AMERICAN UNIVERSITY OF BEIRUT

A COMPARATIVE STUDY OF WHEAT VARIETIES FOR ENHANCED AGRICULTURAL PRODUCTIVITY IN THE MENA REGION

by
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ABSTRACT
OF THE THESIS OF

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Title: A Comparative Study of Wheat Varieties for Enhanced Agricultural Productivity in the MENA Region.

Throughout the 2022/2023 growing season, a field experiment was conducted at the Advancing Research Enabling Communities Centre (AREC) in the Beqaa plain at the American University of Beirut, Lebanon, to assess eleven advanced durum wheat genotypes obtained from the Prima Cereal Med Project, two genotypes (Icaverve & Margherita) sourced from ICARDA, and an imported Italian wheat variety (Demantillo). Results showed that there were no significant differences among treatments for grain yield, hay yield, and spike number. Although statistical significance was not detected, the mean performance indicated that ESDCB-2015/2016-82 and IDSN46-7010 genotypes exhibited the highest productivity, with grain yields of 4.89 t/ha and 4.75 t/ha, respectively. However, significant variations were observed in plant height. The Iride genotype (48.7 cm) differed significantly from the Monastir genotype (55.3 cm) at 110 days after planting, and the Margherita genotype (70.8 cm) differed from the Monastir genotype (78.3 cm) at 113 days after planting. Tiller number also exhibited a significant difference between Saragolla (3.1) and Antalis (4.2). The calculated harvesting index showed a significant difference between Margherita (39.6%) and Iride (46.3%). In addition, proximate analysis was conducted to determine moisture, protein, fat, crude fiber, ash percentages, and starch content, along with the thousand kernel weight for all varieties. In conclusion, while statistical significance was not evident, the mean performance of the genotypes suggests that ESDCB-2015/2016-82 and IDSN46-7010 were the most productive, with grain yields of 4.89 t/ha and 4.75 t/ha, respectively. To contextualize these results, a comparison was made with studies conducted in Lebanon and other countries, providing insights into the genotype, location and agricultural practices effect.

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CHAPTER 1

INTRODUCTION

Durum wheat scientifically known as *Triticum* durum holds significant global agricultural importance, ranking as the 10^{th} most crucial crop, with a production exceeding 36 million tons (Ranieri, 2015). This crop is cultivated across nearly 17 million rainfed hectares worldwide and reached a global production of 38.1 million tons in 2019 (Keenan-Pelletier, 2021). In 2018 The European Union emerged as the leading producer, contributing 9 million tons, followed by Canada, Turkey, the United States, Algeria, Mexico, Kazakhstan, Syria, and India (Xynias et al., 2020).

Within semi-arid regions such as Lebanon, the agricultural sector encounters heightened susceptibility attributed to climate change. This is marked by escalating temperatures, altered precipitation patterns, drought, and other heightened occurrence of extreme weather events (MoE/UNDP/GEF, 2022). These climate risks constrain yields of several crops, including wheat, impacting the livelihoods of a substantial portion of the Lebanese population engaged in farming. The sector's susceptibility is exacerbated by its heavy reliance on irrigation, threatened by challenges like population growth, migration, environmental degradation, and competition from sectors such as tourism, energy, industry, and households. Lebanon's unique challenges within the MENA region arise from its smaller landmass and a more urbanized population compared to neighboring countries (MoE/UNDP/GEF, 2022). To maximize grain yield, farmers should select a rainfed variety that is well-suited to their area, employ a carefully designed supplementary irrigation strategy, and integrate nitrogen fertilization alongside good agricultural practices. The Prima Cereal Med project underscores the importance of these measures for achieving optimal results.

The Prima Cereal Med project is dedicated to advancing research and innovation in cereal production, cultivation techniques, and pest management to boost agricultural productivity throughout the MENA region. This project advocates for the revitalization of ancient grain varieties and cultivated counterparts of tetraploid wheat, as well as untamed wild species that could serve as valuable sources of genes and alleles resistant to pests, resilient against environmental stresses, and possessing essential nutritional attributes.

The objectives of this field experiment were to assess the growth and compare the yield of 14 different wheat varieties. Additionally, we investigated grain quality by evaluating moisture, protein, fat, crude fiber, ash, and starch content. The experiment included eleven wheat strains supplied by the CerealMed project from Beni-Suef University in Egypt. To broaden the comparison scope and enhance the study's relevance to our region, three additional varieties commonly used by Lebanese farmers and known for their high value were incorporated (Icaverve, Margherita and Demantillo).

CHAPTER 2

LITERATURE REVIEW

2.1. Wheat

2.1.1 Historical overview

Wheat is one of the oldest and most widely cultivated grain crops in the world. It is believed to have been first produced as a staple crop around 10,000-8,000 B.C.E. Robert Braidwood, an archaeologist from the University of Chicago, discovered carbonized wheat kernels at the 6,700-year-old site of Jarmo in eastern Iraq. This is the oldest settlement identified and possibly one of the earliest sites of agriculture (Mangelsdorf, 1953). Wheat's unique ability to form dough made it highly valued compared to other grains, leading early civilizations to embrace it for baking (Curtis et al., 2002). Cereals, including wheat, formed the foundation of great civilizations and played a vital role in the Neolithic revolution. They were among the most important agricultural crops, providing a reliable source of nutrition.

While wheat formed the basis of European and Middle Eastern civilizations, Far Eastern cultures relied on rice, indigenous American peoples cultivated maize, and Sub-Saharan African societies revolved around millet (Abis, 2012).Wheat, along with other cereal grains, played a significant role in transitioning from a nomadic hunter-gatherer lifestyle to a settled agricultural one. This shift allowed individuals to dedicate time and effort to activities beyond basic food acquisition. By cultivating grains that could be stored, families and tribes no longer needed to constantly move in search of food from plants and animals. Instead, they established permanent settlements and grow crops that could be safely stored for extended periods after harvest (Diamond, 1997).

Besides serving as a staple food source, the wheat crop held great significance in ancient civilizations, embodying a divine and blissful essence. The ancient Egyptians attributed the enrichment of their lives to the crop, considering it a gift sent by their God, Osiris (Buller, 1919). Meanwhile, the Greeks revered the goddess of wheat, known as Demeter, “the goddess of the earth and its fruits, a deity presiding over or representing the generative powers of nature”(Fowler, 1908). Similarly, in Rome, which was historically referred to as the wheat empire, the goddess Ceres held sway. During autumn, farmers would invoke Ceres, seeking her blessings to safeguard their fields from pests and any detrimental occurrences until the seeds ripened. In summer, when seeds are ripened the Romans offered wheat ears to Ceres celebrating the Cerealia festival. Ceres may have been Demeter's new name among the Romans, yet there is evidence that Ceres' original ancestry was purely Roman (Fowler, 1908).

Buller’s (1919) depiction that was inspired by a painting discovered in Pompeii, Naples, showcases a representation of Demeter, the Greek goddess associated with wheat (Figure 1). In this artwork, her headdress is decorated with wheat heads and stalks, while she holds a sheaf of wheat in her arm. A basket filled with wheat is placed at her feet.

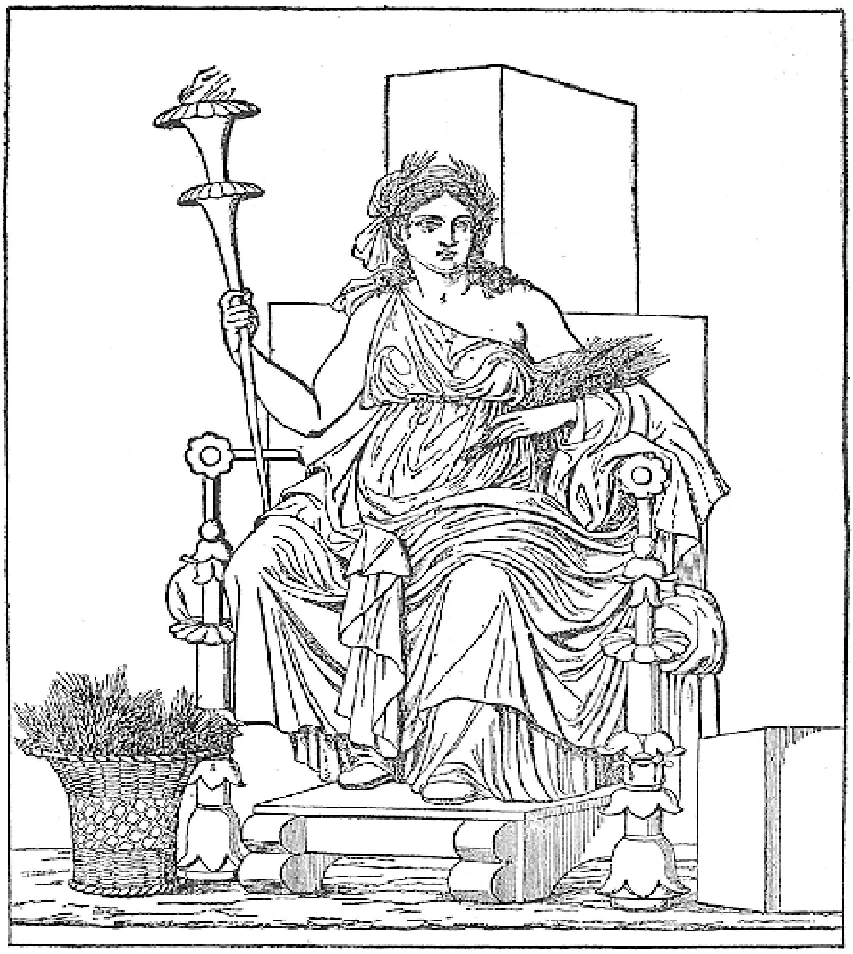

Figure 1. Demeter: The Greek Goddess of Wheat.
Source: (Buller, 1919)

