ABANT IZZET BAYSAL UNIVERSITY

THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

COLD, DROUGHT, AND SALT TOLERANCE LEVELS OF SOME SPECIES AND VARIETIES OF WHEAT

(*Triticum turgidium*)

MASTER OF SCIENCE

DİDEM ASLAN

BOLU, JULY 2017

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APPROVAL OF THE THESIS

COLD, DROUGHT, AND SALT TOLERANCE LEVELS OF SOME SPECIES AND VARIETIES OF WHEAT (*TRITICUM TURGIDIUM*) submitted by **Didem ASLAN** in partial fulfillment of the requirements for the degree of **Master of Science** in **Department of Biology, ABANT IZZET BAYSAL UNIVERSITY** by,

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July 27, 2017

Prof. Dr. Duran KARAKAS ....

Director of Graduate School of Natural and Applied Sciences

To my family

DECLARATION

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Didem ASLAN

ABSTRACT

COLD, DROUGHT, AND SALT TOLERANCE LEVELS OF SOME SPECIES AND VARIETIES OF WHEAT (*Triticum turgidium*)
MSC THESIS
DİDEM ASLAN
ABANT IZZET BAYSAL UNIVERSITY GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF BIOLOGY
(SUPERVISOR: PROF. DR. NUSRET ZENCİRCİ)

BOLU, JULY 2017

Wheat, second the most produced and consumed cereal in the World and in Turkey, is an important crop for both its nutritious and health value. Recently developed technologies has led its use as bio-fuel, too. Wheat production fluctuates a lot since its farming depends on mostly environmental -climatic- factors, acreage per capita decreases because of increased population, and, therefore, is much restricted. Production increase is only possible by higher yield and lower yield losses due to biotic and abiotic factors. Global climate change negatively affect the World by increased human activities. Increased emission gases such as CO_2, CH_4 has caused continuous irreversible natural events. Recent non-seasonal rainfalls and higher temperatures in Turkey are most likely resulted by these climate changes. The abiotic stress due to these changes is one of the main reasons for yield loss in wheat. They seriously decrease yield because of germination period damages. Hence; determining the tolerance of modern and cultivated wild wheat genotypes would be beneficial. The project was studied under laboratory conditions in order to effectively control outer factors. In the study, twelve bread wheat (*Triticum aestivum* L.) cultivars (Gerek-79, İkizce-96, Kıraç-66, Kenanbey, Flamura-85, Momtchil, Bayraktar-2000, Tosunbey, Pandas, Pehlivan, Demir-2000 and Gün-91), and 10 einkorn wheat (*Triticum monococcum* subsp. *monococcum*) populations (Population-1, Population-2, Population-4, Population-5, Population-6, Population-9, Population-10, Population-11, Population-14, and Population-15 were germinated in the growth chambers and tested against different levels of salt, cold, and drought stresses. Against the salt (NaCl), drought and cold stresses, germination rate (GR), germinating power (GP), coleoptile length (CL), shoot length (SL), root length (RL), shoot/root length ratio (SRLR), root fresh weight (RFW), root dry weight (RDW), root fresh weight/root ratio (RFDWR) were measured and/or calculated in a three replicate factorial restricted randomized block design. Wheat cultivars / populations under cold stress significantly differed within themselves and between cold levels. Twelve bread wheat cultivars highly significantly differed for GR, RL, and RDW; significantly for CL and SL; and non-significantly for GP, SRLR, and RFW. The average dendogram resulted in two main groups of both bread and hulled einkorn wheat entries. Seven different drought stress conditions revealed that SL and SRLR were the most sensitive traits and followed by CL and RL. The mean performance of all traits was worsened starting at various drought stress levels, too. The highest decreasing in percent was in SL (100.00%), SRLR (100.00%), and RL (99.07%), and the lowest was in GP (55.9%). The dendogram grouped bread wheat and einkorn wheats into two different groups. The highest GR and GP under salt stress occurred between 0-0.20 M salt, and followed by CL, SRLR, RFW, and RDW between 0-0.15 M, and SL and RFDWR between 0-0.20 M. GR, GP, and RFDWR decreased starting at 0.25 M, and followed by CL, SRLR, RFW, and RDW at 0.20 M, GP and RFDWR at 0.25 M. Pearson linear correlation coefficients for higher sample numbers were significant at various degrees for all values. A significant PC of 0.356 happened for RDW, 0.335 for RL, 0.310 for SRLR, and 0.309 for RFW in PC1. The first three PCs were accounted 90.525% of total variation. The highest of PCs was PC1 (71.946%) and was tailed by PC2 (11.098%), and PC3 (7.481%). The dendogram clearly grouped bread wheat and einkorn wheats into two different groups.

KEYWORDS: Wheat, Einkorn, Cold, Drought, Salt, Stress.

ÖZET

BAZI BUĞDAY (*Triticum turgidium*) TÜR VE ÇEŞİTLERİNİN SOĞUĞA, KURAĞA VE TUZA DAYANIM DÜZEYLERİ
YÜKSEK LİSANS TEZI
DİDEM ASLAN
ABANT İZZET BAYSAL ÜNİVERSİTESİ FEN BİLİMLERİ ENSTİTÜSÜ
BIYOLOJI ANABILIM DALI
(TEZ DANIŞMANI: PROF. DR. NUSRET ZENCİRCİ)

BOLU, TEMMUZ - 2017

Buğday; dünyada ve Türkiye'de en çok üretilen ve tüketilen ikinci sıradaki tahıl olup hem besleyiciliği hem de insan sağlığı açısından önemli bir bitkidir. Yakın zamanlarda geliştirilen teknolojilere bağlı olarak le biyo-yakıt olarak da kullanılmaktadır. Tarımı daha çok çevre-iklim- koşullarına bağlı olduğundan buğday üretimi yıldan yıla dalgalanmakta, artan nüfusla birlikte kişi başına düşen ekim alanları azalmakta ve bu nedenle üretimi sınırlanmaktadır. Üretimi artırmak; verimin artırılması ve canlı ve cansız faktörlerden kaynaklanan kayıpların azaltılması ile mümkündür. Küresel iklim değişikliği; artan insan faaliyetlerinden dolayı, dünyayı sürekli olarak olumsuz etkilemektedir. CO_2, CH_4 gibi gazların artması sürekli geri dönülemez doğa olaylarına yol açmaya devam etmektedir. Türkiye'de son dönemlerde meydana gelen mevsim dışı yağışlar ve yüksek sıcaklıklar büyük olasılıkla iklim değişikliklerinin bir sonucudur. Bu değişikliklerden kaynaklanan cansız stres faktörleri de buğdayda verim kayıplarının ana sebeplerinden biridir. Cansız bu faktörler, verim düşüklüğünü çimlenme döneminde daha çok etkilemektedir. Bu nedenle; modern ve kültüre alınmış buğday genotiplerinin kurağa, soğuğa ve tuza toleranslarının belirlenmesi yararlı olacaktır. Bu çalışma dış koşulların daha iyi kontrol edilebilmesi amacıyla laboratuvarda yürütülmüştür. Çalışmada; Gerek-79, İkizce-96, Kıraç-66, Kenanbey, Flamura-85, Momtchil, Bayraktar-2000, Tosunbey, Pandas, Pehlivan, Demir-2000 ve Gün-91 olmak üzere 12 ekmeklik buğday (*Triticum aestivum* L.) çeşidi ve 10 adet siyez buğdayı (*Triticum monococcum* subsp. *monococcum*); Populasyon-1, Populasyon-2, Populasyon-4, Populasyon-5, Populasyon-6, Populasyon-9, Populasyon-10, Populasyon-11, Populasyon-14 ve Populasyon-15 kurak, soğuk ve tuzlu koşullara karşı iklim dolaplarında çimlendirilmiş ve bu faktörlerin değişik stres düzeylerinde test edilmişlerdir. Çimlenme hızı (ÇH), çimlenme gücü (ÇG), koleoptil uzunluğu (KU), çim boyu (ÇB), kök boyu (KB) çim kök uzunluğu oranı (ÇKUO), kök yaş ağırlığı (KYA), kök kuru ağırlığı (KKA) ve kök yaş kuru ağırlık oranı (KYKAO) ölçülerek ve/veya hesaplanarak 3 tekerrürlü faktöriyel tesadüf blokları deneme deseninde çalışılmıştır. Yedi farklı soğuk stresi altında buğdaylar kendi aralarında ve soğuk düzeylerinde istatistiksel olarak çok önemli farklılıklar göstermişlerdir.

On iki ekmeklik buğday çeşidi ÇH, KU ve KKA bakımından istatistiksel olarak çok önemli; KB ve ÇB bakımından önemli; ÇG, ÇKUO ve KKA bakımından da önemsiz farklılıklar sergilemişlerdir. Öbekağacı siyez ve ekmeklik buğdayları iki ana gruba ayırmıştır. Yedi farklı kuraklık stresi altında en hassas karakterler ÇB ve ÇKUO olmuş onları KU ve KB izlemiştir. Tüm özelliklerin ortalama performansı değişik stres düzeylerinden başlayarak kötüleşmiştir. En fazla düşüş ÇB’de (% 100.00), ÇKUO’da (%100.00) ve KB’de (%99.07), en az düşüş ise ÇG’de (%55.9) gözlenmiştir. Öbekağacı siyez ve ekmeklik buğdayları iki ana gruba ayırmıştır. Tuz stresi altında, en yüksek ÇH ve ÇG 0-0.20 M tuz konsantrasyonunda, en yüksek KU, ÇKUO, KYA ve KKA 0-0.15 M tuz konsantrasyonunda, en yüksek ÇB ve KYKAO ise 0-0.20 M tuz konsantrasyonunda tespit edilmiştir. ÇH, ÇG ve KYKAO değerleri 0.25 M; KU, ÇKUO, KYA ve KKA değerleri 0.20 M tuz konsantrasyonunda düşmeye başlamıştır. Yüksek örnek sayıları için hesaplanan Pearson doğrusal korelasyon katsayıları tüm değerler için çeşitli derecelerde anlamlı olmuştur. Anlamlı AB1 değerleri KKA için 0.356, KB için 0.335, ÇKUO için 0.310 ve KYA için 0.309 hesaplanmıştır. İlk üçte yer alan AB’lerin birikimli varyansı % 90.525 olmuştur. En yüksek AB değeri AB1 için %71.946, onu takip eden AB2 için %11.098 ve AB3 için % 7.481 olarak hesaplanmıştır. Öbekağacı siyez ve ekmeklik buğdayları belirgin iki ana gruba ayırmıştır.

ANAHTAR KELİMELER: Buğday, Siyez, Soğuk, Kurak, Tuz, Stres.

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LIST OF ABBREVIATIONS AND SYMBOLS

%	: Percent
°C	: Centigrade Degree
ABA	: Abscisic Acid
ANOVA	: Analysis of variance
ARI	: Anatolian Research Institute, Eskişehir
B.C.	: Before Christ
Ca^{2+}	: Calcium Ion
CARI	: Çukurova Agricultural Research Institute, Adana
CH_4	: Methane
CL	: Coleoptile Length
Cl^-	: Chloride Ion
cm	: Centimetre
CO_2	: Carbon dioxide
CRIFC	: Central Research Institute for Agricultural Research, Ankara
DF	: Degrees of Freedom
F	: Fisher's protected test
FAO	: Food and Agriculture Organization
GP	: Germinating Power
GR	: Germination Rate
Ha	: Hectare
HCO^{3-}	: Bicarbonate Ion
IPCC	: Intergovernmental Panel on Climate Change
K^+	: Potassium Ion

LSD	: Least Significant Difference
M	: Molarity, Molar
mg	: Milligram
Mg^{2+}	: Magnesium Ion
Min	: Minute
Ml	: Millilitre
MPa	: Megapascal
N_2O	: Nitrous Oxide
Na^+	: Sodium Ion
NaCl	: Sodium Chloride
NO^{3-}	: Nitrate Ion
Ns	: No Significant
PC	: Principal Component
PCA	: Principal Component Analysis
PEG	: Polyethylene Glycol
pH	: Potential of Hydrogen
ppm	: Parts per Million
r	: Coefficient of Correlation
RCBD	: The Randomized Complete Block Design (RCBD):
RDW	: Root Dry Weight
RFDWR	: Root Fresh Weight/Root Ratio
RFW	: Root Fresh Weight
RL	: Root Length
ROS	: Reactive Oxygen Species

SL	**:** Shoot Length
SO_4^{2-}	**:** Sulphate Ion
SPSS	**:** Statistical Package for the Social Sciences
SRLR	**:** Shoot/Root Length Ratio
ssp / subsp.	**:** Sub-species
TARI	**:** Thrace Agricultural Research Institute, Edirne
tRNA	**:** Transfer Ribonucleic Acid

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1. INTRODUCTION

1.1 Wheat

Wheat (*Triticum* ssp.) was first cultivated more than ten thousand years ago in Fertile Crescent and, today, it has provided fundamental food to more than one third of the world's population (Goutam et al., 2013; Rahaie et al., 2013; Shahzad et al., 2013).

The 670.8 million tons of annual global wheat production end up in various foods: especially bread, pasta, noodles, cakes, and biscuits (Eren et al., 2015). The appropriate feed grade of the wheat grain, ease of handling, storage and processing, and due to the wide adaptation limits, wheat is the basic food in the developed and, especially, in developing countries today. As a basic nutrient of about 35% of the world's population, wheat provides 20% of the food calories all over the world (Kün, 1996).

1.1.1 Origins of Ancient Wheat

The data from archaeological studies represents that wheat firstly occurred in the southeast region of Turkey, Lebanon, Syria, the Levant, Israel, Egypt, and Ethiopia (Lev-Yadun et al., 2000). Einkorn (*T. monococcum* ssp. *monoccoccum*), the first cultured wheat, domestication dates back to 9,000 B.C. in Turkey, which is earlier (23,000 B.C.) than the existence of wild barley (*Hordeum* ssp), (Piperno et al., 2004; Tunno and Willcox, 2006). The spreading of the cultivated emmer (*T. dicoccum* Schrank.) began in the Fertile Crescent (Figure 1.1) about nearly 8500 B.C. and then reached to Greece, Cyprus and India at about 6500 B.C. and after a short time Egyptians cultivated, then Germans and Spainish by 5000 B.C.(Diamond, 1997). The oven technology for the bread production was used by early Egyptians at a large-scale. Wheat reached to the English and Scandinavian lands by 3000 B.C. After a 1000 years, it had reached to China. It has globally spreaded and widely cultivated because of better yield, growing properties, and a short 120 day growing season (Cooper, 2015).

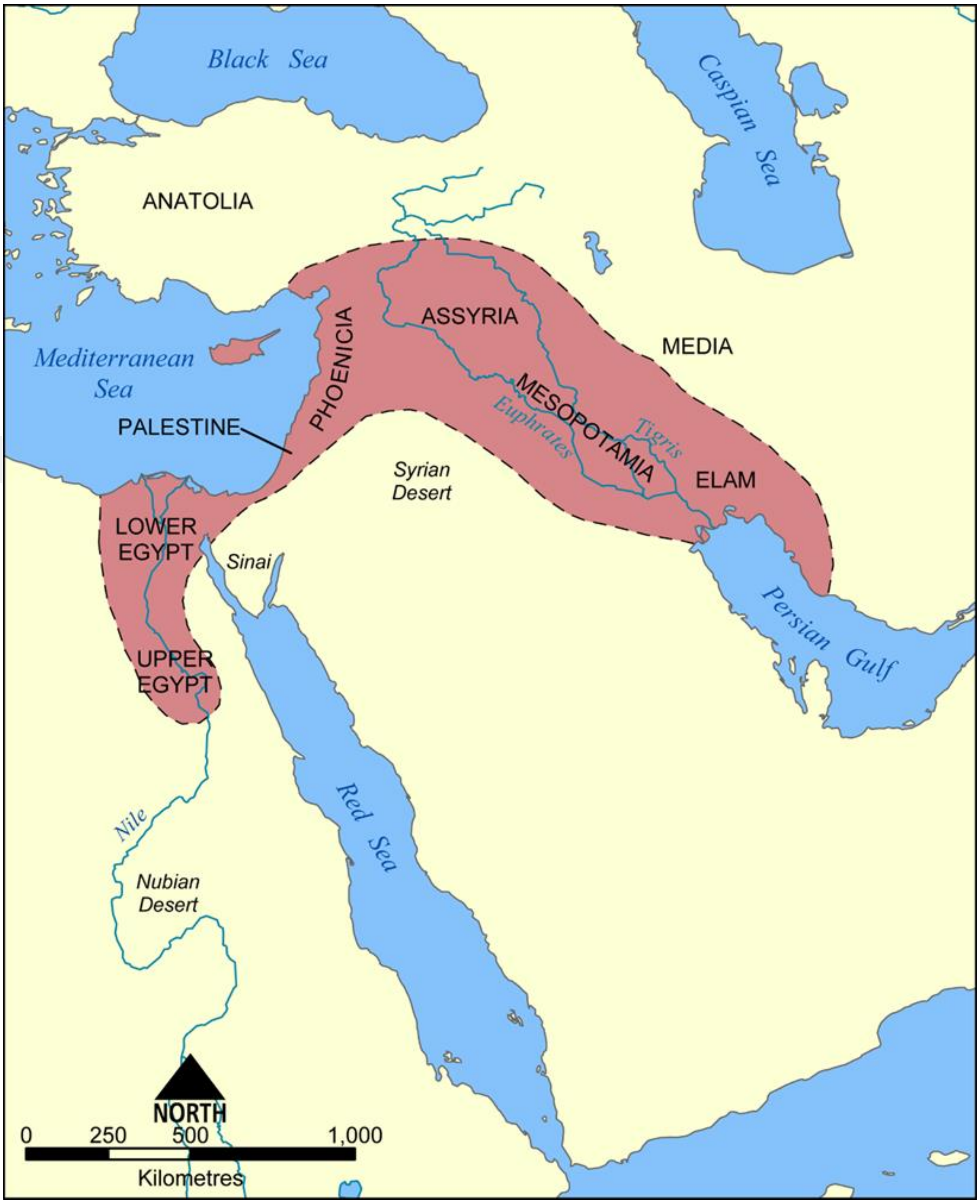

Figure 1.1. The map of Fertile Crescent

1.1.2 The Evolution and Domestication of the Wheat Species

In genome evolution, domestication of plant species is an important issue.

