phenomena associated with global warming, such as changes in rainfall and wind patterns, as well as extreme weather events accompanying the greenhouse effect. However, only weeds will directly respond to increased CO_2 levels. High CO_2 concentrations will particularly positively influence photosynthesis and consequently growth in C3 weeds. Furthermore, decreased stomatal conductance will lead to increased water use efficiency in both C3 and C4 weeds. The distinction between C3 and C4 pathways signifies the divergent biochemical routes utilized by chlorophyll in plant foliage for sugar synthesis. C4 vegetation encompasses a wide array of grasses and maize. Some have contended that C4 flora remains impervious to fluctuations in CO_2 levels. C4 variants exhibit a less conspicuous reaction compared to C3 counterparts (Von Caemmerer et al., 2012). Nevertheless, they do manifest increased resilience to arid conditions owing to stomatal responses that curtail the loss of water vapor. Research has shown that the increased CO_2 concentration affects the tillering and branching, leaf size, plant height, number of buds and flowers, and flowering time of weeds. However, while C3 weeds generally exhibit a greater increase in total weight relative to leaf area in response to CO_2 elevation, C4 plants respond similarly in leaf area and total biomass.

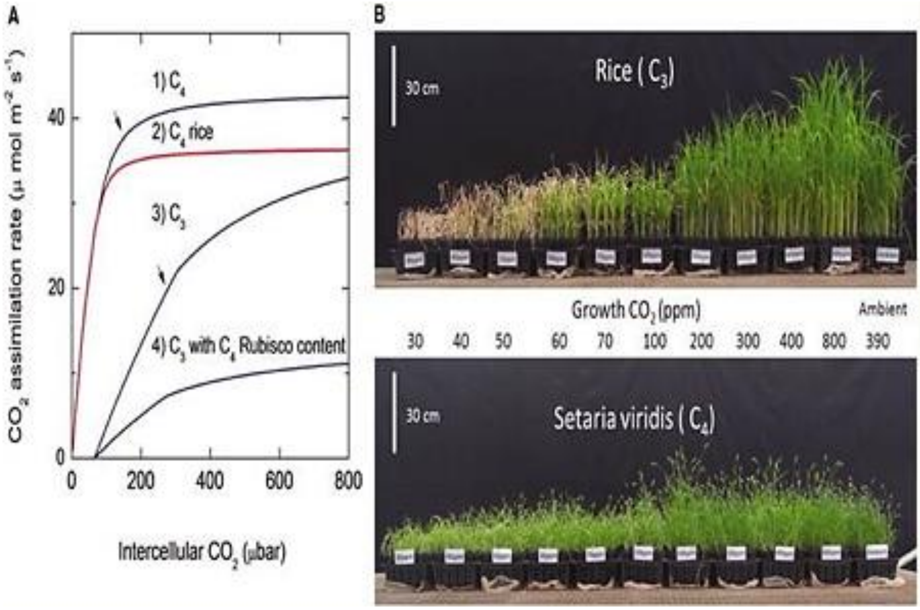

Figure 2. Rice and a wild grass that is the antecedent of Foxtail Millet (Von Caemmerer et al., 2012).

This difference might stem from the lack of increased photosynthetic efficiency in C4 plants, unlike C3 plants. C4 plants possibly compensate for this deficiency by increasing leaf area. However, since leaf development is water-dependent, the increase in biomass is entirely limited to leaf growth. In C3 plants, there is an increase in total plant weight rather than leaf area due to the increased efficiency of photosynthesis. Alongside the growth increase due to the rise in photosynthesis products, there is notably an increase in the root/shoot ratio (Cure and Accock, 1986). This indicates an increase in stored reserve substances in underground organs as CO_2 levels rise. However, the impact of increased CO_2 levels on the root/shoot ratio varies among weed species. Additionally, it's suggested that there could be differences in respiration, the composition and concentration of photosynthesis products, as well as their transport or storage, and possible thickening of leaves (Ziska, 2016). On the other hand, it has been observed that the increased reproductive capacity of Ambrosia artemisiifolia L., under pressure due to the shading effect from other plants, is caused by the increased CO_2 concentration (Stinson and Bazzaz, 2006).