2.1.2 Importance

For centuries, wheat and bread have formed a vital part of our diet, securing our survival. The importance of this crop is justified by its unique characteristics. Firstly, wheat possesses a distinctive property in forming dough, granting it an advantage over other temperate crops. Among all the grains in the plant kingdom, only wheat grains can produce an entirely elastic dough due to the presence of gluten proteins, resulting in the baking of leavened bread (Shewry, 2009). Secondly, wheat displays significant genetic variation, supporting the emergence of approximately 25,000 varieties suitable for a wide range of temperate environments. This genetic diversity allows for its cultivation in various geographic locations, including elevated areas in the tropics and subtropics, ranging from 67°N in Scandinavia and Russia to 45°S in Argentina (Feldman, 1995). These primary reasons contribute to the cultivation of around 10^{14} wheat plants annually across all continents except Antarctica. Consequently, this leads to a remarkable output of over 600 million metric tons of grain from approximately 220 million hectares. Nowadays, wheat serves not only as a symbol of food but also holds significant social and religious value. In Eastern European culture, presenting a loaf of bread to a guest is a customary gesture of welcome. References to wheat and bread in the Bible, like "Man shall not live by bread alone," "Cast thy bread upon the waters," and "Give us this day our daily bread," have become commonly used expressions. Furthermore, The United Nations' Food and Agriculture Organization has adopted the motto "Fiat panis," which translates to "Let there be bread," emphasizing the significance of bread in addressing global food needs. Conversely, hunger has been historically represented by the absence of wheat and bread (Curtis et al., 2002).

2.1.3 Wheat in the MENA region

The people in the MENA region highly depend on imported food. Wheat being the most important commodity, since it plays a crucial part in societies and their consumption habits (traditional food), accounts for around 35% of their caloric intake (Larson, 2012). Most governments in this region use direct protection measures to safeguard local wheat production. The 2007-2008 food crisis and the subsequent increase in global food prices highlighted the issue of food security and self-sufficiency (Ghada Ahmed, August 2013). In brief, the production-consumption balance, considering all the cereals in the MENA region in 1970, registered a deficit of 7 million tons (Mt). This deficit increased to 54 Mt in 2000 and reached 66 Mt in 2010. The expectation for 2050 suggests it could reach 115 Mt. As a result, Arab countries will be obliged to continue importing to meet their cereal needs, as the demand for animal fodder is also on the rise (Abis, 2012). Therefore, in Morocco, Tunisia, Algeria, and Egypt, the average daily consumption of grains per person per day is approximately 600 to 700 grams, whereas in India, it is around 400 grams, and in France, it is about 320 grams (Abis, 2012). Moreover, with this region encompassing 24 countries that hold over 50% of the world's known reserves of oil and 40% of its natural gas, it is still the world's most reliant region on imported food (Cueille, 2011). In 2021 over 54 million metric tons of wheat were imported by the MENA region, covering more than 50% of its consumption (FAOSTAT, 2023a). Not only wheat imports increased 50 % in the Middle East and 20% in North Africa but also local wheat consumption rose by 28 % and in 2011 this growth was 7% greater than the world's average (Abis, 2012).

2.1.4 Wheat in Lebanon

In Lebanon, the fertility and productivity of the soil is highly promising especially in the Beqaa plain which was historically considered to be the silo of the romans. Nonetheless, the country produces only 20 % of its wheat, importing the remaining strategic requirements from various countries and making it one of the most agriculturally insufficient countries in the world (Arafeh & Sukarieh, 2023). For this reason Lebanon is buying about 80% of its wheat from other countries like Ukraine (about 80%), Russia (about 15%), and a few others (about 5%) (Comtrade, 2020). In 2015, they brought in around 625,661 thousand tons of wheat, and this number had gone up each year until it reached 745,158 tons in 2021 (FAOSTAT, 2023a). The reason behind the continuous increase in Lebanese wheat imports is directly related to the growing population, less precipitation, climate change, drought and the Syrian crisis that led to more refugees into the country. This surge in demand for wheat imports is exacerbated by the need to meet the heightened food requirements of both the expanding local population and the influx of refugees. Moreover, the situation worsened on August 4, 2020, when the port blast occurred and destroyed all the wheat reserves in the country. (Gharib, 2022; Graham, 2022).

Besides the country is heavily dependent on irrigated crops such as potato and orchards and the primary crops produced are tomatoes, olives, wheat, cucumbers, oranges, apples, and grapes (FAO, 2004). Over the years the agricultural sector in Lebanon has changed dramatically with crops shifting from traditional staples like wheat and olives to higher-value products like fruits and vegetables. Table 1 provides information on the percentage of useful agricultural areas (UAA) dedicated to different types of cultivation in two different time periods. The table shows that fruit trees, olive farming, and cereals were the main types of cultivation in the region during both periods, with some changes in the percentage of UAA dedicated to each. It was found that there was a reduction of around 6% and 2% in the use of land for industrial crops and cereals, respectively. On the other hand, the land used for fruit trees and legumes increased by approximately 5% and 1.5%, respectively, in 2010 compared to 1998. Additionally, all these arable lands collectively covered an area of 680,000 hectares in 2021 as depicted in Figure 2.

Focusing on wheat in Lebanon, is still the main source of dietary calories for the Lebanese; according to FAO food balance sheets, the per capita supply of wheat represented 46.5% of the caloric intake in 1961. However, by 2002, this ratio had decreased to 30%, and this decrease was due to a change in the type and quality of wheat eaten in Lebanon (FAO, 2005). Ultimately, more recent data shows that one person in Lebanon eats about 130 kilograms of processed wheat each year (Monzer, 2022).

Back when most of the Lebanese were living in rural areas, most of the wheat planted and consumed as bread was from hard and durum wheat. But nowadays with rural population only constituting 10%; to produce Arabic bread or leavened foreign bread (*khubz frengy*), Lebanese wheat must be mixed with other imported types (Cowan, 1965). Unlike the soft wheat that works best for flour, the hard and durum kind is perfect for Lebanese homemade *mouneh* (preserved food items that are prepared during the harvest season to be consumed throughout the year) dishes like *Samid*, *Burgul*, and *Frie*keh (Akhbar, 2020).

Furthermore, when comparing the average yield of wheat in different countries; figure 3 shows that the productivity in industrialized countries such as Italy is clearly higher than Lebanon and its nearby countries. However, the yield of wheat per hectare in Lebanon is comparatively better than its neighboring countries like Jordan, and Syria. Moreover, growth in wheat productivity has been accompanied with the continuous abandonment of land previously used for cereal cultivation. Approximately 80% of the arable lands that have been abandoned for over 30 years were once utilized for planting grains (Hunter, 2006). These lands include Aley in Mount Lebanon, Qobayyat in North Lebanon, North and West Bekaa, Hermel, and Nabatiyeh in South Lebanon (Farajalla et al., 2022).

To elaborate more, in Lebanon wheat is planted, harvested, and milled. Today there are around thirteen mills that are distributed all over the country (BANK, 2016). According to the FAO database, Lebanon produced approximately 100,000 tons of wheat in 2021 over a harvested area that covered 45,000 hectares and the estimated average yield per hectare was around 2.2 tons (FAOSTAT, 2023a). Generally, the productivity of each hectare is directly influenced by the irrigation method employed, whether it is rain fed or irrigated.

Furthermore, for a deeper understanding of the Lebanese wheat trade chain, Figure 4 illustrates a significant increase in wheat demand in Lebanon since imports began to rise sharply between 1995 and 2023. While Ukraine was the primary source of imported wheat for Lebanon prior to 2015, the country shifted its wheat imports to Russia due to economic and political factors. Nevertheless, Lebanon continues to import some wheat from Ukraine. Additionally, in certain years, small quantities of wheat have also been imported from other countries, such as Bulgaria, Turkey, and Syria.

Table 1. Comparison of the useful agricultural area (UAA) between 1998 and 2010. Source: (FAO, 2000 and 2010).

Type of cultivation	Percentage of UAA in 1998	Percentage of UAA in 2010
Fruit Trees	26	31
Olive Farming	23	23
Cereals	22	20
Vegetable Crops	17.5	17
Industrial Crops	10	4
Legumes	2.2	4
Fodder Crops	-	1

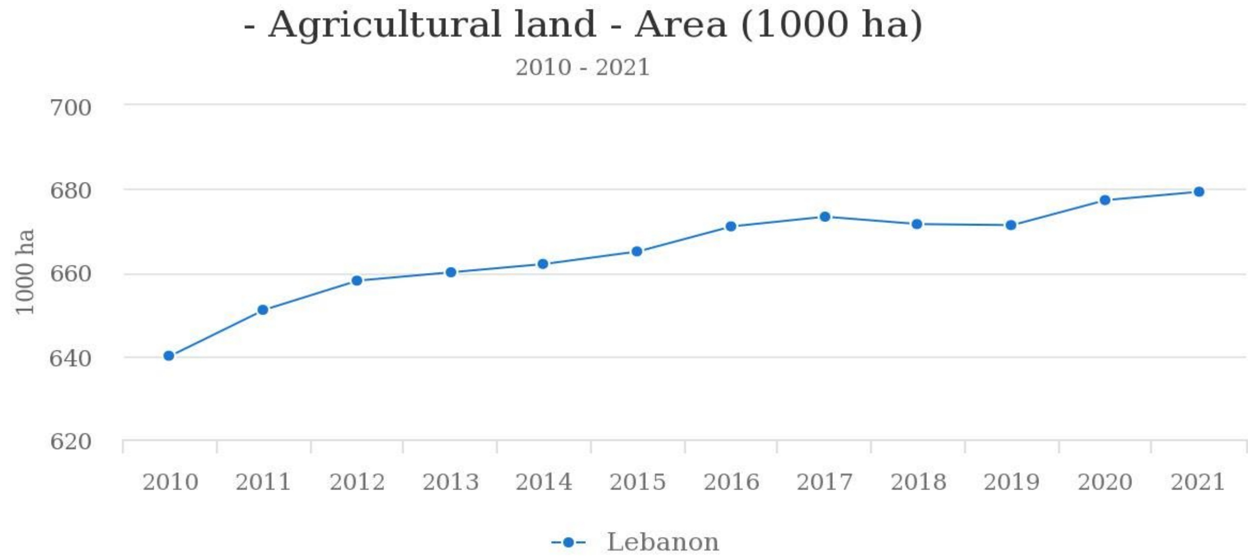

Figure 2. Evolution of agricultural areas in Lebanon (2010-2021).
Source: (FAOSTAT, 2023b).