Firstly, domestication can favour formation and widening of interesting polyploid species. Nearly 7000 to 9500 years ago the hexaploid wheat (*Triticum aestivum* L.) probably chosen by human cultivation (Nesbitt and Samuel, 1995).

Secondly, domestication involves a small number of individuals, and, therefore, causes a reduction in the genetic diversity of the plant species grown compared to wild progenitors (Tanksley and McCouch, 1997).

The third leads to the selection and spread of certain genes and alleles that control domestication, agricultural precaution, and separation of crops from their wild relatives (Clark et al., 2004).

The *Aegilops* and *Triticum* genus, which are in *Poaceae* family, include several diploid species (2n=14) and some tetraploid and hexaploid wheat species via allopolyploidization (Eckardt, 2001; Feldman et al., 1995; Huang et al., 2002). 2n=28, AABB; *T. turgidum* ssp. *durum* was originated via hybridization of a diploid donor of A genome (*T. monococcum* ssp *urartu*, 2n=14; AA) with an unknown species of *Sitopsis*, which is close to *Ae. speltoides*, B genome donor (2n=14, BB) (Blake et al., 1999; Feldman et al., 1995; Huang et al., 2002). After an additional polyploidization occurred 7000 to 9500 years ago between domesticated *T. dicoccum* Schrank. and the diploid donor of the D genome, *Ae. tauschii* (2n=14; DD) species, *T. aestivum* L. (2n=21; AABBDD), the hexaploid wheat, occurred (Figure 1.2).

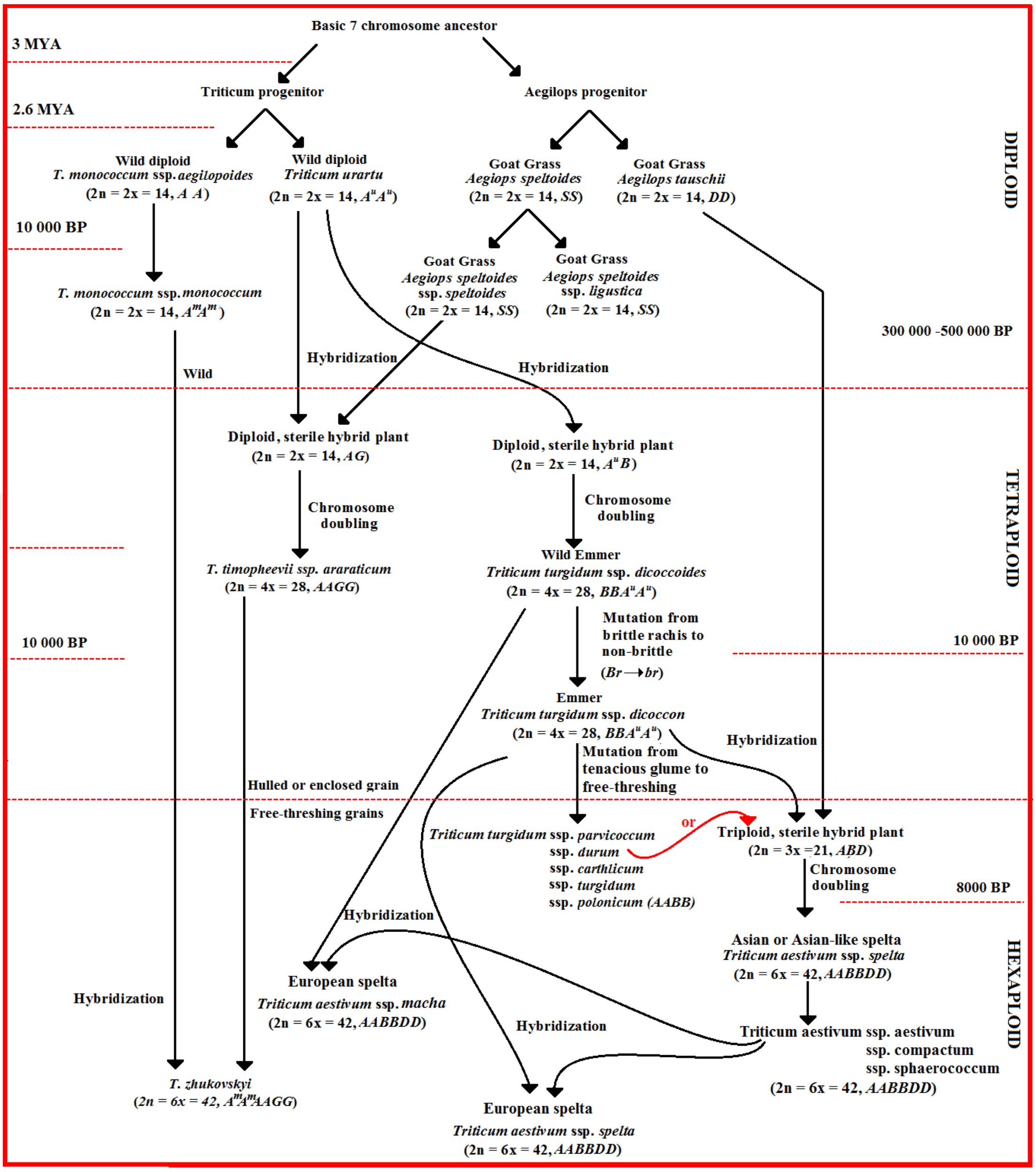

Figure 1.2. Representation of the Evolutionary History of Wheat Species (*Triticum* and *Aegilops*) (modified from Faris et al. (2014) and Peng et al. (2011))

1.1.3 Major Wheat Species

Triticum aestivum L., a widely cultivated hexaploid wheat species is used for bread making. Then, *T. turgidum* ssp. *durum* (durum wheat) is the second most common wheat species. *T. monococcum* ssp. *monococcum,* a diploid species and *T. dicoccum* Schrank, a tetraploid species were limitedly cultivated on far-mountainous regions. Furthermore, Spelta, Vavilovi and Macha are the other cultivated hulled wheat species.

1.1.3.1 Bread Wheat

T. aestivum L. which is also known as common or bread wheat, is hexaploid (AABBDD) with a total of 42 chromosomes (2n=42, six times seven chromosomes) (Heyne, 1987). Similarly, the different wheat species also contain some multiple of the basic haploid set of seven chromosomes. Modern wheat cultivars are either tetraploid (durum, AABB) or hexaploid (common and club-types, AABBDD).

Diploid and tetraploid wheat were domesticated in the Fertile Crescent. Diploid and tetraploid wheat have domesticated approximately 9000 years ago with the hybridization which produced hexaploid wheat occurring more than 6000 years ago (Feuillet et al., 2007; Heyne, 1987).

T. aestivum is a cereal for temperate climates. The minimal temperature for germination of *T. aestivum* seeds is between 3 and 4°C. Flowering begins above 14°C, and also bread wheat, that is the most common cultivated crop in the world, is primary use of bread production, in addition producing of biscuits, noodles, and other baking products.

1.1.3.2 Durum Wheat

Triticum durum L.is a tetraploid and have 2 different but genetically related genomes designated as A and B (2n=28, AABB) (Salamini et al., 2002). The major producing countries of durum wheat are Turkey and Syria especially mountainous areas (Nachit et al., 1995).

It is used in highly in pasta production and other local processed foods (Nachit, 1998). Durum wheat highly use in industrial sector. In addition, because of characteristics of the wheat kernel, elasticity and extensibility of the gluten complex durum wheat is chosen for especially making pasta, bread, and other local foods such as couscous, bulgur (Elouafi et al., 2001).

T. durum has a lower resistance to cold stress on the other hand, it has better resistance to drought stress compared with bread wheat.

1.1.3.3 Hulled Wheats

Einkorn, emmer, spelt, vavilovi, and macha are the most ancient hulled wheat species. Einkorn, *Triticum monococcum* ssp. *monococcum*, is the most basic wheat form with a diploid chromosome numbers (2n=14). Emmer, *Triticum dicoccum* Schrank., that is another ancient wheat, is tetraploid (2n=28), (Kimber and Sears 1983). The hexaploid species *T. spelta*, *T. vavilovii* and *T. macha* are hulled wheats (2n=42).

They are significant food sources for thousands years with a higher genetic resource potential. They are, in time, replaced by higher yielding bread and durum wheat cultivars (Nesbitt and Samuel, 1996). Hulled wheats are good examples of underutilized species. They are less or totally unknown by local cultures and has limited commercial production although they are much important for food security. They are also in danger as other underutilized species. Researchers and policy makers neglect these species because of agronomic, genetic or economic and cultural factors (Ünal, 2009). For example, in Turkey, hulled wheats were cultivated over 100,000 ha during 1948 to 1968. , a sharp decrease has been observed after 1993 as to 12,900 ha (Karagöz, 1996).

Hulled wheat is used in bakery industry and in alternative medicine. Emmer wheat, which has higher fibre than common wheat, is used for making emmer bread (pane di farro), and also beer production. Einkorn is used as often bulgur (cracked wheat) or as animal feed (Cooper, 2015). They are, in general, important species for researchers because of high level protein, carotenoids, phosphorus, zinc, iron, and antioxidants (Brandolini et al., 2007). Because of higher content of fibre, carotenoids, and tocols einkorn is a promising candidate for special foods, baby foods and products (Borghi et al., 1996; Løje et al., 2003).

1.1.3.3.1 Einkorn Wheat

The name of einkorn comes from German, (single grain), The wild species are *Triticum boeoticum* and domesticated form is *Triticum monococcum*.ssp. *monococcum*. Einkorn is a diploid species and it is hulled wheat as emmer. The wild and the cultivated forms are similar but the wild type has larger seeds and constant ear.

Einkorn wheat was the first cultivated form of wheat. The evidence of the wild einkorn was found in Epi-Palaeolithic regions of the Fertile Crescent and domesticated nearly 7500 B.C. DNA fingerprint results showed that the first domestication of einkorn occurred in southeast part of Turkey. During the Bronze Age, its cultivation decreased and nowadays rarely planted. It is found in the market as a health food. It is widely used as bulgur, cracked wheat, or animal feed in mountainous regions of France, Morocco, Balkans and Turkey. It can survives on poor soils that other wheat species fail (Raymond, 2015).

1.1.3.3.2 Emmer Wheat

Triticum dicoccum Schrank., emmer wheat, is also another type of hulled wheat. It belongs to the firstly cultivated wheat types in the Near East. It was commonly cultivated in the ancient world. It is limitedly grown today, especially in far mountainous regions of Europe and Asia. The morphology and genetics of the wild (*Triticum dicoccoides* Koern.) and domesticated emmer (*Triticum dicoccum* Schrank) are similar. Emmer wheat is formed by the hybridization of *Triticum urartu* and unidentified *Aegilops* species related to *A. searsii* or *A. Speltoides* (Raymond, 2015).

Emmer is mainly used as human food but also as animal feed. Some evidence from Turkey and other countries show that emmer is a good material for bread making. These evidences are supported by the widespread production of bread in ancient Egypt, which used to be made by processing of emmer. Nowadays, it is available in bakeries in Germany, Switzerland, and Italy. Because of the high fibre content it is used for pasta making but it is not suitable for human who suffer from gluten allergy or celiac disease (Raymond, 2015).

1.1.3.3.3 Spelt Wheat

Triticum spelta (*T. aestivum* subsp. *spelta*) which is a hulled wheat. It evolved after the hybridization of emmer wheat and a wild grass *Aegilops tauschii* approximately 6000 B.C. in the Middle East and arrived to Europe about 2000 B.C. Until other species of the wheat became dominant in Europe and Roman times, it had a significant role on the other hand it remained a important crop in isolated areas especially in Germany and Switzerland.

It has tolerance of poor soils, needs less fertilizer than common wheat so it is commonly used in organic farming. It is not suitable for people with coeliac disease because of gluten ingredient. The nutritional composition of spelt is same as hard wheat. Usage for baking is suitable because the concentration of gluten is effective and used in some pasta, breakfast cereals, bread and cakes (Vaughan and Geissler, 2009).

1.1.3.3.4 Vavilovi Wheat

Triticum vavilovii is a hexaploid hulled wheat which has long rachillae. This long rachillae give the ear branched appearance (Singh et al., 1957). *T. vavilovii* was reported firstly in 1929 near Lake Van which is located at eastern part of Turkey (Zhukovsky, 1933). Because of its close relation to *T. aestivum* and having two closely linked genes that regulate branching and hulled characters, *T. vavilovii* is local and recently evolved form of wheat probably.

1.1.3.3.5 Macha Wheat

Triticum macha, which is also a hexaploid hulled wheat, firstly found in western part of the Georgia in 1929. Russian botanists said that *T. macha* was related in the origin of free-threshing hexaploid wheats. But, it looks like differ from other hexaploid wheats and it is probably derived from *T. palaeocolchicum*. A study showed that a brittle-rachised form of *T. macha*, var. *megrelicum* Dek. et Men. could be a wild hexaploid so, it could be a candidate ancestor species. *T. macha* was the form of the hybridization from which hexaploid free-threshing wheats derived. There is limited information about distribution and ecology of *T. macha*, it is a minor species and growth in *T. timopheevi* and *T. monococcum* fields as admixture. T. macha is regarded as the other hulled endemic wheats to Transcaucasia, as local forms which evolved in isolation (Perrino et al., 1996).

1.2 Climate and Climate Change

The long-term effects of events that occur in the atmosphere are defined as climate. Climate has tended to change naturally throughout the history of the earth. The change mentioned, however, took place in the middle of the nineteenth century, as a result of natural influences until the industrial revolution. It has been determined that human influence has a significant role in subsequent changes. In this context, climate change is a change in the climate as a result of human influences directly or indirectly damaging the composition of the global atmosphere, in addition to the natural climate change observed over a comparable period of time (Türkeş, 2008).

The most important cause of global warming is the emission of CO_2, CH_4 and N_2O, which are the main greenhouse gases. Many human activities, such as burning fossil fuels, deforestation, industrial processes, uncontrolled urbanization and agricultural practices are driving the release of greenhouse gases in the atmosphere. Considering life spans and releases, CO_2, the most important greenhouse gas, has increased by about 30% since 1750. It is predicted that CO_2 accumulation, which was approximately 280 ppm before the industrial period and 370 ppm in 1999, will reach 700 ppm by the end of the 21stcentury. Existing atmospheric CO_2 increases have resulted in anthropogenic emissions of CO_2, and approximately 75% of these emissions have arisen as a consequence of the burning of fossil fuels (IPCC, 2001).

These increases in greenhouse gas accumulations lead to the creation of a positive radiative forcing that tends to further heat the earth by weakening the cooling effect by increasing short wave radiations in the atmosphere. This positive contribution to the energy balance of the atmospheric system is called increasing or strengthening greenhouse effect. This phenomenon means that the effect of natural greenhouse gases in the atmosphere of the earth has been strengthened by an effect that has been working for hundreds of millions of years, in other words, it is called the natural greenhouse effect. The magnitude of a global warming that can result from an increased greenhouse effect depends on the size of the increase in the accumulation of each greenhouse gas, the radiative properties of the gases, the atmospheric lifetimes and the other greenhouse gases and deposits of other gases in the atmosphere.

Globally, the average temperature of earth and water masses has increased since 1861. This increase was 0.8°C during the 20th century. The hottest ten-year period from 1861 to the present day is the 1990s, and 1998 is the warmest year. On average, between 1950 and 1993, maximum daily surface air temperature per day increased by 0.2°C per decade. This increase is 0.1°C higher than the 10-year increase in daily maximum daytime temperature. The increase in global temperature from 1860 to 1980 was 0.4°C and the temperature increase between 1980 and 2000 was 0.4°C, these changes clearly demonstrate the effects of increasing human activity in recent years. Industrialization in recent years and the increase in the use of fossil fuels, in this context, increased atmospheric CO_2 emissions; The increase in temperature over the past 120 years has made it equal to the increase in temperature during the last 20 years of today (IPCC, 2001).

Rising in the temperature, extreme weather conditions such as flooding, storms and drought are the expected effects of the climate change on the Earth (FAO, 2014). Negative impacts on production of agricultural and also aquaculture are inevitable. All regions of the Earth and all types of food affected by climate change (drought, weather conditions or pathogens that evolve new conditions) at pre- or postharvest stage. In addition, mineral and vitamin contents and other nutritional parameters of the food affected. The increasing in the temperature about 4°C which will impact the quality and the production yield of the crops such as soya, rice and wheat. And it is not too far, the expected year for the rising in the temperature about 4°C is 2060 (IPCC, 2014). The climate changes, in return, induce biotic and abiotic stresses in plants including wheat. Therefore, these stresses are also closely studied and clearly documented at every stage of the crops across the world.