Overall, a positive relationship between temperature and CO_2 concentration has been observed concerning plant development. An increase in plant growth due to elevated CO_2 levels has been identified, predominantly under favorable temperature conditions. Additionally, there have been findings suggesting that increased CO_2 mitigates the effects of unfavorable low or high temperatures (Patterson, 1995). However, these results have shown variability, primarily based on the species, and even within the studied populations. Moreover, increased temperatures have been found to enhance the germination rate of weed seeds, reduce the time required for germination, and positively influence the seedling growth of weeds (Bajwa, 2018). Nevertheless, variations in optimum and maximum germination temperature requirements have been noted, considering the origin of the seeds. This difference is believed to be a consequence of the genetic diversity observed in weeds.

Research conducted with various weed species has revealed an increase in plant growth associated with increased CO_2 levels. However, experiments providing the necessary amounts of nutrients have enhanced weed growth. Nutrients, particularly nitrogen, are among the factors that limit plant growth despite the increase in CO_2 levels. Studies have shown that despite the rise in CO_2, there was no expected increase in plant growth due to stress related to nutrient deficiencies. Furthermore, a direct relationship has been established between CO_2 levels and illumination concerning plant development since light energy is utilized in photosynthesis. Hence, factors other than just CO2 levels and temperature, such as light, water, and nutrient element quantities, play a significant role in the growth of weeds (Özer et al., 2001). All these growth factors or resources operate within the framework of the 'law of minimum.' This implies that despite the increase in temperature and CO_2, the growth level of both cultivated plants and weeds is determined by the scarcest resource.

3.2. The Impact of Weeds and Invasive Species on the Geographic Distribution

Temperature and rainfall are among the most significant ecological factors influencing vegetation in a region. These two factors strongly affect the distribution of weeds as well. Unlike cultivated plants, weeds possess genetic variations that allow them to adapt to diverse ecologies and rapidly colonize and expand their boundaries. While detailed studies determining the adaptive capacity of weeds in agricultural areas to climate change are lacking (Neve et al., 2009), it has been revealed that the increase in CO_2 levels in natural ecosystems facilitates the dominance of invasive species (Smith et al., 2000; Nagabhushan et al., 2023).

Studies indicate that with global warming, especially aggressive species of tropical and subtropical origins could spread further towards northern regions (Patterson, 1995). However, weed species adapted to cold or temperate climates might be negatively affected by new conditions or face challenges from invasive species invading their habitats. Consequently, changes in the boundaries of weed proliferation due to climate change are likely to lead to new interactions between cultivated crops and weeds (Ziska, 2016). During this transition, some new harmful species may emerge, while the impact of currently significant weed species might decrease or these species could entirely disappear.

Apart from the weeds posing problems in agricultural areas, invasive plants threatening both natural and agricultural ecosystems should also be addressed. These invasive weeds, often introduced from external sources and equipped with vegetative reproductive abilities, currently pose significant challenges and have the potential to become even more critical (Ziska and George, 2004; Nagabhushan et al., 2023).

3.3. Effect on Competition

Climate change is anticipated to create highly favorable conditions for plant protection factors. However, weeds, particularly invasive species, known for their high resistance to adverse environmental conditions (Özer et al., 2001), are expected to become significantly more dominant both in agricultural areas and natural ecosystems. The increase in CO_2 concentration, affecting the development and environmental adaptation of cultivated plants and weeds, will also influence the level of competition between them. Depending on the species of cultivated plants and weeds, competition is expected to sometimes shift in favor of cultivated crops and sometimes in favor of weeds (Ziska, 2016).

Yet, the high carbon dioxide conditions brought about by climate changes are generally expected to make C3 weeds more competitive (Ziska, 2000). Indeed, a study revealed that soybean's ability to respond positively to increased carbon dioxide was reduced by weeds. When in competition with a

C3 weed like lamb's quarters (*Chenopodium album*), soybean yield reduction (at high carbon dioxide levels) was at its highest. However, when competing with a C4 plant like redroot pigweed (*Amaranthus retroflexus*), the intensity of competition was lower.

Figure 3. *Amaranthus palmeri* in soybean (Photo by Amit Jhala)

3.4. Effect on Perennial Weeds and Herbicides

Controlling perennial weeds is extremely challenging due to their vegetative reproductive organs. Successful control often necessitates the combined application of mechanical warfare and herbicide use. However, an increase in vegetative reproductive organs like rhizomes, stolons, and roots is expected due to the rise in photosynthetic products. This increase will make the control of perennial weeds even more difficult. Additionally, variations in the surface structure of weed leaves and increased starch accumulation in the leaves of C3 plants due to global warming and increased CO_2 levels result in decreased effectiveness of the herbicides used. Consequently, climate change is likely to lead to an increasing presence of perennial weeds, especially invasive species, in agricultural areas, becoming a larger issue over time (Ziska and Teasdale, 2000; Ziska et al., 2004; Ziska, 2008).