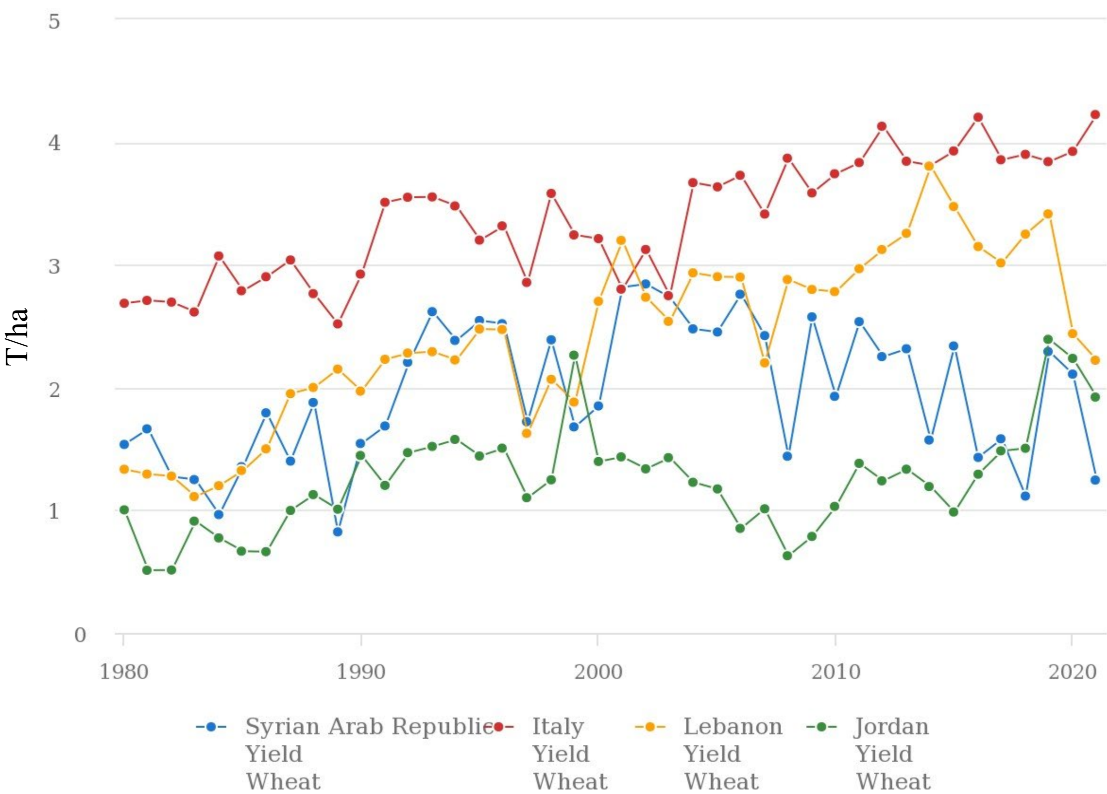

Figure 3. Wheat yield comparison in different countries.
Source (FAO, 2023).

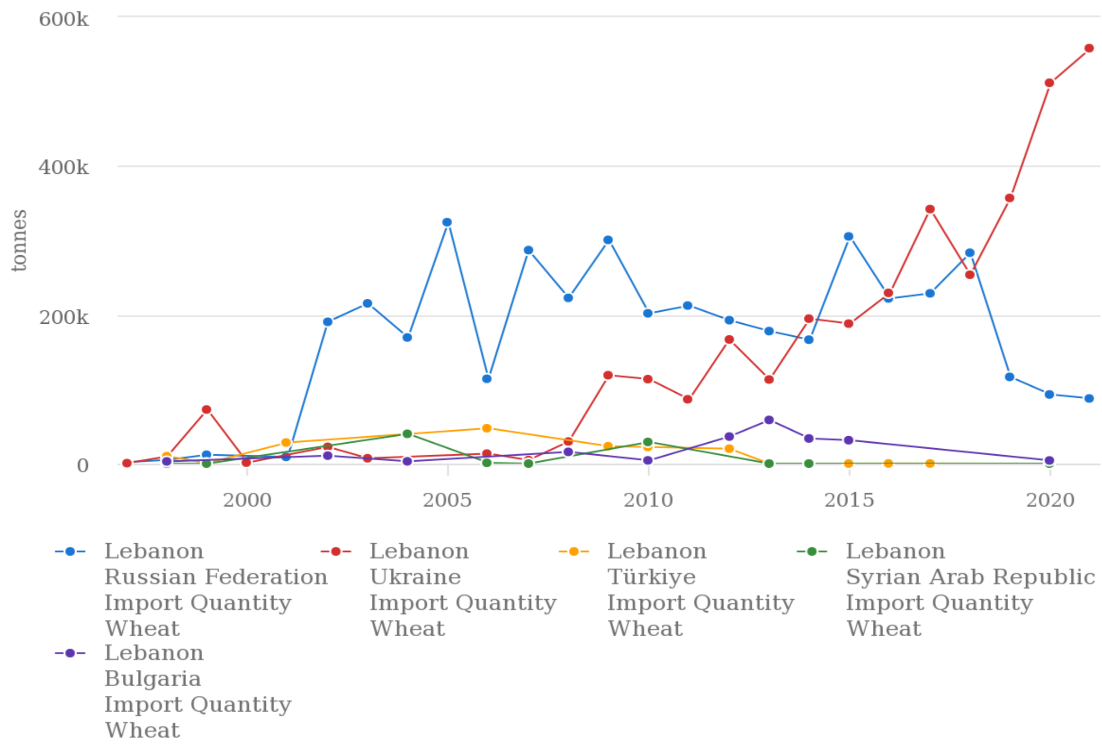

Figure 3. Lebanon's wheat imports from 1995 to 2023: A Detailed Look at Trade Partners and Import Quantities.
Source (FAO, 2023).

2.1.5 Impact of climate change on wheat productivity in Lebanon

Researchers suggest that due to climate change, there would be a necessity to modify diets globally, given that certain crops might become challenging to cultivate in the modified conditions. This could be addressed by transitioning to crops that are well-suited to thrive in these changed climates and could potentially be supported through substitutions (Houghton et al., 2001). Cereals, such as corn and wheat are susceptible to impacts when exposed to temperatures exceeding 30°C, leading to reduced grain production. Hence, the effects of climate change on food systems are anticipated to be extensive, intricate, varying across locations and time, and significantly shaped by socioeconomic factors (Vermeulen et al., 2012). In Lebanon over the preceding years, people have confronted a series of profound challenges, including an economic crisis of substantial magnitude, the 2020 port explosion, the occurrence of natural disasters, and the widespread effects of the COVID-19 pandemic. These compounding adversities, in addition to climate change, have imposed considerable hardships on the citizens (MoE/UNDP/GEF, 2022). This country, which is categorized by a semi-arid climate, experiences warm and arid summers occurring from June to September, as well as chilly and wet winters spanning from December to mid-March. In addition, the yearly average temperature stands at 15°C, with peak temperatures of 30-40°C in the months of July and August (WorldBank, 2022). Besides temperature, most of the rain and snowfall happens between November and March, with the highest concentration – around 75-80% of precipitation – being observed in January, reaching levels of 160-180 mm per month. The remaining 20 to 25% of rainfall occurs during autumn thunderstorms and spring showers. But, the rising impacts of climate change, which include rising temperatures and increased water scarcity; is expected to adversely influence agricultural yields and overall community well-being (MoE/UNDP/GEF, 2022). Furthermore, The Second National Communication Strategy submitted to the UNFCCC, highlighted that the Bekaa valley in Lebanon has been identified as being at significant risk from the effects of climate change. In other words, this Mediterranean region is projected to experience a rise in temperatures of 2 °C and a reduction in rainfall ranging from 10% to 20% by the year 2040 when compared to current conditions. Ultimately this will result in drier and warmer weather patterns. Unfortunately, all these adverse climate-related factors are anticipated to have a substantial negative impact on cereal production in Lebanon (UNDP/MoE, 2011). In brief, the wheat harvest in the Mediterranean is primarily influenced by the amount of rainfall it receives, however temperature also plays a role. The most detrimental impact on wheat cultivation arises from reductions in spring rainfall. The Bekaa plain characterized by a frequent decrease in spring precipitation, is particularly susceptible to these effects. A mere 1°C increase in temperature leads to a substantial 13% decrease in wheat yields. However, it's worth noting that elevated temperatures during autumn months can mitigate the risk of frost (Verner et al., 2018).

2.1.6 Prima and Cereal Med

In 2009 the FAO reported that the global demand for wheat is projected to reach around 840 million tons by 2050, a significant increase from the current output of 642 million tons. However, this estimate does not account for animal feed and fails to consider the adverse effects of climate change on wheat cultivation. To meet this demand, developing nations must increase their wheat production by 77%, with over 80% of the necessary increase achievable through vertical expansion (FAO, 2009).