1.3 Biotic and Abiotic Stresses on Wheat

1.3.1 Biotic Stresses (Wheat Diseases)

There are many diseases, which affect wheat as bacteriological, viral and, fungal and cause heavy yield losses. The most important ones are: bunt (*Tilletia foetida* and *T. caries*), loose smut (*Ustilago nuda*), rusts (*Puccinia striiformis*, *P. graminis f. sp. tritici*, *P. recondita f. sp. tritici*), leaf blotch (*Septoria tritici*), root and foot rots (*Fusarium* spp., *Drechslera sorokiniana*, *Pseudocercosporella herpotrichoides*, *Alternarla alternate*, *Sclerotium* spp., and *Rhizoctonia* spp.). These diseases exist in all region of Turkey. Losses because of rusts are predicted as at 30-35% overall Turkey. In addition, average losses from smut are about 15-20%, from loose smut 0.1-20% depending on the region and weather conditions in the season. The other important diseases are powdery mildew (*Erysiphe graminis f.* sp. *tritici*), dwarf smut (*Tilletia contraversa*), flag smut (*Urocystis tritici*), take-all (*Gaeumannomyces graminis*) and wheat mosaic virus (İren, 1981).

The yield of wheat species is decreased by damages due to different diseases. A combination of susceptible host, pathogen (bacteria, fungi or virus), and a suitable environment are must for an infection. The disease triangle (Figure 1.3) represents the relationship between this three factors and illustrates the balance between the variables which are necessary for infection. The least stable variable of these factors may be environment on disease occurring. Because it changes day-by-day and its control is not possible.

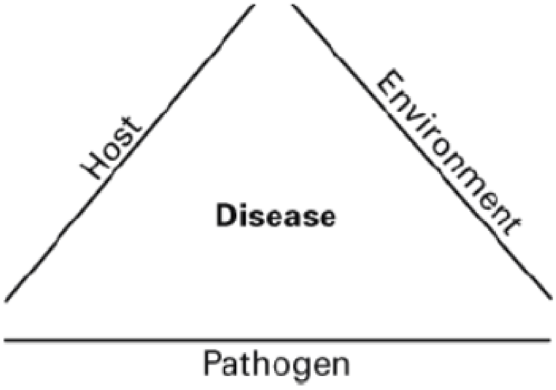

Figure 1.3. The disease triangle (Stevens, 1960)

1.3.2 Abiotic Stress

Salinity, drought or cold are abiotic stresses. The crop yield and/or quality are reduced by the effects of these factors (Li et al., 2010; Mostek et al., 2015; Richter et al., 2015). These stresses limit water absorption (Pierik and Testerink, 2014), decreases osmotic potential in the soil (Izadi et al., 2014), accelerates water loss, causes morphological, biochemical and physiological worsening, and therefore, limits growth and the yield (Mehrotra et al., 2014). If there is a tolerance against these stresses, higher yields can clearly be obtained (Verslues et al., 2006).

1.3.2.1 Cold Stress

Cold stress is another important stress source for plants as well. It is widely ranges all over the Earth, damages wheat species depend on degree, duration, the growing level of the plant, and the stress time (Gupta and Sheoran, 1983). Plants, on the other hand, adopt themselves against cold stress (Gill et al., 2003) and survive by different sophisticated responses as morphological, physiological, and biochemical response mechanisms (Bohnert et al., 1995).

Different temperatures at various growth levels are necessary for wheat (*Triticum* ssp) depending on its growth type, cultivation season, and region. Wheat production ranges from approximately -35°C in winter and 45°C in summer. The optimum temperatures are -10 to -17°C in winter and 30 to 35°C in summer. Wheat is more sensitive in the early growth and the germination stages (Khodabandeh, 2003). The germination process is suitable in higher than 4°C just afterward. Higher temperatures limit germination but maximum 20-22°C increases the rate of germination. The lower temperature for germination is 2°C and an optimum is 8-10°C (Khodabandeh, 2003).

Germination and growth of a plant are regulated by the temperature of the soil until the plant rises from the soil. The controlling of the root temperature is made by the soil temperature which affects root growth, the number and the length of the root in barley and turnip (Macduff and Wild, 1986). At low temperatures as 5°C roots of barley, oats, rye, and wheat stay shorter (Abbasal-Ani and Hay, 1983). Higher temperatures, on the other hand, at 15-25°C grow the roots faster. Finally, the germination is important stage for a successful crop development and it is also affected by temperature significantly (Figure 1.4).

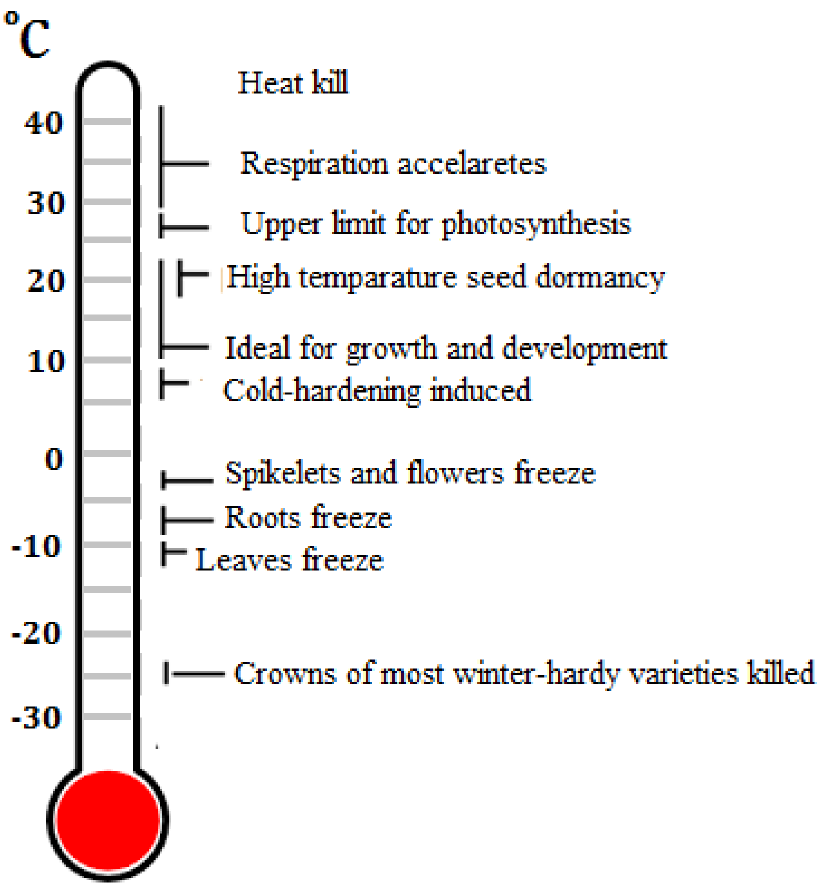

Figure 1.4. General range of the temperature stress conditions for wheat

1.3.2.1.1 Cold Stress during Germination

Germination is to most of the one sensitive stage to soil temperature because of the necessity of the water-intake by enzymatic activity or respiration. (Tobeh and Jamaati-e-Somarin, 2012). Germination normally is regulated by soil temperature before growing of the plant on the soil. Minimum temperatures for mid-winter wheat is about 2°C, optimum range is 8-10°C and maximum is 20-22°C (Khodabandeh, 2003).

Seed germination and quality of it are prerequisites for the standing of the crop plants. Drought and also cold are the limiting factors for the germination process for wheat species by delaying to development and emergence, a significant criteria of surviving and subsequent yielding of many crops (Azam and Allen, 1976; Brigg and Ayten-fisu, 1979).

1.3.2.2 Drought Stress

Drought is also an important and common stress issue for the researchers because expectations about it says that around 1.8 billion people suffer from water shortage and 65% of the Earth’s population live under water stressed environment (Ingram and Bartels, 1996). Plants tolerate drought stress by two ways: drought avoidance and dehydration tolerance. Drought avoidance changes root depth to use rainfall. Dehydration tolerance partially dehydrate plants and regrow when rainfall continues (Kramer and Boyer, 1995; Salekdah et al., 2002). They both are vital processes for the plants. Drought stress may cause some protein changes, antioxidant production, osmotic adjustment, hormone composition, root morphology, stoma machinery, photosynthesis inhibition, reducing in chlorophyll content, growth and transpiration reduction (Lawlor and Cornic, 2002; Szegletes et al., 2000; Yordanov et al., 2000; Zhu, 2002). Many factors can, on the other hand, affect plant responses to drought stress such as plant genotype, growth stage, severity and duration of stress, physiological process of growth, different patterns of genes expression, different patterns of the activity of respiration, activity of photosynthesis, and environmental factors (Rizhsky et al., 2002).

Physiological responses against to drought stress include recognition of the signals came from root, loss of turgor, regulation of the osmotic pressure, reduction of the water potential of the leaf, closing of stomata, changing in the concentration of CO_2, and decreasing in the growing process. Early responses to the drought ensure survival of the plant while maintain resistance to dehydration via accumulation of certain metabolites such as proline, glycine, and betaine to maintain structural integrity and the functionality. Other osmolytic compounds such as sucrose, sugar alcohols, and oligosaccharides increase in amount during stress response. The amounts of these compounds enhance with increased drought (Pinhero et al., 2001). The rate of photosynthesis is, on the other hand, reduced due to the long-term closing in stomata and the limitation of the CO_2 concentration, and reduction ribulose 1,5 biphosphate carboxylase/oxidase (Rubisco) activity (Lawlor 1995, Pinhero et al., 2004).

The electron transport chain in chloroplasts and mitochondria is closely related to carbon metabolism, and under increasing stress conditions. This is known that carbon metabolism and energy balance change both in the chloroplasts and the mitochondria. In these organelles, the imbalance of the energy flow leads to an increase in the production of reactive oxygen species (ROS) and, thus, an oxidative stress (Anjum et al., 2011; Farooq et al., 2009; Suzuki et al., 2012).

ABA (abscisic acid) is known to be increased in plants exposed to drought. ABA is a hormone that allows the stomata to close in drought conditions (Hartung et al., 2002). In plants under drought stress, the amount of ABA in the stoma cells increases, resulting insoluble starch is forming and the K^+ ion is decreasing. As a result, the osmotic pressure of stomata decreases and stomata close. (Çırak and Esendal, 2006).

1.3.2.2.1 Drought Stress during Germination

Germination is the one of the most significant stage during plant growing and it is influenced environmental stresses as drought (Leila, 2007).

The first stage of the germination is water absorption and its absorption level depends on the chemical composition of the seed. Especially, proteins, mucilage and pectin attracts more water than starch because of their hydrophilic natures (Rahmani, 2006). The important role of water for germination is stimulation. Water level of the soil affects to the rate of water absorption by limiting osmotic and suction potential, followed by germination reduces.

Drought plays a significant role in delaying germination rate, reducing shoot growing and production of dry matter (Shekari, 2000).

1.3.2.3 Salt Stress

Soil salinity affects approximately 7% (950 million ha) of land across the world nowadays (Shavrukov et al., 2011), 23% of cultivated and 20% of irrigated land (Vardar and Çifci, 2014). The expectation for next 25 years is 10% increase in salinity and 30% land loss around the Earth (El-Hendawy et al., 2005; Huang et al., 2006; Radi, 2013).

The effects of the salinity are observed in two ways as osmotic and ion specific stresses on plants (Bernstein, 1975; Munns et al., 1995).

1.3.2.3.1 Osmotic stress

Osmotic effect on plants is caused by non-ionic specific factors. The salt in the soil generally decreases the water potential and increases the osmotic soil solution pressure. The increased osmotic pressure limits the extraction of the water from the soil by plants and yield reduces (Leon, 1963).

The plant under osmotic stress losses the water via transpiration by closing stomata, which in turn CO_2 assimilation, therefore, the rate of the photosynthesis and the growth reduce (El-Hendawy et al., 2005; James et al., 2002; James et al., 2008; Kingsbury et al., 1984;). Anomalies in the shoot growth are the most common sign of the salt stress in wheat species (Nuttall et al., 2006). In addition, cell division and the elongation process are decreased by osmotic stress, and reduction in division and elongation in cell division cause smaller and thicker leaves (Fricke and Peters, 2002; Munns and Tester 2008; Passioura and Munns, 2000; Yeo et al., 1991).

1.3.2.3.2 Ionic Stress

Although Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO^{3-}, NO^{3-} and K^+ ions are the essential nutrients for plants in the soil, the higher concentrations of these ions in the soil solution damage the plants (Bernstein, 1975). According to the Tester and Davenport (2003), Na^+ ion causes major ion specific effects in wheat and rice

Accumulation of Na^+ ions in the leaf cytoplasm causes some disturbances in various metabolic processes in plant cells as reducing the activity of enzymes for protein synthesis (compete with K^+ ions for binding sites of K^+ transporters of tRNA) (Bhandal and Malik, 1988; Blaha et al., 2000; Munns, 1993). In addition, high levels of Na^+ in the cell damage the function of sub-cellular components as micro tubules, microfibrils, spherosomes, and ribosomes (Mansour et al., 1993). So, balanced Na^+:K^+ ratio in the cytoplasm is controlled to protect vital processes of plants (Dubcovsky et al., 1996; Gorham et al., 1990; Maathuis and Amtmann, 1999). Dehydration is the one of the effects of the Na^+ accumulation inside the leaf apoplast which causes osmotic stress and decreases the water potential of the cell (Evans and Sorger, 1966; Evans, 1980; Munns, 2002; Oertli, 1968; Xiong and Zhu, 2002).

1.3.2.3.3 Salt Stress during Germination

Seed germination is the important stage of the plant development, and the performances of the crops under salt stress depends on germination, and the later levels of the growth. Germination is a complicated stage includes physiological and biochemical changes because of embryo activation. Salinity affects the germination by either limiting water-taking of seeds, movements of stored reserves, or by affecting the synthesis of proteins and organization of amino acids (Bouaziz and Hicks, 1990; Dodd and Donovan, 1999; Lin and Kao, 1995).

While plants faces to high salinity (NaCl), water absorption and ionic transportation probably are affected and this situation damages the nutrition and/or ionic balance, and physiological process. First stage of the effect of the salinity is changing the osmotic pressure and second stage is causing toxicity and changing enzyme activity. The percentage, rate and seedling development are effected in different ways like these depending on plants (Gul and Weber, 1999; Ungar, 2005).

2. AIM AND SCOPE OF THE STUDY

Global climate change, which affects living and non-living factors, has led to many environmental changes recently. Extreme temperature increases, unexpected seasonal rainfalls, sudden droughts we encountered in the summer of recent years are the effects of climate change.

It is inevitable that sufficient rainfall is necessary for wheat during the development period, sufficient temperature during maturing period, and development depends mostly on external factors, which are influenced by climate change.

The surviving ratio of the plant depends on salt, drought, and cold factors in the germination stage, and these factors affects the development of the plant after emergence. Climate change also enhances the effects of these abiotic factors on wheat. Expected that these losses and problems in yield, quality and production are going to increase day-by-day due to the climate change.

Therefore, determining the tolerance and/or tolerance levels of wheat, which is among the most produced and consumed plants in the world, against abiotic factors would prepare the basis for the development of more superior wheat varieties. For this reason, this study focused on resistance and/or tolerance levels of some modern and cultivated wild wheat species and populations against salinity, drought, and cold during germination periods.

In the study, twelve bread wheat (*Triticum aestivum* L.) cultivars (Gerek-79, İkizce-96, Kıraç-66, Kenanbey, Flamura-85, Momtchil, Bayraktar-2000, Tosunbey, Pandas, Pehlivan, Demir-2000 and Gün-91), and 10 hulled einkorn wheat (*Triticum monococcum* subsp. *monococcum*) populations named as (Population-1, Population-2, Population-4, Population-5, Population-6, Population-9, Population-10, Population-11, Population-14, and Population-15 were germinated in the growth chambers and tested against different levels of drought, cold, and salt stresses.

The wheat cultivars and populations were tested at various salt levels generated by sodium chloride salt (NaCl), artificial drought levels regulated using different levels of Polyethylene Glycol (PEG), and cold temperatures established in the climate chamber.

3. MATERIALS AND METHODS

3.1 Seed Samples

Twelve bread wheat (*Triticum aestivum* L.) cultivars (Gerek-79, İkizce-96, Kıraç-66, Kenanbey, Flamura-85, Momtchil, Bayraktar-2000, Tosunbey, Pandas, Pehlivan, Demir-2000 and Gün-91), and 10 hulled einkorn wheat (*Triticum monococcum* subsp. *monococcum*) populations (Population-1, Population-2, Population-4, Population-5, Population-6, Population-9, Population-10, Population-11, Population-14 and Population -15) were studied against the salt, drought, and cold stress responses during germination stage.

The cultivars of bread wheat (*Triticum aestivum* L.) were supplied by the research institutes in Turkey and einkorn wheat populations by Quality Feed Company, Bolu (Table 3.1).