4. Weed Management in the Context of Climate Change

The future yield obtained under future climate conditions is contingent upon climate change effects, especially on weeds, diseases, pests, and their interactions with crops (Fuhrer, 2003). Consequently, given the changing environmental conditions favoring weeds, achieving desired yield levels is impossible without effective weed control. Therefore, to prevent the yield losses caused by weeds, an effective control method must be implemented. Before deciding on control methods, new strategies should be developed, considering not only the economic cost of control but also factors such as the type and biology of the crop and weed, their ecological demands, and modes of reproduction, alongside the influence of changing environmental conditions on these factors (Özer et al., 2001; Bansal et al., 2019).

Hence, despite recent studies concentrating on weed biology and ecology being rather limited (Neve et al., 2009), the need for research in these areas has increased due to changing climatic conditions. Identifying the adaptive potential of weeds to climate changes should be a priority goal in weed science (Neve et al., 2009). Weed adaptation relies on two prerequisites: genetic variation and selection pressure, often resulting from regional climates, environmental conditions, cultivated practices, and weed management. Weeds adapted to these factors become dominant ecotypes in the region. Therefore, determining the level of genetic diversity among populations and their distribution boundaries due to climate change will be necessary to decide on region-specific control methods. Additionally, integrating all this foundational knowledge into weed population models will reveal the long-term effects of climate change and implemented weed control measures (Neve et al., 2009). Consequently, the extent of changes in weed populations due to climate change and implemented control measures can be identified.

Increased temperature and carbon dioxide levels due to global warming are expected to positively contribute to weed development and habitat expansion but may adversely affect chemical control (Ziska, 1998 and 2008). Consequently, climate changes are likely to make weed control significantly more challenging, further highlighting the importance of weeds. This situation will likely shift the weed-crop competition more in favor of weeds. If weeds are not controlled, the expected increase in yield losses caused by weeds may even make agricultural production impossible. However, the combined effects of factors such as temperature, CO_2 levels, light, and water on weed development and the efficacy of herbicides under field conditions have not been fully elucidated. Therefore, detailed studies in this regard are necessary to draw definitive conclusions.

CONCLUSION

The implications of climate change on weed behavior, growth patterns, and distribution are becoming increasingly apparent. Shifts in temperature, precipitation, and CO_2 levels are expected to significantly influence weed adaptation and spread. While increased CO_2 may promote weed growth, it might also impact herbicide effectiveness and alter the competitive balance between crops and weeds. The adaptive potential of weeds to changing environmental conditions, including genetic variations and selection pressures, underscores the necessity for targeted research in weed biology and ecology.

Recommendations:

1. **Focused Research:** More comprehensive studies are imperative to understand the nuanced effects of climate change on weed biology, distribution, and competitive dynamics. These studies should aim to identify the adaptive mechanisms of weeds in response to changing environmental conditions.
2. **Integrated Strategies:** Develop integrated weed management strategies that account for changing climate parameters. This should involve a multi-faceted approach considering crop-weed interactions, herbicide efficacy, and the ecological demands of both crops and weeds.
3. **Adaptive Control Measures:** Implement adaptive weed control measures that consider regional variations in weed populations and their responses to climate change. Such measures should integrate the use of cultural, mechanical, and chemical control methods tailored to specific ecological niches.
4. **Long-Term Monitoring:** Establish long-term monitoring programs to track the shifting patterns of weed populations in response to

climate change. This will help refine and adapt control strategies over time.

5. **Collaborative Initiatives:** Encourage collaborative efforts among researchers, agronomists, policymakers, and farmers to develop and disseminate updated guidelines and best practices for weed management under changing climatic conditions.