Against this backdrop, the European Union launched a collaborative initiative called PRIMA, 'Partnership for Research and Innovation in the Mediterranean Area' in 2018. Their primary goal of promoting sustainable agriculture, ensuring food security, and improving water management practices across the entire Mediterranean region.
PRIMA serves as a dynamic platform that unites nations from both the northern and southern Mediterranean shores. This platform fosters research and innovation endeavours, aimed at collectively tackling shared challenges and establishing enduring solutions (EC, 2016). A notable project within the PRIMA framework is the 'Cereal Med Project'. This initiative is dedicated to harnessing the potential of cereal crops to strengthen food security in the Mediterranean region. The project is dedicated to advancing research and innovation in cereal production, cultivation techniques, and pest management, all with the aim of boosting agricultural productivity throughout the Mediterranean. While its primary focus is on wheat, it also explores the feasibility of lentils and chickpeas as potential rotational or companion crops. Additionally, the project

advocates for the revitalization of ancient grain varieties and cultivated counterparts of tetraploid wheat, as well as untamed wild species that could serve as valuable sources of genes and alleles resistant to pests, resilient against environmental stresses, and possessing essential nutritional attributes. Moreover, this initiative aims to effectively utilize the extensive expertise, genetic resources and phenotypic data generated by collaborating research organizations. By embracing sustainable and environmentally friendly practices, the project strives to increase cereal yields while conserving natural resources and preserving the delicate balance of the Mediterranean ecosystem. Ultimately the Cereal Med project was executed from May 20, 2020 to May 20, 2023, with the aim of not only improving food security, but also enhancing the overall sustainability and resilience of agricultural systems in the Mediterranean region (*CerealMed - Enhancing diversity in Mediterranean cereal farming systems*, n.d).

2.2. Taxonomy & wheat varieties

2.2.1 Wheat as a grain genus

"Triticum" is the genus for all wheat species, and it derives its name from the Latin term 'Tero,' signifying threshing. Historically (no longer accepted), the species label for bread wheat was *Triticum vulgare*, with 'vulgare' highlighting its commonness. Nowadays, four pivotal cultivated wheat species dominate global agriculture. The foremost of these is bread wheat, scientifically identified as *Triticum aestivum*. This species, characterized by its hexaploid featuring genomes A, B, and D, constitutes over 90% of worldwide wheat cultivation. However, despite its name, bread wheat finds application beyond bread-making, extending to pasta production in specific regions (Khan & Shewry, 2016).

Following closely is the tetraploid wheat, *Triticum durum*, anciently recognized as *Triticum turgidum*. This wheat species is often referred to as macaroni wheat; it possesses genomes A and B and plays a vital role in pasta manufacturing. However, among the less commonly cultivated species are *Triticum monococcum,* an ancestral diploid variety also known as emmer wheat, and *Triticum turgidum*, also recognized as Georgian wheat. The former is primarily grown in parts of Yugoslavia and Turkey, while the latter occupies limited cultivation areas, primarily found in Russia (Feldman & Sears, 1981). Lastly, Choudhary et al. (2021) declare the Taxonomic hierarchy of wheat in Table 2.

Table 2.Taxonomical classification of wheat.
Source: (Choudhary et al., 2021)

Taxonomical rank	Taxon
Kingdom	Plantae
Division	Magnoliophyta
Class	Liliopsida
Order	Cyperales
Family	Gramineae/Poaceae
Subfamily	Pooideae
Tribe	Triticeae
Genus	*Triticum*
Species	*Aestivum*
Common name	Wheatgrass

2.2.2 Wheat of today

Currently, wheat varieties are classified and organized through various methods. Initially, they are distinguished between hulled and free-threshing wheat. Among these, hulled wheat comprises the ancestral wheat varieties. Examples of hulled varieties include einkorn, emmer, and spelt. These traditional variants are commonly cultivated in isolated mountainous regions, where they are acknowledged for their ability to thrive in harsh weather conditions, low fertility soils, and weed infestations, particularly during their seedling stage. Emmer wheat holds significant importance as a crop in the central and northern highlands of Ethiopia, and it persists in small areas of India, Turkey, Italy, and Iran. Einkorn, similarly, is still sown in challenging conditions in countries such as France, Italy, India, Turkey, and Yugoslavia. On a different note, spelt is garnering interest in Europe, particularly in Germany and Switzerland, where there is an increasing demand for traditional products like specialty bread and wheat beers.

On the other hand, free-threshing wheats, also referred to as naked wheat, encompass both tetraploid and hexaploid wheat species. These types are extensively employed for mass wheat production globally. They are frequently sorted based on distinct characteristics such as seed coat color (red and white), endosperm texture (hard and soft), dough strength (strong and weak), and sowing season (winter and spring) (Khan & Shewry, 2016).

2.2.3 Classes and their use

There are five distinct classes of wheat, each used in the production of specific goods. Hard Red Winter (HRW) wheat constitutes 40% of total production and is primarily employed in bread-making. Its versatility extends to all-purpose flour, making it an excellent choice for crafting Asian noodles, hard rolls, flatbreads, and cereals. Hard Red Spring (HRS) wheat, constituting 25% of total production, is noted for its high protein content, adding value to flour blends and being well-suited for hearth breads, rolls, croissants, bagels, and pizza crust. Soft Red Winter (SRW) wheat, due to its low protein content, finds its use in creating cakes, cookies, crackers, pretzels, and flatbreads. White wheat, encompassing both winter and spring varieties, is selected for its application in cakes, pastries, Asian-style noodles, and Middle Eastern flatbreads. Lastly, Durum wheat, known for its hardness, is specifically utilized in pasta production (Hildebrand, 2023; USDA). Figure 5 illustrates the protein ranges and hardness data of wheat seeds providing insight into their potential applications.

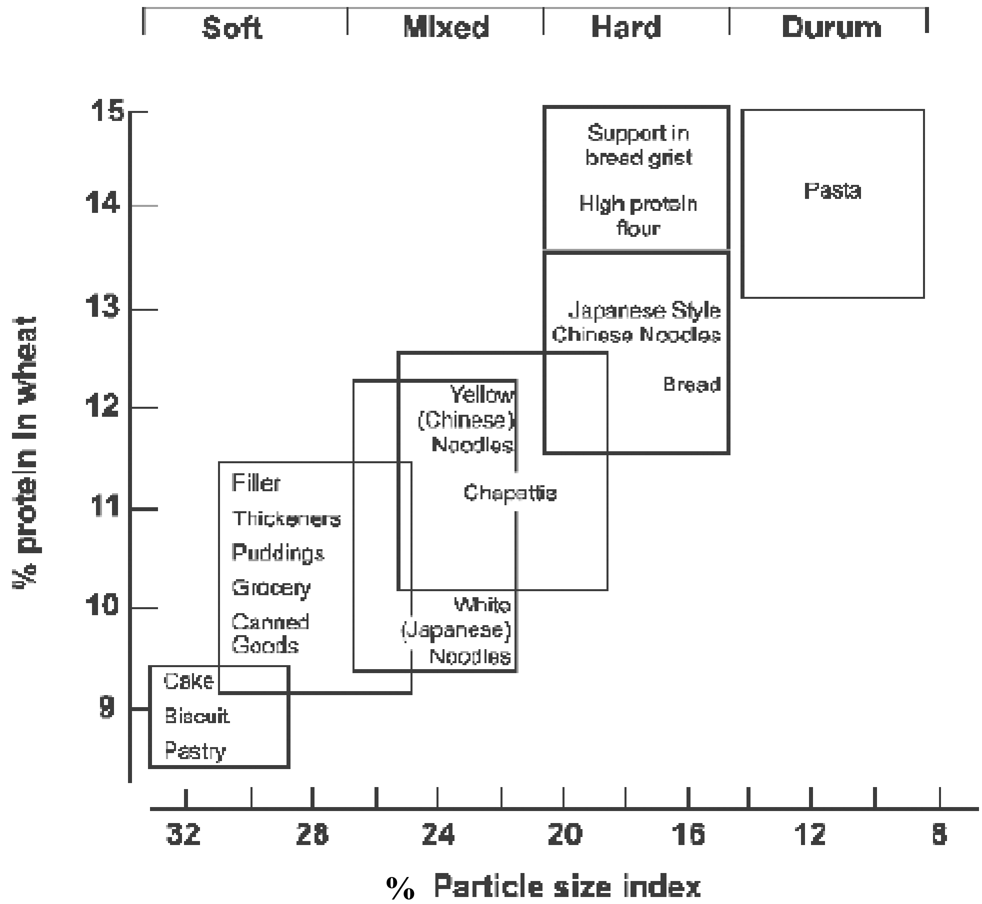

Figure 4. Types of wheat required for the diverse uses of wheat.
Source:(O'Brien & Blakeney, 1985).

2.3. Agronomy

2.3.1 Seedbed preparation

Wheat can be introduced into soil using a variety of soil preparation techniques. One of the intensive approaches involves completely overturning the soil using plows or disks, followed by secondary cultivation using different types of tools like tines, harrows, or disks. On the opposite end of the spectrum, there are minimal-disturbance methods like zero-tillage; where the seed is placed in a groove within the undisturbed soil left after the previous crop's harvest. Choosing the best soil preparation method depends on factors such as soil characteristics, timing and available time, rainfall, equipment, labor, and fuel availability, potential soil erosion, as well as the need to manage weeds, pests, and diseases. Ideally, tillage practices are done to insure intimate contact between the seed and soil to facilitate water imbibition for germination and to assist in the accurate placement of seed at optimum depth (Khan & Shewry, 2016).