Table 3.1. Names and the origins of cultivars and populations (Turkey)

Numbers	Cultivars / Populations	Origins
1	Gerek-79	ARI*
2	İkizce	CRIFC**
3	Kıraç-66	ARI*
4	Kenanbey	CRIFC**
5	Flamura-85	TARI***
6	Momtchill	TARI***

Table 3.1. Names and the origins of cultivars and populations (Turkey) (cont'd)

Numbers	Cultivars / Populations	Origins
7	Bayraktar-2000	CRIFC**
8	Tosunbey	CRIFC**
9	Pandas	CARI****
10	Pehlivan	TARI***
11	Demir-2000	CRIFC**
12	Gün-91	CRIFC**
13	Population-1	Bolu, Seben, Haccağız Village
14	Population-2	Bolu, Seben, Boğaz Region
15	Population-4	Bolu, Seben, Kavaklı Yazı Village, Field # 1
16	Population-5	Bolu, Seben, Kavaklı Yazı Village, Field # 2
17	Population-6	Bolu, Seben, Kavaklı Yazı Village, Field # 3
18	Population-9	Kastamanonu, İhsan Gazi, Çatalyazı Village

Table 3.1. Names and the origins of cultivars and populations (Turkey) (cont'd)

Numbers	Cultivars / Populations	Origins
19	Population-10	Kastamanonu, İhsan Gazi, Uzunoğlu District
20	Population-11	Kastamanonu, İhsan Gazi, Çay District
21	Population-14	Kastamanonu, İhsan Gazi, Center
22	Population-15	Kastamanonu, İhsan Gazi, Center

*: ARI, Anatolian Research Institute, Eskişehir; **: CRIFC, Central Research Institute for Agricultural Research, Ankara; ***: TARI, Thrace Agricultural Research Institute, Edirne; ****: CARI, Çukurova Agricultural Research Institute, Adana.

3.2 Sterilization of Seed Samples

3 x 30 seeds (of each wheat entry per treatment) were surface-sterilized in 96% ethanol for 30 seconds and 10% sodium hypochlorite for 15 min. Then, they rinsed twice in distilled water for each treatments (cold, drought, and salt) (Baloch et al., 2012).

3.3 Cold Stress

3.3.1 Cold Stress Treatment

30 (10 x 3) seeds were germinated on wet filter paper under 7 levels of cold stress: Seeds in petri dishes were tested under treatments of control (23±1), 2, 0, -2, -4, -6, and -8°C. The pHs of each media in petri dishes were adjusted to 5.9 ±1 and germinated at 23±1 °C in for 8 days in a dark growth room.

After 4 days GR (%) and after 8 days GP (%), CL (cm), SL (cm), RL (cm), FRW (mg) and DRW (mg) were measured. Then, SRLR, and RFDWR were calculated.

3.3.2 Statistical Analysis for Cold Stress Treatments

The experiment was set up in a 3 replicate factorial restriction randomized complete block design. Analysis of variance (ANOVA), Fisher's protected test (F), least significant difference (LSD) for mean separation (Gomez and Gomez 1984), Pearson linear correlations among characters (Kalaycı, 2006) were calculated by EXCEL. Principal component analysis (PCA) performances and dendogram drawings were carried out by SPSS (Zobel et al., 1988).

3.4 Drought Stress

3.4.1 Drought Stress Treatments

The sterilized 10 (X 3) seeds were germinated on 5 ml pre-prepared solution added wet filter paper one control and six 100 ml of PEG 600: without PEG 600 (control), 4.57 ml: 0.09 M, 9.14 ml: 13.71 ml: 0.17 M, 18.28 ml: 0.25M, 22.85 ml: 0.34 M, 25.15 ml: 0.43 M, and 27.45 ml: 0.51 M.

Concentration of each entry was adjusted to pH 5.9±1. Seeds were, then, germinated at 23±1°C for 8 days in a dark growth room.

After 4 days GR (%) and after 8 days GP (%), CL (cm), SL (cm), RL (cm),), SRLR, FRW (mg), DRW (mg), RFDWR were measured or calculated.

3.4.2 Statistical Analysis for Drought Stress Treatments

The experiment was a 3 replicate randomized complete block design with factorial restriction. Analysis of variance (ANOVA), Fisher's protected (F) and least significant difference (LSD) tests for mean values separation, Spearman correlations between entries under drought and non-drought conditions (Snedecor and Cochran, 1980; Gomez and Gomez, 1984; Petersen, 1985), Pearson linear correlations (Kalaycı, 2006), drought tolerance indices (El-Hendawy et al., 2005; Mahmoodzadeh et al., 2013; Zencirci et al., 1990), stress susceptibility and tolerance index, mean productivity, and geometric mean productivity (Ali and El-Sadek, 2016) were calculated by Microsoft EXCEL software. In addition, principal component analysis (PCA) and dendograms were run by SPSS statistical software (Zobel et al., 1988).

3.5 Salt Stress

3.5.1 Salt Stress Treatments

The germinations of 10 chosen seeds were initiated on wet filter paper against seven different salt (sodium chloride, NaCl) salt stress treatments of a control group (0 M), and six salt concentrations of 0.05 M, 0.10 M, 0.15 M, 0.20 M, 0.25 M and 0.30 M.

The pH of the solutions were adjusted to pH 5.9 ±1 and the germination process carried out at 23±1 °C for 8 days in a dark growth room. After 4 days germination rate (GR; %) and after 8 days germinating power (GP; %), coleoptile length (CL; cm), shoot length (SL; cm), root length (RL; cm), shoot/root length ratio (SRLR), root fresh weight (RFW; mg), root dry weight (RDW: mg), root fresh weight/root ratio (RFDWR) were recorded or calculated.

3.5.2 Statistical Analysis for Salt Stress Treatments

The experiment was set up in a 3 replicate randomized complete block design with factorial restriction. Analysis of variance (ANOVA), Fisher's protected test (F), least significant difference (LSD) for mean separation (Gomez and Gomez, 1984), Pearson linear correlations among the characters because of higher number of samples (Kalaycı, 2006) were calculated by EXCEL software. Principal component analysis (PCA) for variation components and dendograms were performed by SPSS (Zobel et al., 1988).

4. RESULTS AND DISCUSSIONS

4.1 Cold Stress Treatments

4.1.1 Results

Cold seriously affects crop establishment, worsens crop development and damages crops especially during germination, and reduces yield. This part of the study shows the effect of the drought stress on 12 bread wheat (*T. aestivum* L.) cultivars and 10 einkorn hulled wheat (*T. monoccum* ssp. *monococcum*) populations.

4.1.1.1 Differences between germination stages

After the analysis of the experiments, F values in ANOVA (Table 4.1) represents highly significant (P<0.01) differences between cold levels and cultivars. Blocks were highly significant for GR, GP, RL, SRLR, RFW (P<0.01), significant for CL, SL, and RFDWR (P<0.05, and non-significant for RDW. That meant that the blocking was effective to differentiate cold levels and wheat cultivars / populations, except for RDW.

Germination characters significantly differed (P<0.01) for different cold levels (control, 2, 0, -2, -4, -6, and -8°C). Percent reducing among cold levels including control ranged between 30.09-97.85% for germination characters in the study. The highest decreases (%) were in SL (99.73%), SRLR (97.85%), RDW (95.56%), RFW (94.77%), RL (94.50%), and CL (91.95%). Differences among 12 bread wheat (*Triticum aestivum* L.) cultivars and 10 einkorn (Triticum monococcum subsp. monococcum) wheat populations were also highly significant for GR, RL, RDW, and 10.60 (P<0.01); significant for CL and SL (P<0.05); non-significant for GP, SRLR, and RFW.

Table 4.1. F values for studied characters of GR, GP, CL, SL, RL, SRLR, RFW, RDW, and RFDWR under cold stress: control, 2, 0, -2, -4, -6, -8 °C

Sources of variation	DF	GR†	GP	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Blocks	2	3.14**	1.18**	12.88*	12.88*	4.19**	0.30**	427.10**	3.02^{ns}	18.51*
Treatments	153	21.85**	17.42**	92.16**	92.16**	24.69**	3.01**	2086.59**	17.34**	40.37**
Cultivars	21	14.99**	6.82^{ns}	28.89*	28.89*	7.16**	2.13^{ns}	507.25^{ns}	5.47**	10.60**
Cold levels	6	104.26**	107.35**	602.09*	602.09*	159.68**	9.22**	13863.95**	219.16**	26.63**
Cultivar *Cold levels	126	1.45^{ns}	1.02^{ns}	3.76^{ns}	3.76^{ns}	1.20^{ns}	0.38^{ns}	107.69^{ns}	1.91^{ns}	13.30^{ns}
Error	306	0.75	0.35	1.52	1.52	0.65	0.26	59.26	0.47	22.82*

† GR: Germination Rate, GP: Germination Power, CL: Coleoptile Length, SL: Shoot Length, RL: Root Length, SRLR: Shoot-Root Length Ratio, RFW: Root Fresh Weight, RDW: Root Dry Weight, RFDWR: Root Fresh-Dry Weight Ratio

DF: Degrees of Freedom; *, Significant at the 0.01, **; 0.05 significant at 0.05 probability level, ^{ns} no significant

Differences within GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR under cold levels (control, 2, 0, -2, -4, -6, and -8°C), as reflected by F values in ANOVA, arose and were revealed by LSD to the most extent. Control always had the highest germination values than others (Table 4.2).

Bread wheat cultivars and einkorn wheat populations were differentiated under cold levels, as distinguished by F tests in ANOVA and discriminated by LSD (Table 4.3). Percent decrease among cultivars / populations ranged 41.09-73.85%. Population-5, Population-1, Population-6, Population-2, Population-4, Population-14, Population-10, Population-11, Population-9, Population-15, and Gerek-79 showed the highest GR while İkizce-96 showed the lowest (P<0.05). Population-1, Population-5, Population-6, Population-4, Population-10, Population-2, Population-14, Population-9, Population-11, Gerek-79, and Flamura-85 showed the highest GP while İkizce-96 and Tosunbey showed the lowest (P<0.05). Demir-2000, Population-6, Population-4, Population-1, Population-2, Population-15, Population-5, Gerek-79, Population-11, Population-10, Population-9, and Population-14 showed the highest CL while Kiraç-66 showed the lowest (P<0.05). Population-4, Population-6, Population-15, Population-2, Population-1, Population-11, Population-5, Population-9, Gerek-79, Population-10, and Population-14 showed the highest SL while Kiraç-66 showed the lowest SL (P<0.05). Population-6, Population-1, Population-4, Momthcill, Flamura-85, Population-15, Population-2, Population-11, and Population-9 showed the highest RL while Kiraç-66 (P<0.05). Momthcill, Population-6, Pandas, Population-9, Population-11, Population-1, Gerek-79, and Population-15, İkizce-96, and Bayraktar-2000 showed the highest SRLR while Kiraç-66 and Gün-91 had the lowest (P<0.05). Population-6, Momtchill, Flamura-85, Gerek-79, Population-1, Population-5, Population-4, Population-15, and Population-2 showed the highest RDW while Kiraç-66 showed the lowest (P<0.05). Population-6, Population-4, Population-5, Population-1, and Population-11 showed the highest RDW while Population-15 showed the lowest (P<0.05). Kiraç-66 showed the highest RFDWR while Demir-2000, Tosunbey, Population-4, Gün-91, Bayraktar-2000, Population-1, Kenanbey, and Population-14 showed the lowest (P<0.05). According to the results, mostly einkorn populations had the highest germination character values.

Table 4.2. Differences among GR. GP. CL. SL. RL. SRLR. FW. RDW and RFDWR under cold stress: control, 2, 0, -2, -4, -6, and -8 °C

Cold levels (°C)	GR†	GP	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Control	99.20a	100.00a	3.73a	14.94a	8.36a	1.86a	77.46a	9.23a	12.03a
2	83.20ab	89.70ab	3.19ab	9.72b	5.55ab	1.82ab	52.72ab	6.95ab	11.13ab
0	72.10a-c	94.80a-c	2.61a-c	8.04bc	4.86a-c	1.74a-c	45.31a-c	4.49a-c	10.64a-c
-2	71.80a-d	83.00a-d	2.14a-d	6.59cd	4.45a-d	1.72a-d	40.67a-d	3.88a-d	10.60a-d
-4	63.50a-e	74.11a-e	1.62b-e	3.03e	2.38b-e	1.56a-e	22.03b-e	2.11b-e	10.40a-e
-6	52.90b-f	61.70a-f	1.32b-f	1.31ef	1.53b-f	1.23a-f	13.68b-f	1.34c-e	10.11a-f
-8	31.20e-g	36.50e-g	0.31c-g	0.04fg	0.46c-g	0.04g	4.05c-g	0.41c-g	8.41f-g
% Decrease	68.55	63.50	91.95	99.73	94.50	97.85	94.77	95.56	30.09

† GR: Germination Rate, GP: Germination Power, CL: Coleoptile Length, SL: Shoot Length, RL: Root Length, SRLR: Shoot-Root Length Ratio, RFW: Root Fresh Weight, RDW: Root Dry Weight, RFDWR: Root Fresh-Dry Weight Ratio

Table 4.3. Differences among 12 wheat (*Triticum aestivum* L.) cultivars and 10 einkorn wheat populations under cold stress: control, 2, 0, -2, -4, -6, and -8 °C

Cultivars/ Populations	GR†	GP	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Gerek-79	68.10a-i	79.00a-j	2.32a-i	6.69a-k	4.78a-g	1.76a-e	46.56a-d	4.18b-l	10.64b-e
İkizce-96	46.70i-t	60.70j-v	1.35j-s	4.02g-s	2.71j-t	1.38c-g	26.97i-t	2.70m-u	10.64b-f
Kıraç-66	54.30f-o	71.40e-p	1.22l-u	2.96h-v	2.25l-u	0.66g-s	23.48k-v	2.41m-v	15.28a
Kenanbey	58.10e-n	76.20d-m	1.66h-n	5.14d-n	3.23g-p	0.89f-n	32.78e-m	3.37e-n	10.07c-p
Flamura-85	63.80d-j	77.90a-k	1.86e-m	5.35d-m	4.99a-e	0.85f-p	48.33a-c	4.58a-f	10.72b-e
Momtchill	61.40d-l	74.30d-o	1.96e-l	7.22a-i	5.00a-d	2.52a	49.40ab	4.35b-i	12.03b
Bayraktar-2000	48.60h-r	63.80g-t	1.37i-r	3.48g-u	2.72j-t	1.09e-k	25.98j-u	3.11g-t	9.88c-r
Tosunbey	49.50g-q	62.60j-u	1.29l-u	4.01g-t	3.10i-q	0.84f-q	28.55h-q	3.20g-r	9.26c-u
Pandas	62.40d-k	75.20d-n	1.60h-o	5.08d-o	3.40f-m	2.19a-b	31.95f-o	3.26f-p	10.55b-g
Pehlivan	48.60h-s	64.80g-s	1.57h-q	4.25g-r	2.90j-r	1,21c-j	27.07i-s	3.35e-o	10.46b-h
Demir-2000	53.30f-p	65.50g-r	3.07a	4.26g-q	2.84j-s	1.01e-m	27.41i-r	3.23f-q	9.00c-v
Gün-91	59.50d-m	70.50f-q	1.58h-p	4.46f-p	3.54d-l	0.67g-r	33.17e-l	3.66c-m	9.77c-s

Table 4.3. Differences among 12 wheat (*Triticum aestivum* L.) cultivars and 10 einkorn wheat populations under cold stress: control, 2, 0, -2, -4, -6, and -8 °C (cont'd)

Cultivars/ Populations	GR+	GP	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Population-1	88.10ab	92.90a	2.91a-d	8.20a-e	5.28a-b	1.66b-f	45.03a-e	4.88a-d	9.99c-q
Population-2	87.10a-c	83.80a-f	2.80a-e	8.25a-d	4.50a-i	1.37c-h	39.17a-i	4.30b-j	10.87bc
Population-4	82.40a-c	88.60a-d	2.94a-c	9.47a	5.17a-c	1.48c-f	44.18a-h	5.07ab	9.67c-t
Population-5	90.50a	92.90ab	2.65a-g	7.67a-g	4.94a-f	1,20c-j	44.66a-f	4.94a-c	10.15b-n
Population-6	87.60ab	91.40a-c	2.98ab	9.33a-b	5.62a	2.49ab	50.77a	5.79a	10.28b-k
Population-9	71.40a-g	80.20a-h	2.26a-k	7.42a-h	4.08a-k	1.96a-c	36.35b-k	4.30b-k	10.30b-j
Population-10	80.00a-e	86.20a-e	2.28a-j	6.50a-k	3.40f-n	1,32c-i	31.38g-p	4.36b-h	10.19b-m
Population-11	75.70a-g	79.50a-i	2.31a-I	8.08a-f	4.14a-j	1.95a-d	37.69a-j	4.70a-e	10.32b-j
Population-14	81.40a-d	82.90a-g	2.24a-k	6.35a-l	3.38g-p	1.08e-l	32.18e-n	4.38b-g	10.10c-o
Population-15	71.00a-h	76.40c-l	2.66a-f	9.07a-c	4.73a-h	1.76a-f	41.27a-h	0.64y	10.26b-l

Table 4.3. Differences among 12 wheat (*Triticum aestivum* L.) cultivars and 10 einkorn wheat populations under cold stress: control, 2, 0, -2, -4, -6, and -8 °C (cont'd)

Cultivars/ Populations	GR†	GP	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Decrease %B. Wheat	**31.42**	**20.75**	**60.26**	**51.80**	**55.00**	**73.41**	**47.40**	**47.37**	**41.09**
Decrease % Population	**21.54**	**17.76**	**24.83**	**32.95**	**39.50**	**56,62**	**38.19**	**88.94**	**11.03**
Decrease % Overall	**48.40**	**34.66**	**57.98**	**63.25**	**59.96**	**73.85**	**48.83**	**88.95**	**41.09**

† GR:Germination rate, GP:Germination Power, CL:Coleoptile Length, SL:Shoot Length, RL:Root Length, SRLR:Shoot-Root Length Ratio, RFW: Root Fresh Weight, RDW: Root Dry Weight, RFDWR: Root Fresh-Dry Weight Ratio

4.1.1.2 Cold tolerance indices

Population-6, Population-1, Population-4, Population-2, Population-5, and İkizce-96 were tolerant; Bayraktar-2000, Tosunbey, Kiraç-66, İkizce-96, Pehlivan, and Demir-2000 were susceptible (Table 4.4).