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CHAPTER 8

ANORECTAL MALFORMATION

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Anorectal malformations (ARM) are rare anomalies, occurring in approximately 1 in 4,000-5,000 live births according to various publications. They are more commonly observed in males than females. ARM can manifest as types where the anus is completely closed and types where the rectum is fistulized to the urogenital system. There are various anatomical variations of ARM. There is a familial predisposition and genetic susceptibility. If a family's first-born has an anorectal malformation, the incidence of subsequent pregnancies resulting in ARM is 1%.(6-9)The etiology of ARM is uncertain and is considered multifactorial. Postoperative fecal incontinence, following surgical treatment, is a concerning condition that impairs the quality of life and often leads to ongoing defecation-related issues throughout the patient's lifetime, affecting both the patients and their families.(Pena,2003)

1. Anatomy And Physiology

The sphincter mechanism is variably affected in these patient groups. Absence of development in the striated muscles can be observed, or they may appear entirely normal. Depending on the degree of malformation, the most distal part of the rectum may be located above or below the levator ani muscle. The internal anal sphincter holds significant importance in maintaining continence, and there is no conclusive information regarding its preservation in patients with ARM. On the other hand, in high-type ARMs, some studies have suggested a decrease in nerve cells in the medial ventral horn of the spinal cord (Hedlund, 1990).

Sensory and proprioception functions exhibit varying degrees of impairment in patients with ARM. The response of stretch receptors to rectal distension may be reduced. Constipation is a significant issue, particularly encountered postoperatively, in patients where the rectosigmoid colonic innervation is preserved during surgery. It is a common problem in low-type ARM patients. The cause of constipation is attributed to decreased motility in the rectosigmoid ansa. If megarectosigmoid colon develops due to constipation, bowel movements are further compromised, leading to overflow fecal incontinence. This condition, known as soiling, refers to the passive leakage of stool. It is rarer than constipation. In individuals with good prognosis and well-preserved sphincters, constipation can co-occur with good outcomes (Li, 1993)

2.Etiology

The etiology is uncertain and considered multifactorial. Environmental factors are believed to have minimal influence. It can occur in conjunction with syndromes showing autosomal dominant inheritance such as Townes-Broks, Currarino's, Pallisten-Hall syndromes. On the other hand, it may be associated with chromosomal anomalies such as Down syndrome, 22q11 deletion syndrome (Moore, 2013). (Table1) Studies have shown that ARM cases are often the firstborn children. Furthermore, pregnancies resulting from fertility treatment, multiple pregnancies, and those with maternal fever, epilepsy, or preeclampsia during pregnancy have been found to increase the likelihood of ARM with additional anomalies. Maternal epilepsy during pregnancy poses a five-fold higher risk for all types of ARM (Wijers, 2013).

Table 1. Syndromes Associated with Anorectal Malformations

VACTERL Syndrome OEIS Syndrome	Trisomy 21 (Down Syndrome)	Spondylocostal Dysostosis
(Omphalocele, Cloacal exstrophy, Imperforate anus, Spinal defects)	Trisomy 18 (Edwards Syndrome)	Baller-Gerold Syndrome
Axial Mesodermal Dysplasia	Trisomy 13 (Patau Syndrome)	Ciliopathies
Klippel-Feil Syndrome	Hirschsprung Disease	Fraser Syndrome
Sirenomelia-Caudal	Pallister-Killian Syndrome	Short Rib-Polydactyly Syndrome
Regression MURCS Syndrome (Müllerian canal aplasia, Renal aplasia, Cervicothoracic somite dysplasia)	22q11 Deletion Syndrome	Lowe Syndrome
Cat-Eye Syndrome	Currarino Syndrome	Heterotaxy
Parental Uniparental Disomy 16	Pallister-Hall Syndrome	FG Syndrome
Ulnar-Mammary Syndrome	Townes-Brocks Syndrome	X-linked Intellectual Disability
MIDAS Syndrome		Kabuki Syndrome
		Opitz BBB/G Syndrome
		Johanson-Blizzard Syndrome

3. Classifications

Despite various classifications, the Wingspread classification, an anatomical classification proposed by Stephens and Smith in 1984, has been the most commonly used classification due to its simplicity among those developed until that period (Table 2). In this classification, the position of the blind end of the rectum relative to the levator muscles was taken into consideration, resulting in three main groups: high type (supralevator), low type (infralevator), and intermediate type. Rectobulbar fistula is the most common type in male patients, whereas rectovestibular fistula is most frequently encountered in females (Stephen, 1986).