2.3.2 Sowing methods & seed depth

Using the correct sowing methods ensures the prompt development of a healthy wheat crop in its early stage with a robust root system. Moreover, this approach guarantees an ideal plant density within the field by enhancing the availability of resources such as moisture, sunlight exposure and nutrient absorption (Gul et al., 2015; Harishankar & Tomar, 2017; Sharma et al., 2015). Sowing techniques encompass a range of options including different types of drilling methods (such as seed drills or ferti-seed drills), dibbling, or broadcasting (by hand or utilizing equipment that spans from handheld seed spreaders to sizable pneumatic fertilizer spreaders). These methods are then typically followed by a gentle harrowing process (Khan & Shewry, 2016). When it comes to depths it commonly varies from 0.25 to 0.1 cm. For temperate and moist conditions, the optimal depth is approximately 0.3 cm. However, in drier conditions or environments with high predation pressure, or to mitigate the phytotoxic effects of residual herbicides, deeper planting is preferred (Rebetzke et al., 2007).

2.3.3 Seed treatment

Prior to planting, it's typical to treat wheat seeds with fungicide and/or insecticide. These substances are commonly formulated as liquid concentrates or solutions, which are then either sprayed onto the seeds or mixed with them. The majority of common fungicides belong to the carboxamide, triazole, cyanopyrole, and guanidine families. These chemicals are primarily utilized for controlling wheat smut (*Septoria spp.*), wheat blotch (*Ustilago nuda*) and powdery mildew (*Blumeria graminis*) (Khan & Shewry, 2016). Other copper-based compounds are often used to cleanse the seed surface of external threats and to provide protection against wheat bunt (*Tilletia tritici*) and various Fusarium species (Yarham, 1994).

2.3.4 Seeding rate

The amount of wheat seeds planted per unit area typically varies due to the influence of multiple factors. In cases of poorer seedbeds or diminished seed viability, higher seeding rates are necessary (Khah et al., 1986). Conversely, raising seeding rates without thoughtful evaluation can result in dense canopies forming. This makes plants more vulnerable to diseases and creates strong competition between them, resulting in weaker and taller stems that are highly prone to lodging (Gooding & Davies, 1997). Studies indicate that a seeding rate of 100 kg/ha through drilling is more effective than higher rates (175-200 kg/ha) through broadcast.

2.3.5 Sowing time

The timing of planting is fundamentally influenced by the climate and the requirements of crop rotation. In regions situated at higher altitudes, characterized by cooler summers that permit an extended growing period, crops intended for autumn sowing are commonly planted beforehand. For instance, in northern areas such as Canada, Europe, the United States, Russia and Japan, a significant quantity of winter wheat is typically put into the ground during the months of August and September, whereas spring wheat finds its place in the soil during April and May. In Western Europe, the favored period for winter wheat planting falls between late September and October, with the harvesting phase occurring in the ensuing months of July and August (KHAN & SHEWRY, 2016). In Lebanon, a different scenario unfolds where most farmers opt exclusively for winter wheat cultivation. This choice arises from the scarcity of water, compelling them to rely on rain-fed or supplementary irrigation methods. The bulk of the wheat crop is sown from late October to early December, capitalizing on the replenishment of soil moisture brought by seasonal rainfall. For the harvest season in Lebanon, it takes place from mid-June till mid-July (FAO, 2022).

CHAPTER 3

METHODOLOGY

A field experiment was conducted at the Advancing Research Enabling Communities Center (AREC) of the American University of Beirut in the Beqaa plain. The growing season extended from fall of 2022 until late spring of 2023. The experiment was designed to provide field information on the performance and attributes of 14 wheat varieties within the specific agro-climatic conditions of Lebanon. Therefore, the comparative analysis of these different wheat cultivars evaluates their adaptability and performance under local conditions, specifically focusing on growth, yield, and production characteristics.

3.1. Plant material

The genetic material analyzed, consisted of a total of 14 durum wheat cultivars. Eleven of these cultivars were initially chosen by the CerealMEd project and were obtained from Dr. Sherif El-Areed at the University of Ben-Suef in Egypt, a partner of the PRIMA project. These cultivars were then sent to the American University of Beirut for assessment. Additionally, two more durum wheat cultivars (Icaverve, Margherita) with great potential for distribution to farmers in Lebanon were obtained from ICARDA/LARI. Furthermore, an important Italian variety (Demantillo) commonly planted in Lebanon has been included in the experiment. Table 3 displays a list of the various wheat cultivars used in this experiment.

Table 3. List of wheat cultivars used in this experiment.
Source : (Rajab, 2023).

No.	Wheat Cultivar
1	ANTALIS-CHECK
2	IRIDE-CHECK
3	MARCO_AURELIO-CHECK
4	MONASTIR-CHECK
5	SARAGOLLA-CHECK
6	SVEVO-CHECK
7	ESDCB-2015/2016-82
8	IDSN46-7010
9	MIKI3
10	7 BENI-SUEF
11	SOHAGE 5
12	MARGHERITA
13	ICAVERVE
14	DEMANTILLO

3.2. Site location & climate profile

The experiment was performed at AREC, situated in the center of the Bekaa Valley, the village of Hauch-snied (33°55'N, 36°04'E, 998 m a.s.l.) during the 2022/23 growing season (*Google earth*). The AREC area is hot and dry in summer, cold in winter, with most of the precipitation falling between November and April. Due to its semi-arid to continental environment it is characterized by irregular rainfall (500mm) and frequent droughts (Halwani & Halwani, 2022). Weather data was recorded using the Campbell Scientific Weather Station model CR1000 at AREC. The total precipitation from rain that the wheat plants received during the growing season was approximately 474.8 mm (Figure 6). The highest temperature reached 37.42°C in July and the lowest temperature reached -4.518°C in February.

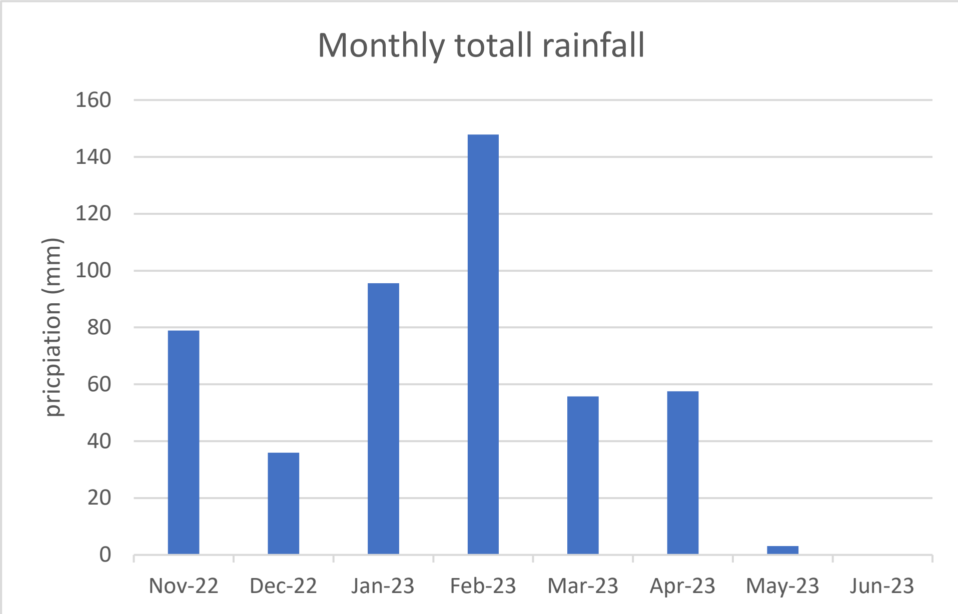

Figure 6. Monthly cumulative rain precipitation throughout the season.

3.3. Experimental design

The experiment conducted was set in a completely randomized design (CRD) in three replications. The total area of the field was 3836 m^2mdivided into 3 equal blocks. Blocks were separated by 3.6m aisles. Each block had 14 plots where the area of each plot was 17.4 m^2 (5.8 m length x 3 m width). The total planted area consisted of 42 plots and covered an area of 730.8 m^2 (14 varieties x 3 replicates). Within the same block was a 2m pathway between each plot. Each plot consisted of 14 rows distant 40 cm apart. Figure.7 describes the plot layout, giving insight on field measurements and the distribution of different treatments (cultivars). Also, Figure 8 displays a satellite image captured by Google Earth, last updated on April 20, 2023.