Table 4.4. Indices for overall cold evaluation of wheat entries from different germination characters which grouped entries into tolerant, moderate, and susceptible

Cultivar/ Populations	Cold tolerance indices	Stress Susceptibility Index	Stress Tolerance Index	Mean productivity	Geometric mean productivity
TOLERANT					
Population-6	2.89	0.12	0.97	17.14	9.83
Population-1	5.44	0.12	0.97	16.33	9.83
Population-4	6.11	0.13	0.97	14.64	9.50
Population-2	6.56	0.24	0.93	14.49	9.66
Population-5	6.56	0.12	0.97	17.60	9.83
Momtchill	7.56	0.73	0.80	19.93	8.94
MODERATE					
Population-11	7.78	-0.02	0.83	14.75	9.13
Gerek-79	8.22	0.85	0.77	17.75	8.76
Population-9	9.33	0.73	0.80	14.44	8.94
Population-15	9.56	0.49	0.87	14.89	9.31
Flamura-85	9.78	1.83	0.50	18.70	7.07
Population-10	10.78	0.73	0.80	14.14	8.94
Population-14	11.44	0.88	0.76	15.93	8.42
Pandas	12.44	0.98	0.73	13.71	8.56
Kenanbey	15.33	1.59	0.57	15.73	7.53
Gün-91	15.56	0.85	0.77	16.14	8.76
SUSCEPTIPLE					
Demir-2000	16.33	0.76	0.79	14.59	8.61
Pehlivan	16.78	2.40	0.34	17.76	5.68
İkizce-96	17.78	2.32	0.37	17.24	6.06
Kıraç-66	18.44	2.07	0.43	14.33	6.58
Tosunbey	19.11	1.46	0.60	17.30	7.75
Bayraktar-2000	19.22	2.02	0.45	15.32	6.47

4.1.1.3 Correlation among germination characters under cold stress

Pearson linear correlation coefficients (r; Kalaycı, 2006) among GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR under cold stress levels of control, 2, 0, -2, -4, -6, and -8°C reflected linear significant correlations at different significance levels (Table 4.5) Those showed highly significant linear relationships, their r ranged between 0.900-1.000, existed among RL-SL, RL-RFW, and RDW-RFW.

Under cold stress, Spearman correlation coefficients were highly significant between GR-GP, GR-CL, GR-SL, GR-RL, GR-RFW, GR-RDW, GP-CL, GP-SL, GP-RL, GP-RFW, GP-RDW, CL-SL, CL-RL, CL-SLRLR, CL-RFW, CL-RDW, SL-RL, SL-SLRLR, SL-FW, SL-RFDWR, RL-SRLR, RL-RFW, RL-RDW, SRLR-RFW, SRLR-RDW, and SRLR-RFDWR. Also, Spearman correlation coefficients were mostly not correlated between characters except CL-SL (0.77), Cl-SRLR (0.62), SL-RL (0.80), RL-RFW (0.94), and SL-RDW (0.87), (P<0.01), and RFW-RDW (0.45), RFW-RFDWR (0.45), and RL-RFDWR (0.52), (P<0.05) without cold stress.

Those higher Pearson and Spearman relationships among root characters might indicate the importance of these root characters against cold stress during germination. Those linear significant relationships, of which their r ranged between 0.700-0.890, occurred among GR-SL and GP-RL. Those lower linear relationships, of which their r happened to be between 0.260-0.490 existed among GR-CL, GP-CL, and CL-SRLR. No linear relationships, of which their r was between 0.000-0.250, did exist among GR-RFDWR, GP-RFDWR, CL-RFDWR, SL-RFDWR, RL-RFDWR, SRLR-RFDWR, RFW-RFDWR, and RDW-RFDWR. Those higher number of no relationship among many characters may reflect the difficulties in cold tolerance studies germination characters.

Table 4.5. Pearson correlation coefficients among the GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR under cold stress

Characters	GR†	GP	CL	SL	RL	SRLR	RFW	RDW
RFDWR	0.08	0.09	0.02	0.05	0.08	0.03	0.07	0.03
RDW	0.78	0.79	0.56	0.98	0.98	0.68	0.99	-
RFW	0.77	0.77	0.55	0.99	0.99	0.67	-	
SRLR	0.54	0.58	0.39	0.67	0.67	-		
RL	0.78	0.78	0.60	1.00	-			
SL	0.78	0.78	0.60	-				
CL	0.49	0.49	-					
GP	0.91							

† GR: Germination rate, GP: Germination Power, CL: Coleoptile Length, SL: Shoot Length; RL: Root Length, SRLR: Shoot-Root Length Ratio, RFW: Root Fresh Weight, RDW: Root Dry Weight, RFDWR: Root Fresh-Dry Weight Ratio.

4.1.1.4 Principal component analysis (PCA)

A PC coefficient is assumed significant if it is ≥0.3 (Hair et al., 1987) although there is no good guidelines about it. Though they were not significant SL (0.156), RL (0.156), RDW (0.156), had the highest values in PC 1; RFDWR (0.99) in PC2; but significant GR (-0.342) in PC3. Cumulative variance of first three PCs summed up to a total of 87.58%. PC1 had a share of 69.24%, PC2 11.15%, and PC3 7.16% in total variation (Table 4.6).

Table 4.6. First three PC coefficients for germination characters, variations by each of them and the total variance explained

Characters	Principal component			Sums of squared	
	1	2	3	% of variance	Cumulative (%)
SL	0.156	-0.028	-0.100	69.24	69.24
SRLR	0.118	-0.049	-0.342	11.15	80.39
CL	0.101	-0.053	10.174	7.18	87.58
GP	0.140	0.065	-0.062		
GR	0.139	0.060	-0.046		
RL	0.156	-0.028	-0.100		
RDW	0.156	-0.044	-0.100		
RFW	0.155	-0.009	-0.112		
RFDWR	0.011	0.990	0.042		

† GR: Germination rate, GP: Germination Power, CL: Coleoptile Length, SL: Shoot Length; RL: Root Length; SRLR: Shoot-Root Length Ratio, RFW: Root Fresh Weight, RDW: Root Dry Weight, RFDWR: Root Fresh-Dry Weight Ratio.

4.1.1.5 Dendograms

An overall dendogram based on averages of 22 wheat samples resulted in two main groups as seen in Figure 4.1. The first main group had 3 sub-groups while the second main group consisted of two subgroups. The first sub-group in the first main group limited to only bread wheat cultivars of İkizce-96, Pehlivan, Bayraktar-2000, Momtchil, and Demir-2000. The second subgroup in the first group had only hulled einkorns of Population-9, Population-11, and Population-2 while the third sub group had of Population-10, Population-14, Kenanbey, Gün-91, Pandas, and Population-15. The second main group also had two subgroups. The first sub-group in the second main group consisted of Population-1, Population-6, and Population-4 while the second sub-group had Gerek-79, Flamura-85, and Momtchil. Population-9 located under the main group 2.

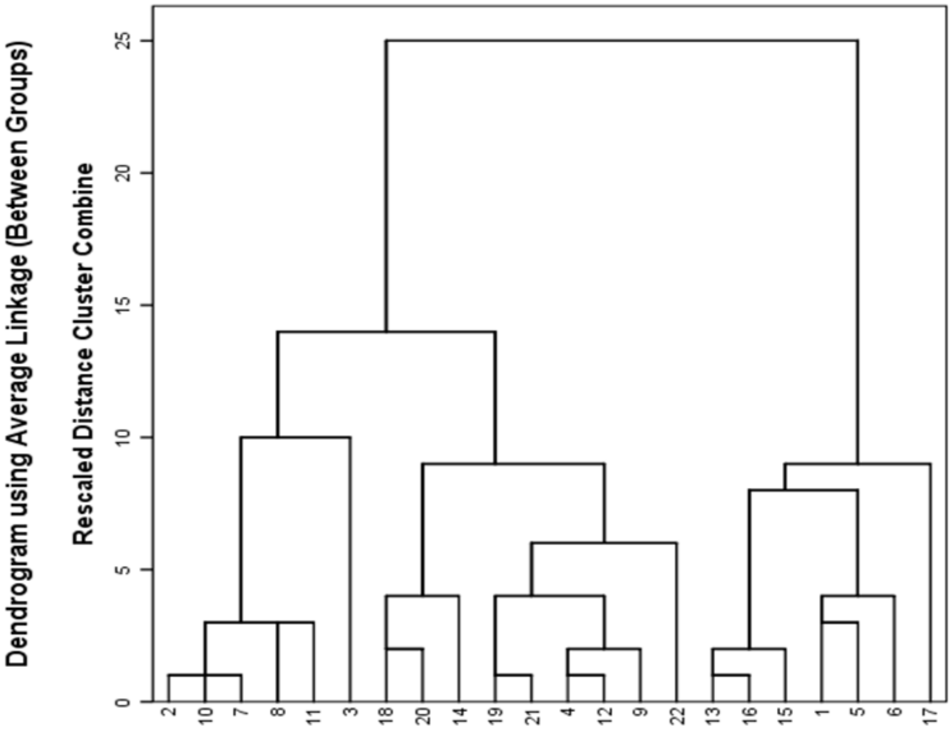

Figure 4.1. Dendogram for both 12 wheat (*Triticum aestivum* L.) cultivars and 10 einkorn (*Triticum monococcum* subsp. *monococcum*) wheat populations (Cold Treatment)

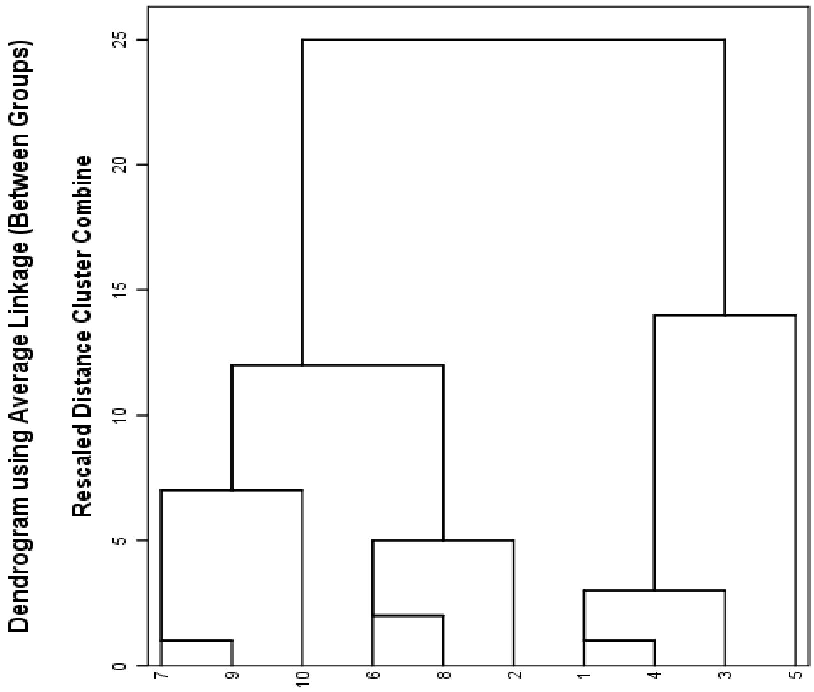

Figure 4.2. Dendogram for 12 bread wheat (*Triticum aestivum* L.) cultivars (Cold Treatment)

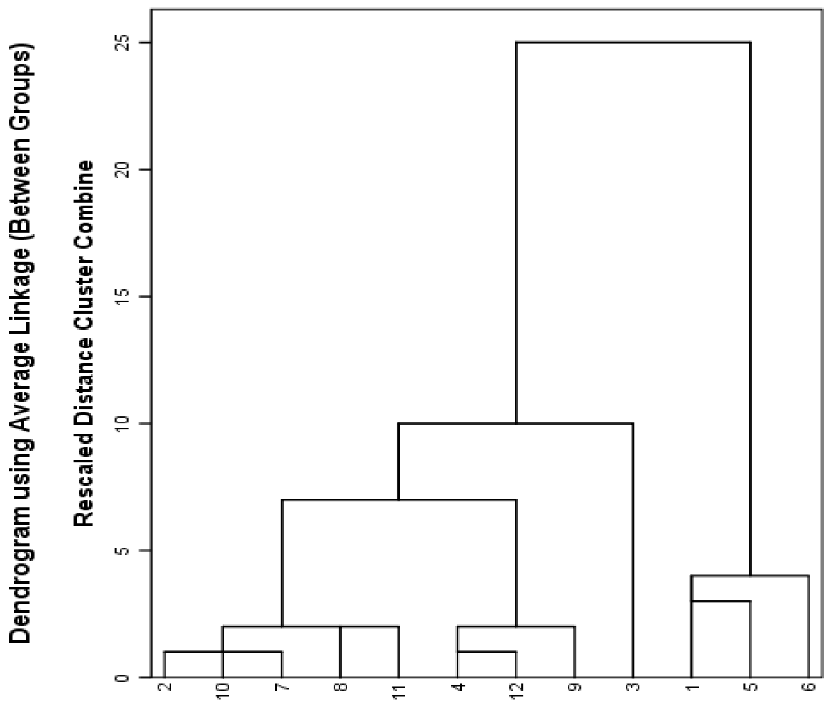

Figure 4.3. Dendogram Dendogram for 10 einkorn (*Triticum monococcum* subsp. m*onococcum*) wheat populations (Cold Treatment)

4.1.2 Discussion

In a study, Mahmoodabad et al. (2011) represented that the lowest germination occurred at 2°C and Gaspard, Sardari, Cascogen, Bezostaja-1, and MV17 cultivars had the highest germination rate with approximately similar shoot length. The shoot lengths were highest at 5°C and lowest at 2°C. Root lengths differences were not significant between samples. Also, Sardari had to the longest coleoptile when Gaspard, Bezostaja-1, and Cascogen followed by MV17 had the lowest coleoptile. The lowest temperature was 2°C. The optimum temperature range was between 2-5°C. The best germination characters were observed at lower temperatures for Bezostaja-1, followed by Sardari.

Cook (1997), Foolad and Lin (1999), and Jones (1986) explained that important differences existed between cultivars during germination stage and early seedling. Chilling temperatures in the cultivated plants ranged 0-12°C during germination, which significantly delayed the onset, decreased the rate, and increased the dispersion of seed germination events (Foolad and Lin, 1997; Foolad and Lin, 1998; Jones, 1986).

Because of environmental stresses, like cold, limited the development of direct-seeded crops. Most common used cultivars of some crops were highly sensitive to cold stress during seed germination while genetic variation, however, existed within the cultivated plants and their related wild species (Foolad and Lin, 1997; Foolad and Lin, 1998; Jones, 1986).

Wheat is a wide range grown crop with the broadest adaptation among all cereal crop species (Heyne, 1987). Cold tolerance in wheat, in a general sense, refers to the performance at the temperatures lower than the ones optimum for growth (about 20ºC). There are significant differences in the growth rate of cultivars at low temperatures and, consequently, in their adaptations to cool climate. The term “cold tolerance” is, however, mostly used to explain a plant’s response to freezing temperatures, under -4ºC.

Cold tolerance indices, which were based on the ranks of cultivars / populations together with other (Ali and El-Sadek, 2016; El-Hendawy et al., 2005; Mahmoodzadeh et al., 2013) indices were calculated to group wheat entries. Cold tolerance indices, as explained by Oyiga et al. (2016), and Zencirci et al. (1990), grouped the samples as tolerant, moderate, and susceptible. (Table 4.4). Stress susceptibility index, stress tolerance index, mean productivity and geometric mean productivity, which were compared by Ali and El-Sadak (2016) did not went along with drought tolerance indices.

The correlation coefficients between grain yield under normal and post-anthesis water stress for crown viability under freezing stress (temperatures below zero) were to be negative was studied by Saeidi et al. (2012). Coefficients between grain yield in post-anthesis water stress with crown viability under freezing stress at -3 and -5°C, were high, r=0.86 and r=0.64, respectively. Lower yielding cultivars, particularly at post-anthesis water stress were more resistant to prevailing of freezing stress at early growing season after winter, which suggested that higher yielding cultivars for post-anthesis water stress also had to be more resistant to freezing stress at early growing season.

And there is no dendogram of germination characters in wheat has been represented in the literature before so the comparison of the results of this study with previous studies was not possible same as comparing of PC values.

4.2 Drought Stress Treatments

4.2.1 Results

Drought is one of the serious stress factors across all wheat growing regions. This part of the study shows the effect of the drought stress on 12 bread wheat (*T. aestivum* L.) cultivars and 10 einkorn hulled wheat (*T. monoccum* ssp. *monococcum*) populations.

4.2.1.1 Differences between germination stages

Analysis of variance revealed that blocks differed for SL, RL, RFDWR ($P<0.05$), GR, GP, CL, SRLR, RFW, RDW ($P<0.01$), drought levels for all characters ($P<0.01$), and cultivars / populations for GR, GP, CL, RL, RDW, RFDWR ($P<0.01$), and for SRLR and RFW ($P<0.011$). There was no difference in SL for cultivars and populations. Except GR, RL, and RDW ($P<0.01$), no cultivar / population by drought level interactions occurred (Table 4.7).