Table 2. The Wingspread classification in anorectal malformations (ARM)

	HIGH	INTERMEDIATE	LOW	UNCLASSIFIABLE
Female	Fistula-free anorectal agenesis Rektovaginal fistula	Rektovestibula fistula Rektovaginal fistula	Anovestibular fistula Anocutaneous fistula Anal stenosis	Rare Malformations Persistan cloaka
Male	Fistula-free anorectal agenesis	Rectrourethral fistula Fistül-free anal agenezis	Anocutaneus fistula Anal stenosis Anovestibular fistula	Rare malformations

Unlike the Wingspread classification, Pena proposed a classification based on the location of malformations. He indicated that the Stephens-Smith classification was inadequate for evaluating treatment and prognosis. Therefore, he suggested that it would be more useful to directly refer to the lesions in females and males by their names rather than classifying anorectal malformations as low, intermediate, and high. (Pena, 1995). In 2005, the Krickenbeck classification was established.

Table 3. Pena Classification in Anorectal Malformations

GENDER	MALFORMATION
MALE	Perineal fistula Rectovesical fistula Rectourethral prostatic fistula Rectourethral bulbar fistula Fistula-free anorectal agenesis Rectal atresia or stenosis
FEMALE	Rectovestibular fistula Anocutaneous fistula Rectal atresia or stenosis Fistula-free anorectal agenesis Persistent cloaca

4. Associated Anomalies

In anorectal malformations, the overall incidence of associated anomalies is generally known to range between 30% and 75%. The closer the distal end of the blind-ending bowel is to the proximal portion, the higher the frequency and severity of associated anomalies. Particularly, anomalies in the genitourinary system are quite common (Smith, 1988).

In approximately 60% of cases with high and intermediate-type anorectal malformations, genitourinary malformations and vesicoureteral reflux are present, while in low-type anorectal malformations, the frequency of genitourinary malformations is only about 15-25%. When looked at without classification, the frequency ranges between 35-85%. There are various reasons for the significant variation in these figures, such as the referral of only severe cases to certain clinics, differences in radiological studies in each case, and advancements in imaging techniques. The most common genitourinary system anomaly is vesicoureteral reflux (VUR). Renal agenesis and dysplasia are the second most common. In boys with anorectal malformations, undescended testis is observed in 3-19% and hypospadias in 6%. Among girls, vaginal duplication, bicornuate uterus, uterus didelphys, and other vaginal and uterine anomalies are seen in approximately one-third (Ganesan, 2012).

With anorectal malformations (ARM), cardiovascular anomalies are also common. Approximately 22% of cases exhibit anomalies such as ventricular septal defect (VSD) and tetralogy of Fallot. Gastrointestinal system anomalies are also highly prevalent, with esophageal atresia seen in 10% of anorectal malformations. Duodenal and small bowel atresias, Hirschsprung's disease, and malrotations accompany ARM at a rate of 1-2% (Smith, 1988).

Vertebral anomalies are more associated with the sacrococcygeal region, such as sacral agenesis and spina bifida. The absence of one sacral vertebra does not have a significant impact on the prognosis. However, the absence of two or more vertebrae can affect the development of anal incontinence. Tethered cord, among spinal anomalies, is most commonly associated with anorectal malformations. The presence of a tethered cord is known to have negative effects on bowel function. Additionally, anomalies of the skeletal system, such as hip dislocation and hemivertebra, can also be observed (Raffenspenger, 1990).