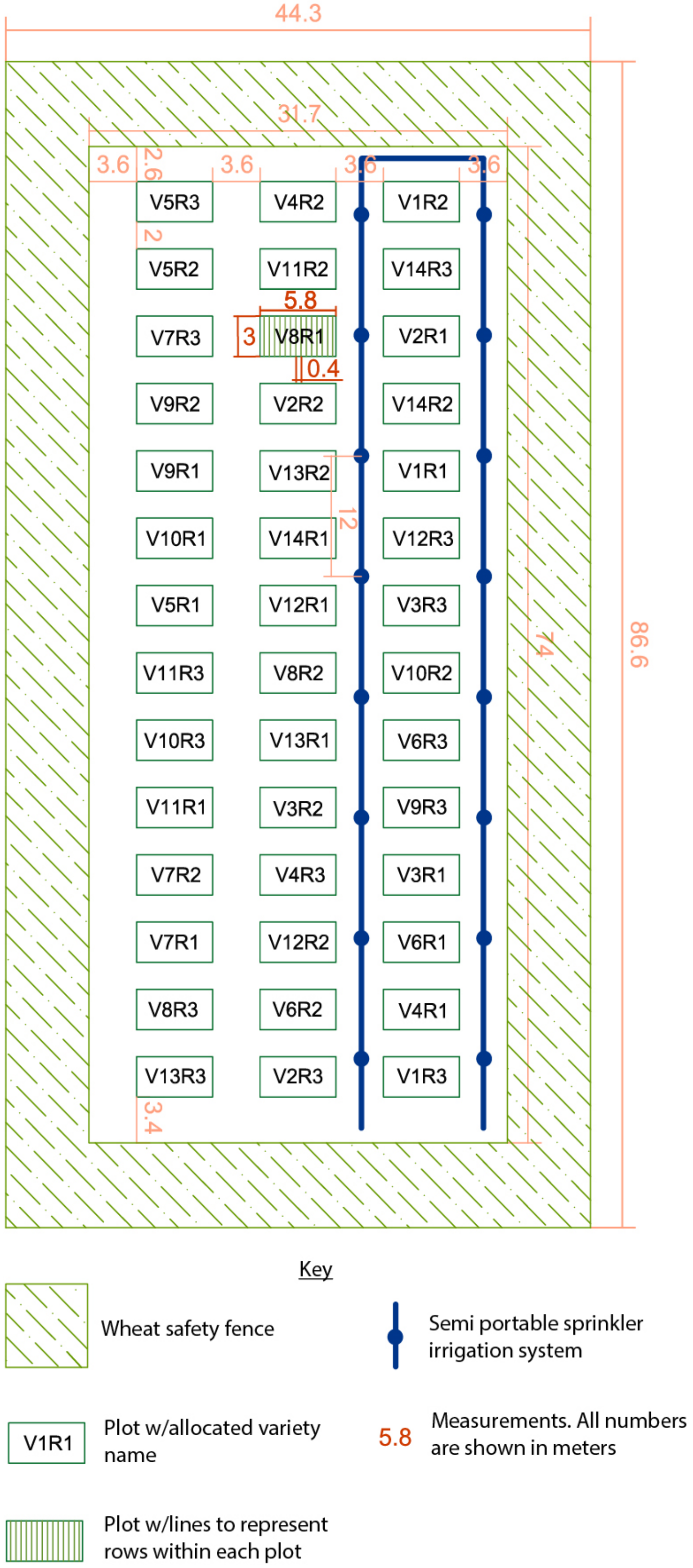

Figure 7. Experimental field layout.

Figure 5. Satellite view of the field experiment-AREC.
Source: (*Google earth*).

3.4. Soil analysis & fertilization.

3.4.1 Sampling and laboratory analysis

Before planting, a composite soil sample was collected from the field by gathering soil cores randomly at a 15 cm depth. These cores were selected following a zigzag pattern, and a composite sample was formed from 20 different sampling points. Analysis was conducted for soil texture, pH, electrical conductivity (EC), available sodium, available potassium, available phosphorus, free calcium carbonate percentage (CaCO3%) and organic matter. Also for the availability of sodium, potassium, phosphorus and micronutrients such as iron, zinc, copper and manganese (Table 4).

Table 4. Summary of soil analysis.

Parameters	Results	Method/instrument used
Soil texture	Clay	Bouyoucos method
Sand	2.56	
Silt	25	
Clay	72.44	
EC 2:1	561 µc/cm	EuTech CyberScan Con 11
PH	7.24	EuTech CyberScan Ph11
Na	88 mg/Kg	Flame Photometer BWB technologies
K	580 mg/kg	
P	40 mg/kg	Oslen method
Free CaCO3	8%	HCl;NaOH titration
Fe	12.25 mg/kg	DTPA Extraction/Atomic Absorption Spectroscopy
Zn	1.05 mg/kg	
Cu	2.55 mg/kg	
Mn	78.25 mg/kg	
% Organic matter	3.75%	Walkley-Black Wet Combustion

3.4.2 Chemical fertilizers used.

Two inorganic fertilizers were used throughout the growing season:

1. NPK 15:15:15, produced in Vietnam. Applied one week prior to sowing by hand at a rate of 100kg/ha.

2. Granular Urea fertilizer 46%Nitrogen, produced in Russia. Applied by hand at the Feekes 6 stage at a rate of 200kg/ha.

3.5. Seed Treatment

Seeds were soaked in a suspension of copper oxychloride (85%W/W) at a rate of 2g/L of water for a period of 1 hour and then left to dry (Figure 9).

Figure 9. Seed treatment with copper oxychloride.

3.6. Land preparation

Land preparation began with the use of a two-way plow equipment for primary tillage. This was followed by secondary tillage using a tandem disk harrow to break down larger clods. In the final stage, the beds were prepared with a Zahle plow (furrow opener) at a depth of 5 cm.

3.7. Sowing of seeds

Seeds were sown on December 8, 2022. They were broadcasted by hand in bands within the rows at a rate of 173 kg/ha at a depth of 2-3 cm. Each plot, which measured 17.4 m^2, had been sown with 300 g of wheat seeds. After distributing the seeds by hand, the rows were covered.

3.8. Supplementary Irrigation

During the growing season, two supplemental irrigation sessions were conducted, with the first one on February 29, 2023, and the second on May 15, 2023, providing a total of 84 millimeters of water to the crops. The irrigation system in use was a portable sprinkler setup with a peak flow rate of 1.9 cubic meters per hour when operating at a pressure of 4 bars. At this pressure level, each individual sprinkler dispensed 12 millimeters of water per hour. Specifically, the sprinkler model employed was the Rain Bird 14070H, a ¾-inch (19mm) full-circle, brass impact sprinkler. Concerning the spacing of lateral lines, they were positioned at intervals of 12 meters by 12 meters, and the total count of sprinklers in use was 16.

3.9. Management

3.9.1 Weeding

At Feeks 8 and 10.1, weeds and volunteer's crops were removed by hand within plots, while a rotary tiller was utilized along the field pathways to ensure the complete elimination of weeds, as shown in Figure 10.

Figure 10. Mechanical weed management between the plots by the rotary tiller.

3.9.2 Bird control

For bird control, various methods were implemented from the flowering stage until ripening, starting on June 5th and continuing until harvest.

1. Planting wheat crops as a buffer zone around the experimental plot (5 m wide).
2. Employing workers who walk in the field with noise-producing cans to scare out the birds.
3. Utilizing reflective scare tape.
4. Installing one big scarecrow.
5. Employing solar-powered devices that emit sounds to repel incoming birds (Figure 11).

The first solar device was an ultrasonic bird repeller with a motion sensor (effective at 180°) that deters pest birds using sound frequencies. It is equipped with a battery for use during nighttime. The second device consists of a metal oil gallon, a motor connected to a metal wire that produces noise when the motor is active due to the impact of the metal gallon and the metal wire. It incorporates a solar panel (12V, 6W).

Figure 11. Images of hand-made solar bird repellent devices.

3.10. Data collection

The data collection encompassed various parameters, including plant height (measured at three distinct time points with 20-day intervals, with a sample size of n=30), the number of tillers (n=30), spike count per square meter, grain weight per square meter, thousand-grain weight, and hay dry weight per square meter. Figure 12 and Figure 13 depict the collection of spikes and hay. To measure spike count and hay dry weight, we employed a 1x1 meter metal frame. The dry weight of hay per square meter was determined by cutting all the straw from the soil surface, which was subsequently air-dried for a period of 30 days. Determination of grain weight per square meter involved threshing the collected ears, while the thousand-grain weight was determined following a count of 1000 seeds. Ears were threshed using an *Almaco SBT small bundle seed thresher*. The clean seeds obtained were weighed and recorded as the grain weight per square meter. Furthermore, the harvesting index was calculated using this formula:

$$HI\% = \frac{Grain\,Yeild}{Biological\,Yeild\;(Grain + Straw)}\,x\;100$$

Finally, to determine grain quality a proximate analysis was done using the *NIRS DS2500*. The analysis included moisture, protein, fat, crude fiber, ash, and starch.

Figure 12. Cutting spikes of wheat.

Figure 13. Collected spikes and hay.

3.11. Statistical analysis

Statistical analyses were conducted using IBM SPSS Statistics 25. The experimental design employed in this study was a Completely Randomized Design (CRD). To compare the means of cultivar parameters, a one-way ANOVA (analysis of variance) was initially performed. Subsequently, a Tukey test was applied for post-hoc mean separation. Significance levels were set at $\alpha = 0.05$, which corresponds to a confidence level of 95%.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter presents and discusses the results obtained from the field experiment. The findings obtained are organized into three sections, each of which will be discussed and interpreted in depth. The first section presents the statistical findings related to the agronomic traits, productivity, and yield for the 14 wheat cultivars. The second section explores the proximate composition of the different wheat grain cultivars, providing valuable insights on grain quality and composition. The final section discusses our research findings with existing literature, with a particular focus on the wheat cultivars for which comprehensive data are available. It is essential to acknowledge that our discussions/comparisons are confined to these specific 14 varieties which were included in this study.

4.1. Plant characteristics, productivity, and yield

Table 5 displays data for 14 wheat cultivars, presenting two key parameters: the average plant height at three specific time points: 90 days after planting (90 DAP), 110 DAP, and 130 DAP. The second parameter pertains to the average number of tillers per plant (n=30). At 90 DAP, the results did not reveal any statistically significant differences in mean plant height among the various cultivars. Margherita [12] and Miki3 [9] exhibited the highest and lowest mean heights, measuring 25.4 cm and 22.9 cm, respectively. Despite these variations, the lack of statistical significance suggests that the observed differences may be due to variations among treatments. In contrast, at 110 DAP, the mean plant height exhibited notable variations among the cultivars. Monastir [4] stood out with a significantly higher mean height of 55.3 cm, a statistically significant difference when compared to Iride [2], Miki3 [9] and Margherita [12]. These differences are indicative of distinct genetic and environmental influences on plant growth at this stage of development. At 130 DAP, Monastir continued to dominate with a significantly taller mean height of 78.3 cm compared to Margherita, which measured 70.8 cm. Over the course of the growth season, Monastir proved to be the tallest plant in the study, as evidenced by the observed considerable difference, whilst Margherita continually displayed the shortest stature after being the tallest in early stages of growth (90DAP) . These results emphasise the dynamic character of wheat growth, stressing the unique responses of cultivars at various phases and stressing the significance of environmental and genetic factors in dictating plant height. Additionally, Table 5 reveals a significant difference in the mean number of tillers per plant, with the cultivar Antalis [1] recording 4.2 tillers per plant, significantly higher than Saragolla [5], which exhibited 3.1 tillers per plant. It's noteworthy that this significance was observed exclusively between these two cultivars, representing the highest and lowest values in terms of tiler count.