Table 4.7. F values in analysis of variance for the GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR under drought effect of PEG 600: 0 (Control), 4.57 ml: 0.09M, 9.14 ml: 13.71 ml: 0.17 M, 18.28 ml: 0.25M, 22.85 ml: 0.34M, 25.15 ml: 0.43M, and 27.45 ml: 0.51M.

Sources of variation	DF	GR†	GP	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Blocks	2	10.67**	3.78**	0.07**	8.64 *	3.34 *	0.27**	9.02**	2.97ns	0.67 *
Treatments	153	27.92**	17.87**	1.13**	56.25**	44.18**	5.88**	56.16**	39.53**	13.31**
Cultivar	21	6.18**	3.90ns	0.07**	1.98 *	5.91**	0.62ns	7.68ns	7.11**	1.26**
Levels	6	189.83**	113.06**	8.83**	456.42*	339.71**	37.81**	434.21**	295.62**	100.25**
Cultivar *Levels	126	1.23**	1.20ns	0.03ns	0.71ns	0.72**	0.48ns	0.78ns	0.74**	0.40ns
Error	306									

† GR: Germination Rate, GP: Germination Power, CL: Coleoptile Length, SL: Shoot Length, RL: Root Length, SRLR: Shoot-Root Length Ratio, RFW: Root Fresh Weight, RDW: Root Dry Weight, RFDWR: Root Fresh-Dry Weight Ratio

DF: Degrees of Freedom; *, Significant at the 0.01, **; 0.05 significant at 0.05 probability level, ns no significant

Higher mean of all characters was observed for control group than those under drought. Some characters were higher also at some other lower PEG 600 levels up to 0.25-0.34M. Starting 0.43-0.51M PEG 600, whole characters totally disturbed. The highest decreasing (%) was in SL (100%), SRLR (100%), RFW (100%), CL (98.69%), RDW (97.60%) and the lowest in GP (55.90%) (Table 4.8).

Table 4.8. Differences between for GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR under drought effect of PEG 600 (0 (Control), 0.09M, 0.17 M, 0.25M, 0.34M, 0.43M and 0.51M).

Levels	GR†	GP	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Control	98.50 A	100.00 A	4.08 A	14.08 A	8.64AB	1.89AB	87.26 A	7.60 A-C	11.46 A
0,09M	98.00AB	100.00AB	4.57 AB	12.29 B	9.01 A	3.96 A	86.41AB	9.90 AB	8.71AB
0,17M	94.40A-C	97.60A-C	4.11 A-C	7.37BC	7.48A-C	0.97 B	68.04A-C	9.96 A	6.83A-C
0,25M	90.90A-D	95.20A-D	1.95 A-C	0.74 D	4.49A-C	0.12 B	36.87A-C	6.73 A-C	5.49B-D
0,34M	83.90A-E	87.30A-E	0.33 D	0.00DE	1.85 C	0.00 B	13.78 C	2.94 A-C	4.93B-E
0,43M	63.20A-F	75.50A-F	0.16 D	0.00DE	0.38 C	0.00 B	3.53 C	0.90 C	4.45B-E
0,51M	26.70 F	44.10FG	0.06 D	0.00DE	0.08 C	0.00 B	0.99 C	0.24 C	4.11B-E
% Decrease	72.89	55.90	98.69	100.00	99.07	100.00	98.87	97.60	64.13

† GR=Germination rate; GP=Germination Power; CL=Coleoptile Length; SL=Shoot Length; RL=Root Length; SRLR=Shoot-Root Length Ratio; RFW=Root Fresh Weight; RDW=Root Dry Weight; RFDWR=Root Fresh-Dry Weight Ratio.

The Population-4 (92.90), Population-6 (92.90), Population-5 (91.00), Population-1 (88.60), Population-2 (88.10), Population-9 (86.70), Population-15 (84.80), Gün-91 (83.30), and Population-11 (82.40) showed higher GR while Kıraç-66 (62.90) showed the lowest (Table 4.7). When compared, Population-6 (92.90), Population-5 (91.00), Population-4 (94.30), Population-1 (93.30), Population-9 (86.70), Population-2 (88.10), Gün-91 (83.30), Population-15 (88.60), Population-10 (88.10), Population-14 (78.10), Kenanbey (86.70), and Population-11 (85.70) showed highest GP while Pehlivan (71.90) showed the lowest. Similarly, Bayraktar-2000 (2.73), Kenanbey (2.68), Gün-91 (2.63), Gerek-79 (2.57), Demir-2000 (2.53), Momtchil (2.46), İkizce-96 (2.39), Population-1 (2.37), Population-5 (2.24), and Pehlivan (2.23) showed the longest CL while Population-10 (1.66) showed the lowest. Cultivars and populations did not differ for SL. Bayraktar-2000 (5.97), Gerek-79 (5.79), Kenanbey (5.65), Pandas (5.64), Momtchil (5.55), Tosunbey (5.50), Gün-91 (5.33), Flamura-85 (5.26), İkizce-96 (5.26) and Demir-2000 (4.63) showed the longest RL while the Population-10 (3.20) showed the shortest. Population-5 (1.76) showed the highest SRLR while Flamura-85 (0.64) showed the lowest. Kenanbey (68.46), Bayraktar-2000 (55.87), Momtchil (55.02), Gün-91 (51.55), Tosunbey (51.46), Flamura-85 (50.00), İkizce-96 (48.97), Gerek-79 (47.12), and Pandas (46.14) had the heaviest RFW while Population-10 (27.22) showed the lowest. Kenanbey (7.73), Bayraktar-2000 (7.60), İkizce-96 (6.99), Gün-91 (6.61), Momtchill (6.36), and Flamura-85 (6.25) had the heaviest RDW while the Population-10 (3.76) showed the lightest. Momtchil (7.60), Tosunbey (7.52), Gerek-79 (7.41), Population-9 (7.18), Gün-91 (7.02), Kıraç-66 (6.98), and Flamura-85 (6.97) showed the highest RFDWR while Population-10 (6.10), Population-4 (6.09), Population-5 (6.05), İkizce-96 (6.05), Population-1 (6.05), Population-6 (5.95), and Population-11 (5.85) showed the lowest one.

Table 4.9. Differences between 12 bread wheat cultivars and 10 einkorn wheat populations under the effect of PEG 600: 0 (Control), 4.57 ml: 0.09M, 9.14 ml: 13.71 ml: 0.17M, 18.28 ml: 0.25M, 22.85 ml: 0.34M, 25.15 ml: 0.43M, and 27.45 ml: 0.51M.

Cultivars	GR⁺	GP	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Gerek-79	70.38f-q	80.50g-q	2.57a-d	5.74a-c	5.79ab	0.68k-s	47.12a-h	5.79c-h	7.41a-c
Ikizce-96	76.70d-m	83.30d-m	2.39a-g	5.56a-d	5.26a-i	0.69k-r	48.97a-g	6.99a-c	6.05h-s
Kıraç-66	62.90o-v	76.20l-t	2.01f-n	3.58a-u	3.77j-q	0.68k-r	40.24d-k	5.57c-k	6.98a-f
Kenanbey	78.60c-j	86.70a-k	2.68 ab	5.76ab	5.65a-c	0.73k-p	58.46 a	7.73 a	6.52d-k
Flamura-85	72.90g-s	82.90e-o	1.80i-s	4.08a-s	5.26a-h	0.64l-t	50.00a-f	6.25 a-f	6.97a-g
Momtchil	75.20e-o	82.90e-p	2.46a-f	4.94a-m	5.55a-e	0.76i-n	55.02a-c	6.36 a-e	7.60 a
Bayraktar-2000	78.10c-l	83.30d-n	2.73 a	5.47a-f	5.97 a	0.76i-n	55.87 ab	7.60 ab	6.36d-n
Tosunbey	73.80f-p	80.00g-r	1.81i-r	3.60a-u	5.50a-f	0.69k-r	51.46a-e	5.87b-g	7.52 ab
Pandas	73.30g-r	79.00g-s	1.86h-q	5.30a-h	5.64a-d	0.83i-m	46.14a-i	5.76c-j	6.42d-l
Pehlivan	66.20j-u	71.90q-v	2.23a-j	4.74a-o	4.34c-k	0.91e-l	37.44f-p	4.58f-q	6.61c-I
Demir-2000	70.00j-t	75.70l-u	2.53a-e	6.34 a	4.63a-j	1.04c-j	44.32b-j	5.76 c-I	6.52d-j
Gün-91	83.30a-h	89.00a-g	2.63a-c	4.79a-n	5.33a-g	0.95d-k	51.55a-d	6.61a-d	7.02a-e

Table 4.9. Differences between 12 bread wheat cultivars and 10 einkorn wheat populations under the effect of PEG 600: 0 (Control), 4.57 ml: 0.09M, 9.14 ml: 13.71 ml: 0.17 M, 18.28 ml: 0.25M, 22.85 ml: 0.34M, 25.15 ml: 0.43M, and 27.45 ml: 0.51M (cont'd)

Cultivars	GR[+]	GP	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Population-1	88.60a-d	93.30a-d	2.37a-i	5.46a-f	3.82h-p	1.09b-i	38.65d-m	5.21d-l	6.05h-t
Population-2	88.10a-e	91.90a-f	2.04e-m	5.15a-j	3.69j-r	1.14b-f	32.62i-t	4.19g-t	6.65c-h
Population-4	92.90 a	94.30a-c	2.09d-k	5.12a-k	3.96f-n	1.12b-h	34.13h-r	4.66e-p	6.09h-q
Population-5	90.00a-c	94.80ab	2.24a-i	5.25a-i	3.91h-o	1.76 a	37.68f-o	5.13d-m	6.05h-r
Population-6	92.90 ab	95.70 a	2.15c-k	5.02a-l	4.19e-m	1.14b-g	38.61d-e	4.88d-n	5.95h-u
Population-9	86.70 a-f	92.40a-e	2.07d-l	5.39a-g	4.24e-l	1.23b-d	39.62d-l	4.86e-o	7.18a-d
Population-10	76.20d-n	88.10a-i	1.66k-u	3.95a-t	3.20k-u	1.17b-e	27.22k-v	3.76l-v	6.10h-p
Population-11	82.40a-i	85.70a-l	1.72k-t	4.18a-r	3.46j-t	1.24 b	29.44j-u	4.07h-u	5.85h-v
Population-14	78.10c-k	88.10a-j	1.89g-p	4.41a-q	3.67j-s	1.24bc	34.68h-q	4.41g-r	6.23e-o
Population-15	84.80a-g	88.60a-h	1.99f-o	4.55a-p	3.54j-t	1.35 b	33.80h-s	0.64 y	6.40d-m
Decrease % Bread wheat cultivars	**24.48**	**19,21**	**30.97**	**37.84**	**36.85**	**32.63**	**35.95**	**39.73**	**19.34**
Decreaese % Einkorn Populations	**15.93**	**9.65**	**29.95**	**1,28**	**24.52**	**31.81**	**31,29**	**87,71**	**18,52**
Decrease % Overall	**32.29**	**24.87**	**39.19**	**43.53**	**46,39**	**63.63**	**53.44**	**51.36**	**23.02**

[+] GR=Germination rate; GP=Germination Power; CL=Coleoptile Length; SL=Shoot Length; RL=Root Length; SRLR=Shoot-Root Length Ratio; RFW=Root Fresh Weight; RDW=Root Dry Weight; RFDWR=Root Fresh-Dry Weight Ratio

4.2.1.2 Correlation among germination characters under drought stress

Pearson linear correlation coefficients (r; Kalaycı 2006) between GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR were significant at different levels (Table 4.10.a).

Table 4.10.a. Pearson correlation coefficients between GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR under drought stress

Characters	GR+	GP	CL	SL	RL	SRLR	RFW	RDW
RFDWR	0.419	0374	0.708	0.812	0.747	0.621	0.783	0.915
RDW	0.674	0.650	0.893	0.722	0.924	0.513	0.915	-
RFW	0.636	0.605	0.923	0.889	0.976	0.633	-	
SRLR	0.413	0.381	0.687	0.758	0.610	-		
RL	0.655	0.621	0.915	0.857	-			
SL	0.525	0.488	0.877	-				
CL	0.627	0.593	-					
GP	0.926	-						

Those highly linear significant relationships, of which their r ranged between 0.900-1.000, existed among GR-GP, CL-RFW, CL-RL, RL-RDW, RL-RFW, and RFW-RDW. Those linear significant relationships, of which their r ranged between 0.700-0.890, occurred only between CL-RDW. Those lower linear relationships, of which their r happened between (0.260-0.490) existed between GR-RFDWR, GR-SRLR, and GP-RFDWR, GP-SRLR, GP-SL, and RL-RFDWR. No lowest linear relationships, of which their r was between (0.000-0.250), did exist among any of the character pairs. Spearman correlation coefficients between GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR both with and without drought stress were calculated (Table 4.10.b) as well. Under drought stress, GR-GP, CL-RDW, CL-RFW, CL-SRLR, CL-RL, SL-RFDWR, SL-RFW, SL-RL, RL-RDW, RL-RFW were positively GP-SRLR negatively correlated (P<0.01). Without drought stress, few characters were correlated: SL-RFDWR, RL-RDW, RL-RFW (P>0.01) GR-CL, RFW-RFDWR, RFW-RDW (P<0.05) were positively; RL-SRLR, SRLR-RFW were negatively correlated (P<0.05).

Table 4.10.b. Spearman correlation coefficients between GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR under drought and control (no-drought)

Characters	GR[†]	GP	CL	SL	RL	SRLR	RFW	RDW
UNDER DROUGHT								
RFDWR	-0.26††	-0.12	0.20	0.86	0.50	0.22	0.46	0.18
RDW	-0.13	-0.10	0.83	-0.01	0.67	0.47	0.46	
RFW	-0.14	0.08	0.62	0.63	0.86	0.38	-	
SRLR	-0.45	-0.67	0.73	0.35	0.56	-		
RL	-0.17	-0.30	0.61	0.83	-			
SL	-0.18	-0.46	0.84	-				
CL	-0.12	-0.29	-					
GP	0.70	-						

Table 4.10.b. Spearman correlation coefficients between GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR under drought and control (no-drought) (cont'd)

Characters	GR†	GP	CL	SL	RL	SRLR	RFW	RDW
CONTROL								
RFDWR	0.36††	-0.28	0.16	0.86	0.32	-0.33	0.44	0.02
RDW	-0.37	0.23	-0.09	-0.08	0.79	-0.36	0.44	-
RFW	-0.15	0.13	-0.01	-0.24	0.86	-0.47	-	
SRLR	0.22	0.01	0.41	-0.25	-0.45	-		
RL	-0.09	0.14	-0.11	0.27	-			
SL	0.34	-0.05	0.57	-				
CL	0.46	0.03	-					
GP	0.16	-						

† GR=Germination rate; GP=Germination Power; CL=Coleoptile Length; SL=Shoot Length; RL=Root Length; SRLR=Shoot-Root Length Ratio; RFW=Root Fresh Weight; RDW=Root Dry Weight; RFDWR=Root Fresh-Dry Weight Ratio.

†† Significance at 0.01 is 0.549 and at 0.05 is 4.33.

4.2.1.3 Principal Component Analysis (PCA)

A PC coefficient is significant if it is ≥0.3 (Hair et al., 1987) although there is no clear guidelines about it. RL (0.378), RDW (0.494), and RFW (0.354) formed PC 1; SL (0.305), and SRLR (0.822), RFDWR (0.359) PC2; GP (0.622), and GR (0.593) PC3. Cumulative variance of first three PCs summed up to a total of 92.254%. PC1 had a share of 73.491%, PC2 12.666%, and PC3 6.097% in total variation (Table 4.11).

Table 4.11. First three PC coefficients for germination characters, variations by each of them, and the total variance explained.

Characters	Principal component			Sums of squared	
	1	2	3	% of variance	Cumulative %
SL	0.038	0.305	-0.105	73.491	73.491
SRLR	-0.513	0.822	0.092	12.666	86.157
CL	0.257	-0.019	-0.062	6.097	92.254
GP	-0.248	-0.015	0.622		
GR	-0.235	0.003	0.593		
RL	0.378	-0,160	-0,083		
RDW	0.494	-0.385	-0.027		
RFW	0.354	-0.107	-0.103		
RFDWR	-0.012	0.359	-0.166		

† GR=Germination rate; GP=Germination Power; CL=Coleoptile Length; SL=Shoot Length; RL=Root Length; SRLR=Shoot-Root Length Ratio; RFW=Root Fresh Weight; RDW=Root Dry Weight; RFDWR= Root Fresh-Dry Weight Ratio.

4.2.1.4 Dendograms

An overall dendogram based on the averages of 22 entries resulted in two main groups (Figure 4.4). There were two 2 sub-groups for each group.

The first main group had all einkorn populations, Kıraç-66, and Pehlivan. Population-13, Population-17, Population-16, Population-18, Kıraç-66 and Population-10 were in the first subgroup of main group 1. Population-21, Population-22, Population-15 and Population-14 were in the second subgroup of main group 1. Population-19 and Population-20 were the third subgroup of main group 1.