5. Diagnosis

Anorectal malformations are not a group of diseases that require urgent surgical intervention. If the patient is fitted with a nasogastric tube to decompress the digestive tract and receives appropriate fluid and electrolyte support, there is sufficient time to understand other associated anomalies. Once the type of anomaly is accurately determined, an appropriate treatment plan is established. The main objectives of the examinations, imaging, and laboratory studies in this context are to understand the type of atresia, demonstrate fistulas, and detect additional anomalies. The level of atresia, the necessity for colostomy, and the presence of additional anomalies are of paramount importance. The success of surgical treatment is closely related to the existing additional anomalies, the surgical technique to be applied, and especially the innervation status of the anorectal region. For this reason, in a newborn diagnosed with anorectal malformation, in addition to routine examinations, vertebral, anal, cardiac, tracheoesophageal, renal, and limb anomalies should be carefully investigated. Indeed, the ideal scenario involves obtaining detailed information through fetal ultrasonography, if necessary, fetal MRI, amniocentesis, and other examinations during the prenatal period, allowing for comprehensive knowledge before birth. Evaluations conducted, particularly in the prenatal and early postnatal periods, focusing on central nervous system and spinal dysraphism anomalies, carry significant importance for predicting the success of postnatal surgical treatment or considering the termination of pregnancy. In a neonate with a presumptive diagnosis of anorectal malformation, a detailed examination should be conducted to determine the gender, identify anal, urethral, and genital fistula openings, and characterize the content if present. Posteroanterior chest X-rays should evaluate diaphragmatic levels, pleural sinuses, heart and lung shadows, vertebral and rib anomalies, and the possible midline air-fluid level in the proximal pouch in cases of esophageal atresia. Direct abdominal X-rays should examine pneumoperitoneum, air-fluid levels in the intestines, lumbosacral anomalies, and calcifications. Intravenous fluid-electrolyte therapy should be initiated by discontinuing oral feeding, routine blood biochemistry analyses should be performed, and broad-spectrum antibiotics should be started. The radiological examination known as an invertogram, crucial for recognizing the malformation and determining its type, was first conducted by Wangesteen and Rice in 1930 and continues to be applied today. Invertogram, which determines the level of anal atresia, has become a classic procedure for surgical treatment of high-type anal atresias, involving colostomy opening, definitive surgery, and subsequent colostomy closure. However, in recent times, cross-table lateral X-rays have replaced invertograms in routine practice. With this method, a radiopaque marker is placed on the anal region after 24 hours postpartum, and a lateral X-ray is taken in the knee-chest position to evaluate the distance between the radiopaque marker and the distal rectal pouch. To provide a clearer depiction of additional anomalies and the level of the rectal pouch, ultrasonography (USG) and, if necessary, computed tomography (CT) examinations should be performed (Başaklar, 2006).

In approximately 90% of cases with anorectal malformations, the type of malformation can be identified through perineal examination. In a male infant with a closed anus, the presence of meconium or gas discharge from the penis indicates a rectourethral fistula. When meconium comes from a small opening where the anus should be, between the radix of the penis and the coccyx in male infants, it suggests an anocutaneous fistula and is a characteristic finding of this low-type atresia.

The signs of low-type atresia include the presence of skin folds resembling a suitcase handle (ket band), the presence of meconium deposits in the scrotal raphe as white or black dots (pearl sign), and swelling at the location where the anus should be when the baby strains or cries (bulging). In female infants, examining the perineum and the entrance to the vagina is important for determining the type and level of the anomaly. If the baby does not have an anus, and there is no ectopic anus or fistula opening in the perineum, careful examination of the vestibule where the labia majora meet posteriorly is necessary. In a female infant with a closed anus, the observation of stool coming from the vagina most likely indicates a cloacal malformation or rectovaginal fistula. If there is no hymen, the vulva is structurally abnormal, and there is no visible urethral meatus, and if there is only a single orifice, it is highly likely to be a cloacal malformation (Lewitt, 2012).

6. Treatment

After identifying the type of anorectal malformation and associated anomalies, the first step is to engage in a discussion with the patient's family. The crucial point here, especially in the case of high-type anorectal malformations, is that even if the surgery is successful, there is a possibility that their child may not achieve normal anal continence. Generally, families have high expectations, anticipating a complete recovery from the condition. It is essential to explain in detail to the family that the more challenging phase will likely be in the postoperative period. The type of anorectal malformation and combinations of anomalies should be determined, and an evaluation should be made regarding the decision for either primary surgical intervention without colostomy or the choice of initially performing colostomy followed by delayed surgical intervention. Colostomy is a traditionally employed and safe initial treatment for patients with anorectal malformations, ensuring the baby's nutrition and development (Schmiedeke, 2008). Prior to definitive surgical intervention, neural anomalies affecting continence and the condition of sphincter muscles should be reassessed. Anterior, posterior, and lateral lumbosacral X-rays, fistulography, cystoscopy, examination of sphincter muscles with an electrostimulator, pelvic magnetic resonance imaging (MRI), and if necessary, electromyography (EMG) should be performed. The PSARP (Posterior Sagittal Anorectoplasty) technique, developed by Pena and de Vries in 1982 and still considered the standard surgical method for ARM treatment worldwide, is known to provide better preservation of sphincter muscles and perirectal nerves (De Vries, 1982).