Table 5. Mean crop height (CH) in cm on a 20-day interval and number of tillers per plant (TPP at 90 days) for the different wheat cultivars (n=30).

No.	Genotype/Cultivars	CH			TPP
		DAP			
		90	110	130	90
1	ANTALIS-CHECK	23.6	50.6^{ab}	75.0^{ab}	4.2^{a}
2	IRIDE-CHECK	23.3	48.7^{a}	72.2^{ab}	3.9^{ab}
3	MARCO_AURELIO-CHECK	24.1	49.9^{ab}	72.2^{ab}	4.0^{ab}
4	MONASTIR-CHECK	25.1	55.3^{b}	78.3^{b}	4.0^{ab}
5	SARAGOLLA-CHECK	25.1	50.2^{ab}	72.5^{ab}	3.1^{b}
6	SVEVO-CHECK	24.3	50.4^{ab}	72.0^{ab}	4.2^{ab}
7	ESDCB-2015/2016-82	24.1	52.3^{ab}	76.6^{ab}	3.2^{ab}
8	IDSN46-7010	24.9	49.8^{ab}	71.7^{ab}	3.8^{ab}
9	MIKI3	22.9	48.2^{a}	71.0^{ab}	3.4^{ab}
10	BENI-SUEF7	24.1	50.0^{ab}	73.0^{ab}	3.6^{ab}
11	SOHAGE 5	25.2	52.5^{ab}	71.0^{ab}	3.2^{ab}
12	MARGHERITA	25.4	48.1^{a}	70.8^{a}	3.6^{ab}
13	ICAVERVE	25.0	51.2^{ab}	74.8^{ab}	3.5^{ab}
14	DEMANTILLO	24.4	49.3^{ab}	73.8^{ab}	4.2^{ab}
	*SEM**	*0.20*	*0.39*	*0.47*	*0.085*

CH: crop height; TPP: tillers per plant; DAP: days after planting

a,b Means in a column with different alphabetical superscripts are significantly different (p<0.05).

**SEM = Standard Error of the Mean*

Table 6 presents the remaining agronomic and production parameters for the 14 wheat cultivars. These parameters include the mean of spikes number square/m^2, grain yield/m^2 (Economic yield), the dry weight of hay/m^2 (Biological yield), and the calculated harvesting index. Notably, for the parameters related to the number of spikes, grain yield, and hay yield, there were no statistically significant differences observed among the wheat varieties, suggesting similar production capacities across these cultivars. However, it is worth noting that the observed variations in means may be attributed to factors beyond genotypic differences.

Upon closer examination of the harvesting index data within the table, substantial disparities become apparent, providing valuable insights into the production characteristics of these wheat cultivars. The highest recorded harvesting index, at 46.3%, was achieved by the Iride cultivar [2], demonstrating a statistically significant distinction from the Margherita variety [12] with a harvesting index of 39.6%. Notably, the lower harvesting index of Margherita is accompanied by the lowest grain weight per square meter (369.6g/m^2). In contrast, the ESDCB-2015/2016-82 cultivar [7] exhibited the highest grain yield, reaching 480.9g/m^2, which corresponds to an estimated production of approximately 4.8 tons per hectare. Additionally, the Beni-Suef cultivar [10] displayed the highest number of spikes per square meter (437) and the greatest hay yield per square meter (691.2g). However, it yielded the second-lowest harvesting index (39.7%), potentially due to a relatively lower number of grains per spike. These findings shed light on the diverse production characteristics of the wheat cultivars and underscore the significance of the harvesting index as an indicator of grain yield efficiency in the context of broader agronomic and production parameters.

Table 6. Mean of spike number, grain yield, hay yield, and harvesting index in different wheat cultivars (n=30).

No.	Genotype/Cultivars	SN/m²	Y(g/m²)	HY(g/m²)	HI %
1	ANTALIS-CHECK	397.0	467.6	634.5	42.2[ab]
2	IRIDE-CHECK	372.3	463.3	540.0	46.3[b]
3	MARCO_AURELIO-CHECK	371.7	467.9	627.9	42.7[ab]
4	MONASTIR-CHECK	396.3	419.0	572.6	42.1[ab]
5	SARAGOLLA-CHECK	381.0	458.3	543.1	45.6[ab]
6	SVEVO-CHECK	321.0	420.4	602.7	41.1[ab]
7	ESDCB-2015/2016-82	347.0	480.9	618.0	43.8[ab]
8	IDSN46-7010	381.0	475.0	554.6	46.1[ab]
9	MIKI3	246.3	397.7	559.9	41.4[ab]
10	BENI-SUEF7	437.3	454.9	691.2	39.7[ab]
11	SOHAGE 5	399.7	426.1	636.4	40.1[ab]
12	MARGHERITA	398.0	369.6	561.9	39.6[a]
13	ICAVERVE	400.0	429.3	556.9	43.7[ab]
14	DEMANTILLO	383.7	390.9	589.0	40.0[ab]
	SEM	12.43	9.02	10.44	0.50

SN: spike number; Y: grain yield; HY: Hay yield; HI: Harvesting index.
[a,b] *Means in a column with different alphabetical superscripts are significantly different (p<0.05).*
[*] *SEM = Standard Error of the Mean*

4.2. Grain quality and composition

In Table 7, the highest thousand kernel weight (TKW) was observed at 52.5g for the Saragolla cultivar [5] at a moisture level of 10.1%. In contrast, Monastir [4] exhibited the lowest TKW at 40.5g, with a moisture level of 9.1%. Notably, Antalis [1], Marco Aurelio [3], Monastir [4], Svevo [6], and Icaverve [13] exhibited protein percentages within the range of 13% to 13.4%. Among these, Antalis [1] had the highest protein percentage (13.4%) and the lowest fat percentage (1.88%), while Beni-Suef [10] had the lowest protein percentage (12.0%) and the highest fat percentage (2.36%). The percentage of fibre in these wheat cultivars ranged from 2.18% to 2.48%, and the percentage of ash fell within the range of 1.26% to 1.44%. Starch percentage varied between 65.9% and 63.3%, with the ESDCB-2015/2016-82 [7] having the highest starch percentage.

Table 7. Thousand kernel weight (TKW) and proximate analysis of various wheat cultivars.

No.1	Genotype/Cultivars	TKW(g)	M%	P%	F%	CF %	A%	S%
1	ANTALIS-CHECK	45.8	9.8	13.4	1.88	2.43	1.44	63.4
2	IRIDE-CHECK	44.3	9.4	12.5	2.07	2.45	1.32	64.3
3	MARCO_AURELIO-CHECK	45.7	9.5	13.03	2.10	2.48	1.39	64.3
4	MONASTIR-CHECK	40.5	9.1	13.2	2.15	2.44	1.32	63.7
5	SARAGOLLA-CHECK	52.5	10.1	12.5	2.07	2.35	1.38	64.4
6	SVEVO-CHECK	45.6	9.3	13.12	2.10	2.29	1.39	63.6
7	ESDCB-2015/2016-82	48.7	9.9	12.6	2.05	2.37	1.29	65.9
8	IDSN46-7010	45.8	9.4	12.5	2.05	2.36	1.39	63.9
9	MIKI3	45.6	9.8	12.5	2.04	2.36	1.34	63.9
10	BENI-SUEF7	45	9.3	12.0	2.36	2.25	1.29	64.3
11	SOHAGE 5	47.6	9.8	12.5	1.96	2.40	1.28	63.7
12	MARGHERITA	46.9	9.1	12.2	2.12	2.18	1.27	65.0
13	ICAVERVE	48.0	9.4	13.0	2.00	2.42	1.40	63.3
14	DEMANTILLO	47.5	9.6	12.1	2.09	2.18	1.26	65.0

TKW: thousand kernel weight; M%: moisture percentage; P%: protein percentage; F%: fat percentage; CF%: crude fiber percentage; A%: ash percentage; S%: starch percentage.

4.3. Comparison with Previous Studies

This section discusses and compares the results of this paper with other findings, focusing on the understanding of non-genotypic factors' impact on the performance of these varieties. It is important to note that a few varieties have not been thoroughly analyzed due to limited data.

4.3.1. Saragolla:

During the 2015-2016 growing season in Mosciano Sant'Angelo, Italy, Calzarano et al. (2018) observed that the Saragolla cultivar yielded 5.5 t/ha. This represented a notable one-ton increase compared to the calculated yield of Saragolla in our experiment, which was 4.5 t/ha (Calzarano, 2018). Notably, the same cultivar in Italy, despite its higher yield, produced 255 spikes/m^2, which was lower than the spike number we obtained in our research. This difference in yield might be attributed to differences in TKW which was 71 g in Italy—considerably higher than our findings of 52.5g. Regarding plant height, we found it to be quite consistent with Italy, standing at 72.5 cm in Lebanon and 72 cm in Italy (Calzarano, 2018). However, these production disparities could be influenced by a range of factors such as environmental conditions, soil texture, soil fertilizers and agricultural practices. In Italy, the wheat was fertilized at a rate of 150 Kg N/ha, whereas in our experiment it received 107 kg N/ha, with variations in the timing and type of application. Furthermore, in the following season (2016-2017), Calzarano et al. (2018) found that, after employing consistent agricultural practices but witnessing higher rainfall (650 mm), there was a different outcome: the yield dropped to 3.3 T/ha. This result not only contrasts with the previous season but also falls below the calculated yield we obtained in our experiment.