The second main group had only bread wheat cultivars: Gerek-79, İkizce-96, Kenanbey, Flamura-85, Momtchil, Bayraktar-2000, Tosunbey and Demir-2000 (Figure 4.4). Bread wheat cultivars, based on the averages, formed two main dendograms. Gerek-79, Pandas and Demir-2000 settled in the first sub - group of the main dendogram 1. Flamura-85, Tosunbey, Gün-91 and İkizce-96 were in the second, and Momtchil, Bayraktar-2000 and İkizce-96 in the third subgroup of main dendogram 1 (Figure 4.5). Einkorn populations (Figure 4.6) fitted into three sub groups. Population-21, Population-1, Population-5, Population-4 and Population-9 were in the first sub-sub-group; Population-14, Population-15 and Population-4 were in the second sub-sub-group and Population-10 and Population-11 were the third sub group.

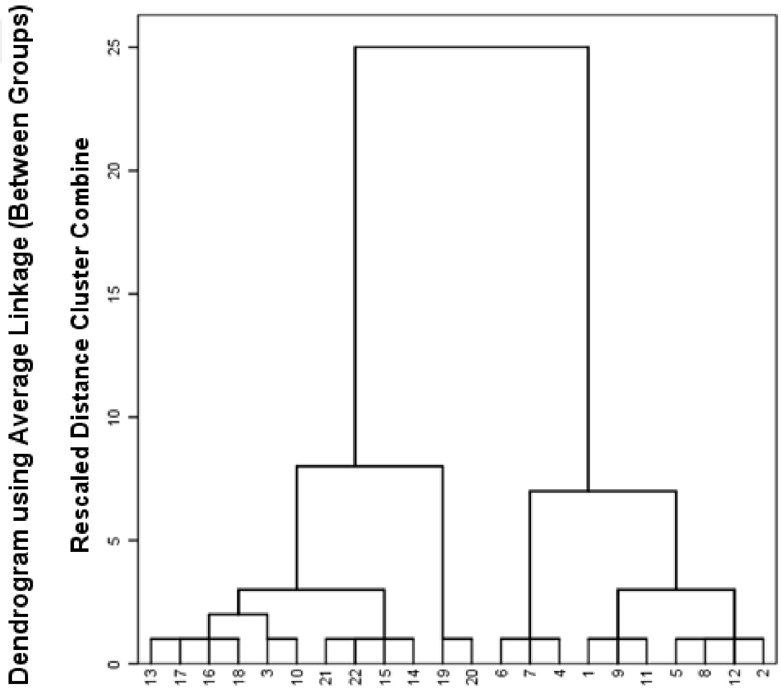

Figure 4.4. Dendogram for both 12 wheat (*Triticum aestivum* L.) cultivars and 10 einkorn (*Triticum monococcum* subsp. *monococcum*) wheat populations (Drought Treatment)

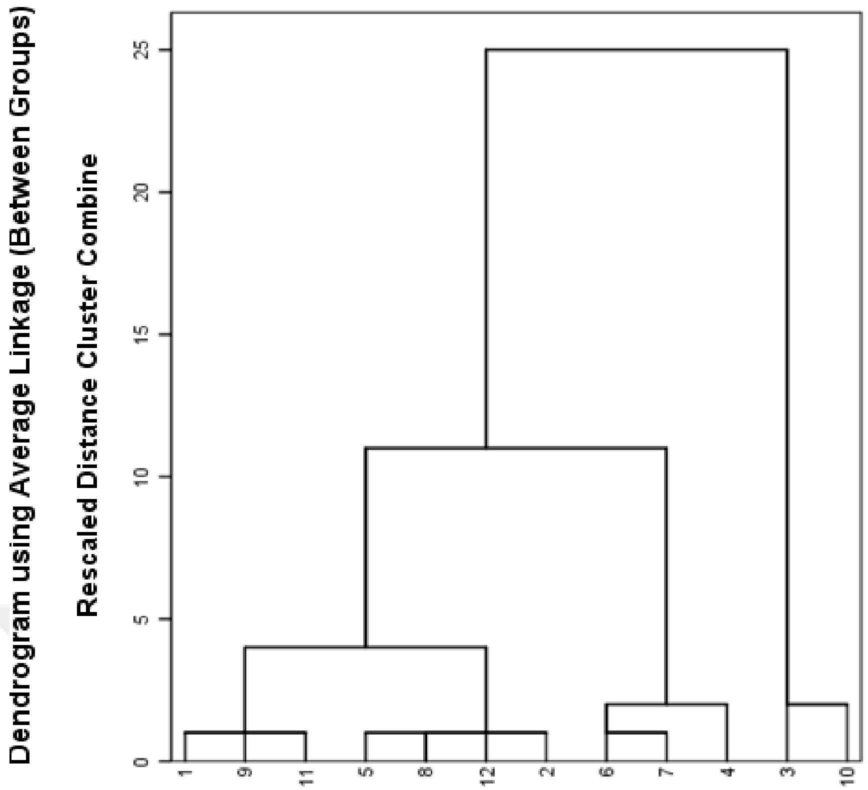

Figure 4.5. Dendogram for 12 bread wheat (*Triticum aestivum* L.) cultivars Drought Treatment)

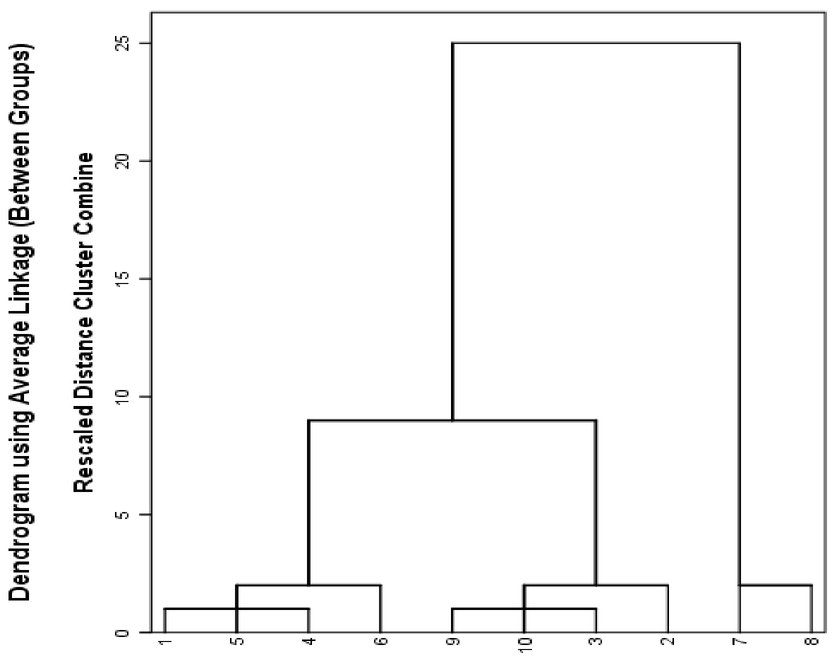

Figure 4.6. Dendogram for 10 einkorn (*Triticum monococcum* subsp. m*onococcum*) wheat populations (Drought Treatment)

4.2.2 Discussion

Previous studies represents some similar and differ results to what we found in this study. Under low water conditions (drought stress), the observations of Sapra et al.(1991), Kumar and Singh (1998), and Dhanda et al.(2004) showed that wheat genotypes have different germination percentages. Öztürk et al. (2016) showed in a study, the average germination was dramatically reduced from 94.9% to 67.7% under -5 bar osmotic potential. Germination time and percentage decreased in wheat (Lafond and Fowler, 1989; Dhanda et al.2004; Razzaq et al.2013). RL, RFW, and RDW decreased (Dhanda et al., 2004; Rauf et al., 2007; Ahmadizadeh et al., 2011; Baloch et al., 2012) with increasing in drought stress. RL reduced from 45.55 to 64.91% under –0.6 and –0.8 MPa treatments (Rauf et al., 2007). Also, similarly RL values reduced from a 53.8 - 74.4% in wheat genotypes (Baloch et al., 2012; Dhanda et al., 2004).

The drought tolerance indice, which was based on the ranks of cultivars / populations together with other (El - Hendawy et al.2005; Mahmoodzadeh et al., 2013; Ali and El – Sadek, 2016) indices were calculated to group wheat entries. Drought tolerance indice, as reported by Zencirci et al. (1990) and Oyiga et al. (2016) grouped the entries as tolerant, moderate, and susceptiple (Table 4.12). As seen from the Table 4.10, Kenanbey, Bayraktar - 2000, Gün 91, Momtchill, Population - 9 and İkizce - 96 were tolerant; Pehlivan, Flamura - 85, Population - 14, Kıraç - 66, Population - 11 and Population - 10 were susceptible. Stress susceptibility and tolerance index, mean and geometric mean productivity were compared according to Ali and El - Sadak (2016) were not related with the drought tolerance indices.

Table 4.12. Indices for overall drought evaluation of wheat entries from different germination characters, which grouped entries into tolerant, moderate, and susceptible

Cultivar/ Populations	Drought tolerance indices	Stress susceptibility index	Stress tolerance index	Mean productivity	Geometric mean productivity
TOLERANT					
Kenanbey	6.67	0.87	0.93	21.05	9.66
Bayraktar	7.33	0.00	1.00	18.18	9.67
Gün-91	7.44	0.87	0.93	18.51	9.66
Momtchill	9.00	1.30	0.90	20.30	9.49
Population-9	9.00	0.87	0.93	16.12	9.66
Ikizce	9.00	1.39	0.89	18.63	8.82
MODERATE					
Gerek-79	9.22	1.30	090	17.84	9.49
Population-5	9.78	0.43	0.97	15.98	9.83
Demir-2000	9.89	1.34	090	17.59	915
Population-1	10.33	0.87	0.93	17.49	9.66
Population-6	10.67	0.00	1.00	17.96	10.00
Population-4	11.33	0.00	1.00	15.55	10.00
Population-2	12.22	0.87	093	14.69	9.66
Pandas	12.44	1.30	090	18.53	9.49
Tosunbey	12.78	2.17	0.83	19.14	9.13
Population-15	13.78	0.00	1.00	15.33	10.00
SUSCEPTIPLE					
Pehlivan	14.00	1.79	0.86	16.36	8.98
Flamura85	14.00	0.93	0.93	18.24	8.99
Population-14	14.22	0.45	0.97	16.17	9.50
Kıraç-66	16.22	1.86	0.86	1611	8.64
Population-11	16.56	-0.08	0.90	14.82	9.49
Population-10	17.11	2.17	0.83	13.88	9.13

Shoot lengths, which were highly affected by stress (Baloch et al., 2012), showed significant differences (57.5-68.4%) under drought stress conditions (Dhanda et al., 2004; Naylor and Gurmu, 1990; Rauf et al., 2007). SL was the plant characteristic property under stress (Jajarmi, 2009). And also, had positively correlated with GR, RL, and (Rauf et al.2007). The CL in older seed and coleoptile emergence in general were restricted under low water potential (Naylor and Gurmu, 1990). Wheat genotypes, as expected, responded differently against drought stress and their developments decreased 70.02-85.34% at -0.6 MPa and -0.8 MPa compared to no stress (Ahmadizadeh et al., 2011). A longer coleoptile, which was expected to play a significant role in seedling establishment (Baloch et al., 2012) was observed. Shoot length and seed vigour index decreased (Dhanda et al., 2004; Naylor and Gurmu, 1990; Öztürk et al., 2016), which indicated greater susceptibility of shoot than root length.

Not many correlation coefficients have been calculated in the previous studies, comparison, therefore, was hardly possible. Dhanda et al. (2004) found that genotypic correlations were calculated higher than the phenotypic ones in the same direction, which indicated the inherent associations amongst various characters. Root-to-shoot length ratio (Sharma and Lafever, 1992; Siddique et al., 1990) showed weak relationships with other traits under normal conditions, but under osmotic stress it was negatively correlated with shoot length (r=0.42, P<0.01) and membrane thermal stability (r=0.42, P<0.05), which indicated that the under soil part of the plants played a significant role under drought stress. In this study, characters were much more and highly correlated under stress than under no-stress conditions.

4.3 Salt Stress Treatments

4.3.1 Results

Salinity affects the crops mostly, reduce the growing of the crops and yield. Understanding the effect of salinity on plants is necessary to protect wheat species from the effects of it. This part of the study shows the effect of the salt stress on twelve bread wheat (*T. aestivum* L.) cultivars and 10 einkorn hulled wheat (*T. monoccum* ssp. *monococcum*) populations.

4.3.1.1 Differences between germination stages

Analysis of variance (ANOVA) for three replicate factorially restricted randomized block design (Table 4.13) represented that means for all treatments were highly significant (P<0.01). The entries of 12 bread wheat and 10 einkorn wheat were meaningfully differentiated for GR, CL, SL, RL, FW, RDW, and RFDWR but GP and SRLW (P<0.01), when the effects of the salt concentrations were separated from. Salt concentrations of 5 ml: 0 (control), 0.05M., 0.10 M., 0.15M., 0.20M., 0.25M., and 0.30M were also highly significant for all germination characters studied (P<0.01): GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR. There was no cultivar by salt concentration interaction existed for any germination character. Blocks for GR, GP, CL, SL, RL, SRLR were highly significant (P<0.01), for RFW significant and RFDWR (P<0.05), and for RDW non-significant.

Table 4.13. F values in analysis of variance for GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR under salt; sodium chloride (NaCl) concentrations of 5 ml: 0 (control), 0.05M., 0.10 M., 0.15M., 0.20M., 0.25M., and 0.30M) stress.

Sources of variation	DF	GR†	GP	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Blocks	2	36.50**	34.10**	7.17**	6.75**	8.87**	7.90**	4.08*	0.42ns	3.65*
Treatment	153	8.25**	7.13**	26.90**	27.50**	17.26**	15.83**	22.88**	18.15**	5.29**
Cultivar	21	2.57**	0.57^{ns}	5.29**	2.21*	4.00**	1.04^{ns}	6.91**	5.22**	3.12**
Doses	6	50.29**	52.35**	188.57**	210.13**	124.36**	61.22**	157.65**	129.64**	24.42**
Cultivar *Doses	126	0.34^{ns}	0.31^{ns}	1.03^{ns}	0.76^{ns}	0.40^{ns}	0.51^{ns}	0.60^{ns}	0.30^{ns}	0.46^{ns}
Error	306									

† GR: Germination Rate, GP: Germination Power, CL: Coleoptile Length, SL: Shoot Length, RL: Root Length, SRLR: Shoot-Root Length Ratio, RFW: Root Fresh Weight, RDW: Root Dry Weight, RFDWR: Root Fresh-Dry Weight Ratio

DF: Degrees of Freedom; *, Significant at the 0.01, **; 0.05 significant at 0.05 probability level, ^{ns} no significant.

Differences existed among GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR under 5 ml of 0 (control), 0.05M., 0.10M., 0.15M, 0.20M., 0.25M., and 0.30M NaCl concentrations, as revealed by F tests were separated by least significant difference (LSD) to most extent. The highest values were always for control (0 ml salt) group. The highest GR and GP development was induced by 0-0.20M salt doses range; CL, SRLR, RFW, and RDW between 0-0.15M; SL and RFDWR between 0-0.20M. GR, GP, and RFDWR worsened at 0.25M. CL, SRLR, RFW, and RDW at 0.20M, and GP and RFDWR at 0.25M (Table 4.14).

Table 4.14. Differences among for GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR under salt; sodium chloride (NaCl) concentrations of 5 ml: 0 (control), 0.05M., 0.10 M., 0.15M. 0.20M., 0.25M., and 0.30M) stress.

Salt doses	GR†	GP	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Control	9.89^{A}	10.00^{A}	4.09^{A}	12.35^{A}	7.70^{A}	10.00^{A}	76.24^{A}	7.11^{A}	11.27^{A}
0.05	9.49^{AB}	9.99^{AB}	3.88^{AB}	10.00^{B}	5.70^{AB}	9.98^{AB}	65.88^{AB}	6.12^{AB}	11.22^{AB}
0.10	9.36^{A-C}	9.59^{A-C}	2.96^{A-C}	5.47^{C}	4.00^{A-C}	9.59^{A-C}	48.34^{A-C}	4.81^{A-C}	10.70^{A-C}
0.15	8.76^{A-D}	9.04^{A-D}	2.06^{A-D}	2.16^{D}	2.39^{B-D}	9.05^{A-D}	32.30^{A-D}	3.52^{A-D}	9.82^{A-D}
0.20	7.67^{A-E}	8.41^{A-E}	1.11^{C-E}	0.50^{E}	1.30^{B-E}	8.41^{D-E}	19.36^{B-E}	2.37^{B-E}	8.29^{A-E}
0.25	6.30^{B-F}	7.39^{C-E}	0.44^{C-F}	0.07^{E}	0.75^{C-F}	7.39^{E-F}	12.03^{C-F}	1.66^{C-F}	7.95^{C-F}
0.30	5.07^{E-G}	6.06^{E-G}	0.24^{C-G}	0.00^{E}	0.38^{C-G}	6.06^{F-G}	5.92^{C-G}	1.00^{C-G}	6.99^{D-G}

† GR= Germination rate; GP=Germination Power; CL=Coleoptile Length; SL=Shoot Length; RL=Root Length; SRLR= Shoot-Root Length Ratio; RFW= Root Fresh Weight; RDW= Root Dry Weight; RFDWR=Root Fresh-Dry Weight Ratio.