The main principle of the Posterior Sagittal Anorectoplasty (PSARP) surgery is the midline approach. The right and left halves of the midline are equally opened, and in this area, there are no nerves and vessels crossing from the sides. There are parasagittal muscle fibers running parallel beneath the skin, extending on both sides. The muscle complex structure, intersecting perpendicularly with parasagittal fibers, is present on both sides, and after rectal repair, the rectum is positioned within this muscle complex. The ischiorectal fat layer is found between the parasagittal muscles. The structure of the levator muscle extends parallel to the skin incision beneath the subcutaneous fat. The levator muscle structure is funnel-shaped, and the narrow opening of this structure forms the muscle complex on the sides. The levator is incised directly in the midline, and surgical repair is performed based on the type of anomaly. If present, rectourethral fistula is ligated. The rectum is mobilized and pulled through. In the repair of perineal and vestibular fistulas, the rectum is placed within the muscle complex of the levator. In females, all malformations can be repaired using the PSARP technique. In males, while PSARP is sufficient in 90% of patients, a laparotomy or laparoscopy is required in a 10% subgroup with high-type atresia (rectovesical fistula) (Pena, 1995). In patients with cloacal malformations, an abdominal approach may be necessary. Total urogenital mobilization allows for the repair of the rectum, vagina, and urethra in cloacal anomalies.

Surgical techniques have been compiled based on the results of the Krickenbeck conference, as presented in Table 4 (Holschneider, 2005), for publication in a scientific journal.

Table 4. International Classification of Surgical Techniques

PSARP
Anterior sagittal approach
Sacroperineal operation
Perineal operation
Pull-through with laparoscopy
Abdominosacroperineal pull-through
Abdominoperineal pull-through

7. Follow-up

In patients who have undergone surgical treatment for anorectal malformation and associated anomalies, the current goal of follow-up, starting from the age of 3, is to achieve continence in children. Constipation and excessive accumulation in the rectosigmoid colon are particularly observed in low-type malformations. The frequency of constipation decreases as the severity of ARM increases (Levitt, 2012).

The ARM types with the highest rates of Voluntary Bowel Movements (VBM) are perineal, vestibular, bulbar fistula, and fistula-free ARM patients. Constipation is likely in these patient groups, and there is a reduced tendency for soiling as a result. The rate of voluntary bowel movements ranges between 79% and 97% (In Kloaca, prostatic fistula, and vesical fistula types of ARM, the rate of soiling is high, and the rate of constipation is lower. The goal during the first three years is to prevent constipation and prevent the expansion of the rectum and sigmoid colon. A constipation-preventive diet, along with laxatives if necessary, aims to achieve fecal continence through voluntary bowel movements.

Soiling is a less common form of stool leakage compared to constipation. In types with a good prognosis, where the sacrum is well developed and the sphincters are in good condition, soiling may coexist with constipation. Patients with impacted feces and observed soiling are considered pseudo-incontinent, and the treatment involves clearing the impacted feces. Subsequently, patients are observed to be continent. In some patients, soiling is a sign of true fecal incontinence. The treatment for these patients involves a bowel training program (BEP) (ARM Society. Bowel Education Program 2014)

Groups of patients are presented with common principles of treatment before the BEP. Written information is provided, and a question-and-answer session is conducted. The treatment goals are explained, and the duration of treatment is 7-10 days. In the initial phase of treatment, patients are divided into two groups based on contrast enema, which assesses the width of the rectum and sigmoid colon and the accumulation of fecalomas. Fecaloma accumulation is the cause of constipation. Fecal incontinence is related to the incomplete daily emptying of the rectum and sigmoid colon, leading to overflow-type leakage and soiling (pseudo-incontinence).

Patients who undergo surgery using the abdominoperineal approach and have the rectum resected are prone to diarrhea due to the lack of rectal reservoir. Incontinence treatment in this patient group is more challenging due to the rapid transit of stool. The goal in this patient group is to achieve daily bowel movements with a constipating diet, if necessary, by administering motility-slowing drugs to ensure the accumulation of feces in the colon. This is coupled with daily enemas to achieve complete evacuation.

In some cases, there may be a need for secondary surgery. This primarily involves correcting complications arising from the primary surgery. Repair of rectourethral/genital fistulas, retraction, and persistent urogenital sinuses left behind in cloacal malformations, as well as the correction of vaginal and urethral stenosis resulting from this surgery, are the main conditions that may necessitate a redo PSARP. Secondary surgery may also be required for fecal incontinence and pseudo-incontinence due to megarectosigmoid (Pena, 1993).

In individuals with ARM, urinary, sexual functions, and psychological processes should not be overlooked and should be closely monitored (Huibregtse, 2014).

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