4.3.2. Iride:

In a study by Bentivenga et al. (2020), Iridae cultivar was subjected to testing for susceptibility to *Fusarium* head blight (FHB) in Reggio Calabria, South Italy. Various parameters were collected during their assessment. Iridae in South Italy was found to yield 4.4 t/ha and had a thousand kernel weight (TKW) of 41.1 grams. Notably, these values were slightly lower than our findings, where Iridae exhibited a yield of 4.6 t/ha and a TKW of 44.3 grams. However, the plant height in South Italy, which averaged 75.3 cm, was slightly higher than in Lebanon, where the height reached 72.2 cm. This difference could be attributed to the distinct amounts of precipitation received in the two regions. In South Italy, the average annual precipitation was 803 mm, significantly higher than in the Bekaa region. It's worth mentioning that the protein content remained consistent at 12.5% (Bentivenga et al., 2020). Given that the same seeding ratio was employed in both experiments, the minor production differences might be linked to variations in nitrogen fertilization. In Italy, the rate of nitrogen used was 82 kg/ha, in our experiment it was 107 kg/ha. Other factors such as temperature, precipitation, biotic factors, and agricultural practices may also contribute to the observed performance differences. Additionally, Bentivenga et al. (2020) confirmed in their study that Iridae and many other cultivars are susceptible to *fusarium* head blight.

4.3.3. Monastir:

In 2018, the company Sanbio collaborated with Kamel Bedwihesch, a local wheat farmer in the City of Béja, Tunisia, to assess the impact of their new fertilizer technology, Sanbio EPSOMIT, on the wheat variety 'Monastir.' The average annual rainfall in Beja was 600 mm. In their study, the sowing ratio was the same (200 kg/ha), but their nitrogen application rate was notably higher than ours (around 230 kg N/ha), along with a higher phosphorus application (around 70 kg P/ha). In their control treatment, we observed an additional yield of 0.6 t/ha compared to our results. This difference in yield may be attributed to variations in fertilizer type and rate, farming practices, precipitation and other environmental factors (Sanbio, 2018).

4.3.4. BeniSuef-7:

Gomaa et al. (2018) reported that the BeniSuef-7 cultivar achieved a grain yield of 545 g/m^2, surpassing our findings of 454 g. The biological yield was also higher at 870 g/m², compared to our 691 g/m². Furthermore, the TKW was 56.34 g, exceeding our results. The only parameter that showed a lower value was the number of spikes/m², which stood at 257.3, lower than our findings of 437.3. In their study, the sowing rate was approximately 166 kg/ha, which was lower than the rate used in our experiment. Additionally, their experiment took place in Egypt in Sharq El Owainat, characterized by sandy soil, in contrast to the clayey soil of the Bekaa plain in Lebanon. Variations in soil physical properties, temperature, precipitation, and agricultural practices could potentially explain the differences in BeniSuef-7's performance between Lebanon and Egypt. Other parameters, such as the number of spikelets/spike and the number of grains/spikelets, are crucial traits that contribute to explaining the performance differences of the same variety in different countries(Gomaa et al., 2018).

4.3.5. Miki3:

Hussain et al. (2022) reported a yield of 2.3t/ha for the Miki3 variety in Iraq, which was lower than our findings where the same variety yielded 3.9t/ha. Additionally, the plants in their study were 16 cm shorter compared to our results. Not only did our research indicate a superior grain yield, but we also observed a slightly higher TKW. These disparities in the performance of the Miki3 variety could potentially be attributed to various environmental factors. Furthermore, differences in agricultural and management practices between the two studies need to be considered. For example, Hussain et al. (2022) used a seeding rate of 120 kg/ha, while we planted 200 kg of seeds

/ha. Moreover, their application of nitrogen fertilizer totaled around 55 kg/ha, which may have influenced the outcomes when compared to our study (Hussain et al., 2022).

4.3.6. Antalis, Marco Aurelio and Svevo:

In their study Tavoletti and Merletii (2022) observed that the varieties Antalis, Marco Aurelio, and Svevo in Italy yielded 6.21 t/ha, 6.29 t/ha, and 5.46 t/ha, respectively. These three varieties outperformed our findings. This could be due to high rainfall between September and December 2019 (256mm) which delayed planting till January 22, 2020. The nitrogen application rate was 180 kg/ha. Moreover, they recorded higher protein percentages for this season, with Antalis at 12.8%, Marco Aurelio at 14.7%, and Svevo at 14.2%. These percentages also surpassed our results (Tavoletti & Merletti, 2022). Consequently, these varieties exhibited superior performance in Italy compared to our region, potentially due to various environmental factors such as temperature, rainfall, and soil type. This enhanced performance in terms of both yield and protein content can be attributed to the nitrogen application received by the plants. Bole and Dubetz (1986) found that in Canada for every additional ton per hectare of the producer's target yield, nitrogen rates can be increased by approximately 30 kg/ha.

4.3.7. Margherita and Icaverve:

These varieties, developed by the International Center for Agricultural Research in the Dry Areas (ICARDA), underwent testing in 18 different countries. The sowing rate for all countries was set at 140 kg/ha. The Margherita variety exhibited varying yields in each country, as follows: 7.2 t/ha in Lebanon, 5.6 t/ha in Spain, 3.5 t/ha in India, 3.4 t/ha in Jordan, and 2.3 t/ha in both Mexico and Iraq (Bassi & Sanchez-Garcia, 2017). The most surprising result was the impressive 11 t/ha yield of Icaverve in Egypt.

When comparing these results to our findings, Margherita yielded only 3.6 t/ha, surpassing the results obtained in Jordan, Iraq, and India. However, Margherita performed better in Lebanon and Spain. The exceptional performance of irrigated Icaverve in Egypt and supplementally irrigated Margherita in Lebanon features the importance of conducting in-depth studies to better understand the impact of various factors on their growth and development. These factors include Seedbed preparation, planting density, farming practices applied, precipitation, supplementary irrigation, sowing date, weed management, soil type, and fertilizer usage. Finally, researchers found that analysis of variance revealed significant notable impacts stemming from the environment, genetic factors, and the interaction between genetics and the environment concerning traits such as phenology, plant height, grain yield, and grain size. The results showed that genetic factors accounted for 1% of the overall grain yield variation, while the genotype-environment interaction explained a substantial 9.6% of the total variation in grain yield (Bassi & Sanchez-Garcia, 2017).

4.3.8. Sohage 5:

In Biba, Egypt, Eissa et al, (2022) revealed that sowing Sohage 5 seeds in late November, coupled with irrigation at planting and five supplementary irrigations totaling 2,820 m^3, yielded approximately 9.7 t/ha. However, these results raised questions particularly regarding the substantial water usage associated with achieving the 9.7 t/ha (Eissa et al., 2022) . While in Saudi Arabia and Sudan, an estimated 7,000 m^3/ha of water is required to optimize yield, resulting in a range of 7-8 to/ha (Bashour, 2023). In Egypt, the spike count for the Sohage 5 variety was measured at 527 spikes/m^2, and the thousand kernel weight (TKW) averaged 55.87 grams. It is evident that the productivity of this durum wheat variety exceeds our own findings. This disparity could be primarily attributed to differences in irrigation and farming practices.

4.3.9. Demantillo, ESDCB-2015/2016-82, IDSN46-7010:

These three varieties require further investigation to understand their production characteristics in various environments. In particular, the two varieties, ESDCB-2015/2016-82 and IDSN46-7010, which yielded the highest grain output in our experiment, show promising potential for increased productivity in Lebanon and other countries.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

In this study, eleven advanced durum wheat genotypes, including two cultivars (Icaverve and Margherita) sourced from ICARDA, and an imported wheat variety (Demantillo), were rigorously evaluated at the Advancing Research Enabling Communities Centre (AREC) in Lebanon throughout the 2022/2023 growing season. Despite the diversity in genotypes, the analysis of variance revealed no significant differences among varieties for grain yield, hay yield, and spike number. Additionally, the analysis of variance highlighted distinct variations among genotypes in parameters such as plant height, tiller number, and the calculated harvesting index, particularly among specific cultivars. Although statistical significance was not detected, the mean performance indicated that ESDCB-2015/2016-82 and IDSN46-7010 exhibited the highest productivity, with grain yields of 4.8t/ha and 4.7t/ha, respectively. In addition, the comprehensive examination of these durum wheat varieties underlines their suitability for Middle Eastern bread, chapati, and pasta production, given their consistent protein content. Notably, the lack of significant differences in grain and hay yields implies similar economic and biological yield potential for all 14 cultivars. However, the observed performance deviations from existing literature underscore the substantial impact of environmental factors and farming practices, particularly fertilization and supplemental irrigation, on wheat yield.

5.2. Recommendation

Since the results of this field experiment showed that there was no significant difference among the 14 tested genotypes in various collected parameters, it will be early to give recommendation after only one year trial in the field. Therefore, based on these field studies it is recommended that:

- This study should be repeated prior to issuing a definitive recommendation to prospective *Triticum Durum* growers in the Beqaa plain.
- This study should be extended by retesting a few of the highest-yielding varieties. It is recommended to focus on the retesting of ESDCB-2015/2016-82 and IDSN46-7010, as they demonstrated the top two highest yields. Additionally, consider evaluating three other varieties that exhibited good performance in both grain and hay yield: Antalis, Iride, and Marco_aurelio.
- More experiments should be conducted to explore the optimal timing of supplemental irrigation, specifically during the grain filling period, which has the potential to enhance yield.
- Further investigation is required to assess the protein quality of these varieties, as it significantly influences baking quality and dough strength.

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