Differences among Gerek-79, İkizce, Kıraç-66, Kenanbey, Flamura-85, Momtchill, Bayraktar-2000, Tosunbey, Pandas, Pehlivan, Demir-2000, Gün-91, Population-1, Population-2, Population-4, Population-5, Population-6, Population-9, Population-10, Population-11, Population-14, and Population-15, as apparent by F tests, existed for all germination characters. Differences were grouped by LSD (Table 4.15). Population-14, Population-1, Gün-91, Population-5, Population-6, Gerek-79, Kenanbey, Population-4, Population-15, Population-2, and İkizce-96 showed the highest GR while Pehlivan and Bayraktar-2000 showed the lowest (P<0.05). Gün-91, Bayraktar-96, Population-1, Population-6, and Population-14 showed the highest GP while Pehlivan and Population-10 showed the lowest (P<0.05). Gerek-79, Momtchill, Demir-2000, Bayraktar-96, and Pehlivan showed the highest CL, Population-9, Population-10, and Tosunbey showed the lowest (P<0.05). Bayraktar-2000, Demir-2000, İkizce, and Pehlivan had the highest SL, Population-10 and Population-14 had the lowest (P<0.05). Bayraktar-2000, Gerek-79, İkizce, Gün-91, Pehlivan, and Tosunbey had the highest RL, Population-9 and Population-10 had the lowest (P<0.05). Population-2, Population-4, Population 5, Population-1, İkizce, and Bayraktar-2000 had the highest SRLR, Population-10, Population-11, Population-15, and Tosunbey had the lowest (P<0.05). Bayraktar-2000, Gün-91, İkizce-96, Gerek-79, Demir-2000, Tosunbey, Momthcill, and Flamura-85, and Population-5 had the highest RFW while Population-11, Population-9, and Population-10 had the lowest (P<0.05). Bayraktar-2000, Gün-91, İkizce-96, Gerek-79, Demir-2000, Tosunbey, and Momtchill had the highest RDW but, Population-15 and Population-11 had the lowest (P<0.05). Gün-91, Tosunbey, Demir-2000, Kenanbey, Pehlivan, Momtchill, Pandas, and İkizce-96 had the highest RFDWR whereas Population-9 had the lowest (P<0.05).

Table 4.15. Differences among 12 wheat (*Triticum aestivum* L.) cultivars; Gerek-79, İkizce, Kıraç-66, Kenanbey, Flamura-85, Momtchill, Bayraktar-2000, Tosunbey, Pandas, Pehlivan, Demir-2000, and Gün-91 and 10 hulled einkorn (*Triticum monococcum* subsp. *monococcum*) wheat populations: Population-1, Population-2, Population-4, Population-5, Population-6, Population-9, Population-10, Population-11, Population-14, and Population-15 under salt stress.

Cultivars	GR^{+}	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Gerek-79	8,71^{a-d}	3.02^{a}	5.60a-c	4.20ab	0.66a-c	47.93a-d	5.00ab	9.56b-l
İkizce	8.36^{a-g}	2.27^{b-g}	5.30a-e	4.11a-c	0.75a-e	48.30a-c	4.65a-d	10.10b-h
Kıraç-66	7.25^{g-n}	2.06^{e-j}	4.06d-n	3.14b-k	0.59a-n	40.29a-j	4.40a-f	9.02c-n
Kenanbey	8.54^{a-e}	1.94^{f-l}	4.24b-j	3.21b-j	0.59a-j	42.32a-i	3.98b-j	10.50a-d
Flamura-85	8.04^{a-i}	1.91^{f-m}	3.81f-p	3.61a-p	0.49f-n	43.35a-h	4.79a-c	9.61b-j
Momtchill	8.21^{a-h}	2.83^{ab}	4.70b-g	3.51b-i	0.68a-g	46.90a-g	4.63a-e	10.29b-f
Bayraktar-2000	6.39^{m-q}	2.79^{a-d}	6.44a	5.09a	0.74a-e	52.28a	5.37a	9.78b-i
Tosunbey	8.21^{a-h}	1,56^{g-s}	3.70f-q	3.93a-g	0.44a-q	47.22a-f	4.21a-h	10.77ab
Pandas	7.68^{b-k}	1.90^{f-n}	4.22b-k	3.07b-l	0.65a-k	34.96b-m	3.50d-o	10.25b-g
Pehlivan	6.82^{k-p}	2.71^{a-e}	5.10a-f	3.96a-f	0.60a-f	38.37a-l	3.76c-l	10.40a-e
Demir-2000	7.43^{e-l}	2.80^{a-c}	5.66ab	4.06a-d	0.68a-f	47.53a-e	4.31a-g	10.58a-c
Gün-91	8.79^{ab}	2.51^{a-f}	4.50b-i	4.01a-e	0.52a-i	50.05ab	3.93b-k	12.06a

Table 4.15. Differences among 12 wheat (*Triticum aestivum* L.) cultivars; Gerek-79, İkizce, Kıraç-66, Kenanbey, Flamura-85, Momtchill, Bayraktar-2000, Tosunbey, Pandas, Pehlivan, Demir-2000, and Gün-91 and 10 hulled einkorn (*Triticum monococcum* subsp. *monococcum*) wheat populations: Population-1, Population-2, Population-4, Population-5, Population-6, Population-9, Population-10, Population-11, Population-14, and Population-15 under salt stress (cont'd).

Cultivars	GR†	CL	SL	RL	SRLR	RFW	RDW	RFDWR
Population-1	8.79^{a-b}	2.12^{b-I}	4.21c-l	2.40h-q	0.78a-l	30.01h-o	3.57c-n	8.30i-s
Population-2	8.46^{a-f}	2.03^{e-k}	4.69b-h	2.56h-o	0.87a-h	27.53j-q	2.83i-t	9.59b-k
Population-4	8.54^{a-e}	1.88^{f-o}	3.88e-o	2.05j-s	0.79ao	27.58j-p	3.11g-p	9.11b-m
Population-5	8.75^{a-c}	2.13^{b-h}	5.36a-d	3.04b-m	0.79ad	39.57a-k	4.03b-i	8.85d-o
Population-6	8.75^{a-c}	2.03^{ek}	4.13d-m	2.82c-n	0.53a-m	31.82f-n	3.61c-m	8.15i-u
Population-9	8.00^{a-j}	1.5^{lt}	3.38g-t	1.87j-u	0.68a-t	24.30k-t	2.89i-r	7.83m-v
Population-10	7.29^{g-m}	1.55^{g-t}	2.57o-v	1.90j-t	0.38b-v	24.05l-u	2.59l-v	8.32i-r
Population-11	7.18^{h-o}	1.60^{g-r}	3.61g-s	2.55h-p	0.44a-s	21.37m-u	2.63l-u	8.17i-t
Population-14	8.96^{a}	1.66^{g-p}	3.25h-u	2.36h-r	0.54a-k	25.72j-s	2.99h-q	8.33i-q
Population-15	8.54^{a-e}	1.65^{g-q}	3.62g-r	2.36h-r	0.44a-r	25.90j-r	0.64y	8.63f-p

† GR= Germination rate; GP=Germination Power; CL=Coleoptile Length; SL=Shoot Length; RL=Root Length; SRLR= Shoot-Root Length Ratio; RFW= Root Fresh Weight; RDW= Root Dry Weight; RFDWR= Root Fresh-Dry Weight Ratio.

4.3.1.2 Correlation among germination characters under salt stress

Pearson linear correlation coefficients (r; Kalaycı 2006) among GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR under salt (NaCl) concentrations of 5 ml: 0 (control), 0.05M., 0.10M., 0.15M., 0.20M., 0.25M., and 0.30M stress reflected significance at different levels (Table 4.16). Those highly significant linear significant relationships (r= 0.900-1.000) existed between RFDWR-SL, RDW-SL, and RDW-RFW. Those linear significant relationships (r=700-0.890) occurred between GP-RDW, CL-RDW, CL-RFW, CL-SRLR, CL-RL, RL-SRLR, SRLR-RDW, and SRLR-RFW. Those lower linear relationships (r=0.260-0.490) existed among GR-RFDWR, GR-SL, and RL-RFDWR. No lowest linear relationships with r=0.000-0.250 did exist among any of the character pairs.

Table 4.16. Pearson correlation values among GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR for GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR under salt; sodium chloride (NaCl) concentrations of 5 ml: 0 (control), 0.05M., 0.10 M., 0.15M., 0.20M., 0.25M., and 0.30M) stress.

Characters	GR†	GP	CL	SL	RL	SRLR	RFW	RDW
RFDWR	0.448	0.508	0.657	1.000	0.448	0.509	0.671	0.579
RDW	0.623	0.705	0.891	0.579	0.925	0.755	0.912	
RFW	0.587	0.651	0.860	0.671	0.890	0.744		
SRLR	0.573	0.611	0.843	0.509	0.679			
RL	0.561	0.631	0.865	0.656				
SL	0.448	0.508	0.657					
CL	0.628	0.690						
GP	0.757							

† GR= Germination rate; GP=Germination Power; CL=Coleoptile Length; SL=Shoot Length; RL=Root Length; SRLR= Shoot-Root Length Ratio; RFW= Root Fresh Weight; RDW= Root Dry Weight; RFDWR= Root Fresh-Dry Weight Ratio.

4.3.1.3 Principal Component Analysis (PCA)

A PC coefficient is significant if it is ≥0.3 (Hair et al., 1987). RDW (0.356), RL (0.335), SRLR (0.310), and RFW (0.309) produced PC 1; SL (0.613) and RFDWR (0.613) PC2; GR (0.779) and GP (0.633) PC3. Cumulative variance of first three PCs was a total of 90.525%. PC1 had a share of 71.946%, PC2 11.098%, and PC3 7.481% in total variation (Table 4.17).

Table 4.17. First three PC coefficients for germination characters, variations by each of them, and the total variance explained.

Characters	Principal component			Sums of squared	
	1	2	3	% of variance	Cumulative %
SL†	-0.210	0.613	-0.052	71.946	71.946
SRLR	0.310	-0.178	-0.031	11.098	83.044
CL	0.284	-0.060	-0.075	7.481	90.525
GP	-0.200	-0.053	0.633		
GR	-0.294	-0.068	0.779		
RL	0.335	-0.022	-0.204		
RDW	0.356	-0.154	-0.096		
RFW	0.309	-0.018	-0.163		
RFDWR	-0.210	0.613	-0.052		

†SL=Shoot Length; GP=Germination Power; CL=Coleoptile Length; GR= Germination rate; RL=Root Length; SRLR= Shoot-Root Length Ratio; RFW= Root Fresh Weight; RDW= Root Dry Weight; RFDWR= Root Fresh-Dry Weight Ratio.

4.3.1.4 Dendograms

An average based overall dendogram for all 22 entries rose to two main groups (Figure 4.7). Each of these two group also had two sub-groups. The first main group had mostly einkorn populations and Pandas bread wheat in its two subgroups. Population-21, Population-22, Population-18, Population-19, Population-14, Population-15, and Population-20 were in the first subgroup 1 while Population-13, Population-17, and Pandas were in the second subgroup. The second main group had mostly bread wheat cultivars and einkorn Population-16. The third subgroup contained Kenanbey, Flamura-85, Kıraç-66, Population-16, Pehlivan while fourth subgroup had Gerek-79, İkizce-96, Momtchill, Demir-2000, Tosunbey, Gün-91, and Bayraktar-2000.

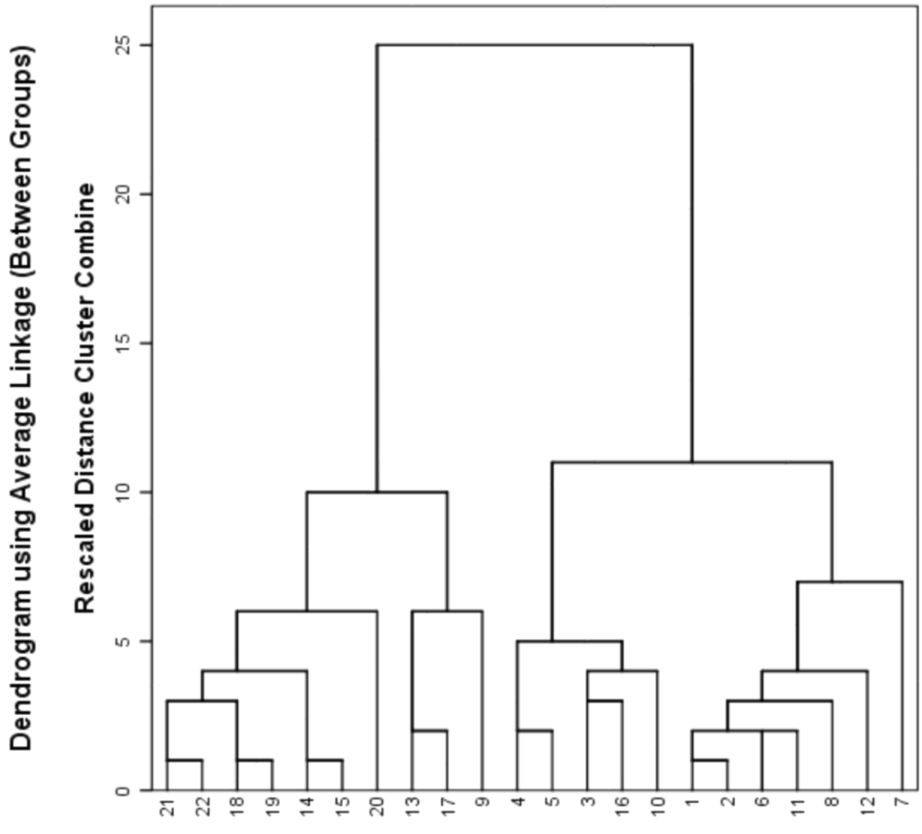

Figure 4.7. Dendogram for both 12 wheat (*Triticum aestivum* L.) cultivars and 10 einkorn (*Triticum monococcum* subsp. *monococcum*) wheat populations (Salt Treatment)

Bread wheat cultivars, formed two average based dendograms (Figure 4.8), in which possessed seven and five of total 12 cultivars. Gerek-79, İkizce-96, Demir-2000, Momtchill, Tosunbey, Gün-91, and Bayraktar-2000 settled in the first sub-group while Flamura-85, Kenanbey, Kıraç-66, Pehlivan, and Pandas in the second sub-group.

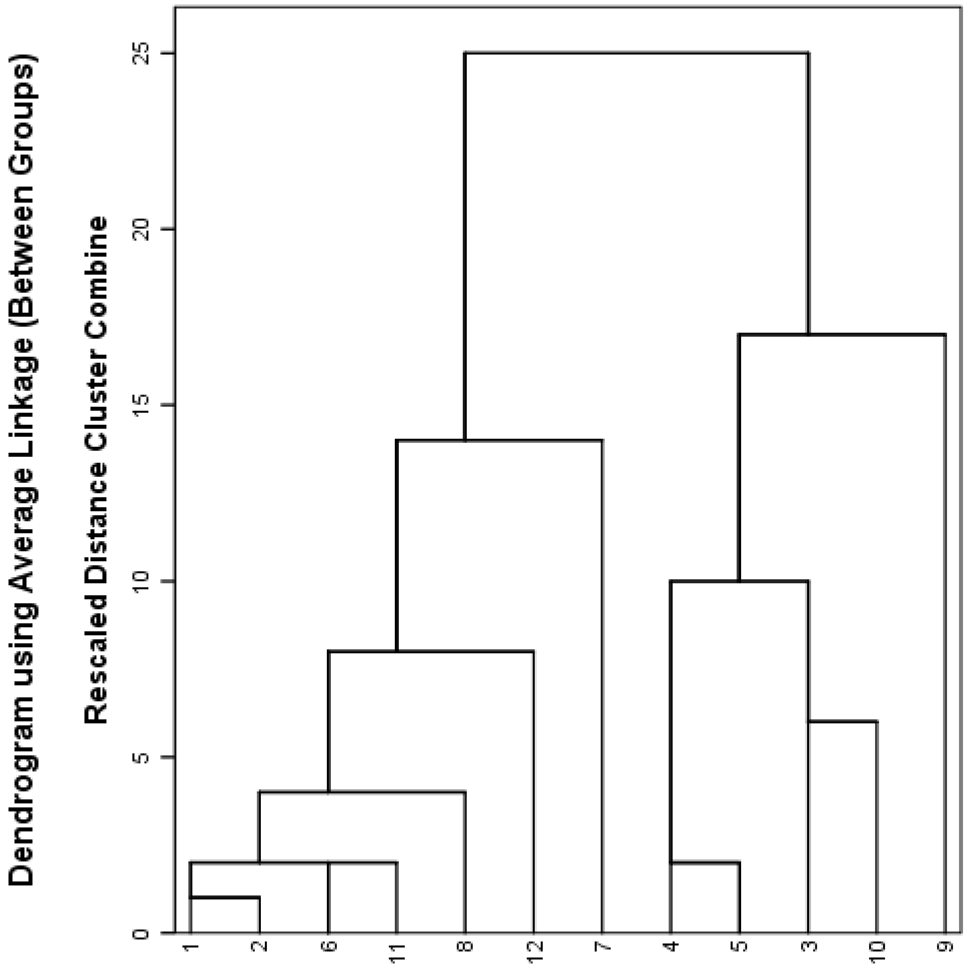

Figure 4.8. Dendogram Dendogram for 12 wheat (*Triticum aestivum* L.) cultivars (Salt Treatment)

Einkorn populations, established on averages (Figure 4.9), fitted into two sub groups except Populations-16. Other populations: Population-21, Population-22, Population-18, Population-19, Population-14, Population-15, and Population-20 were in one sub-sub-group and Population-13, and Population-17 in another sub group.

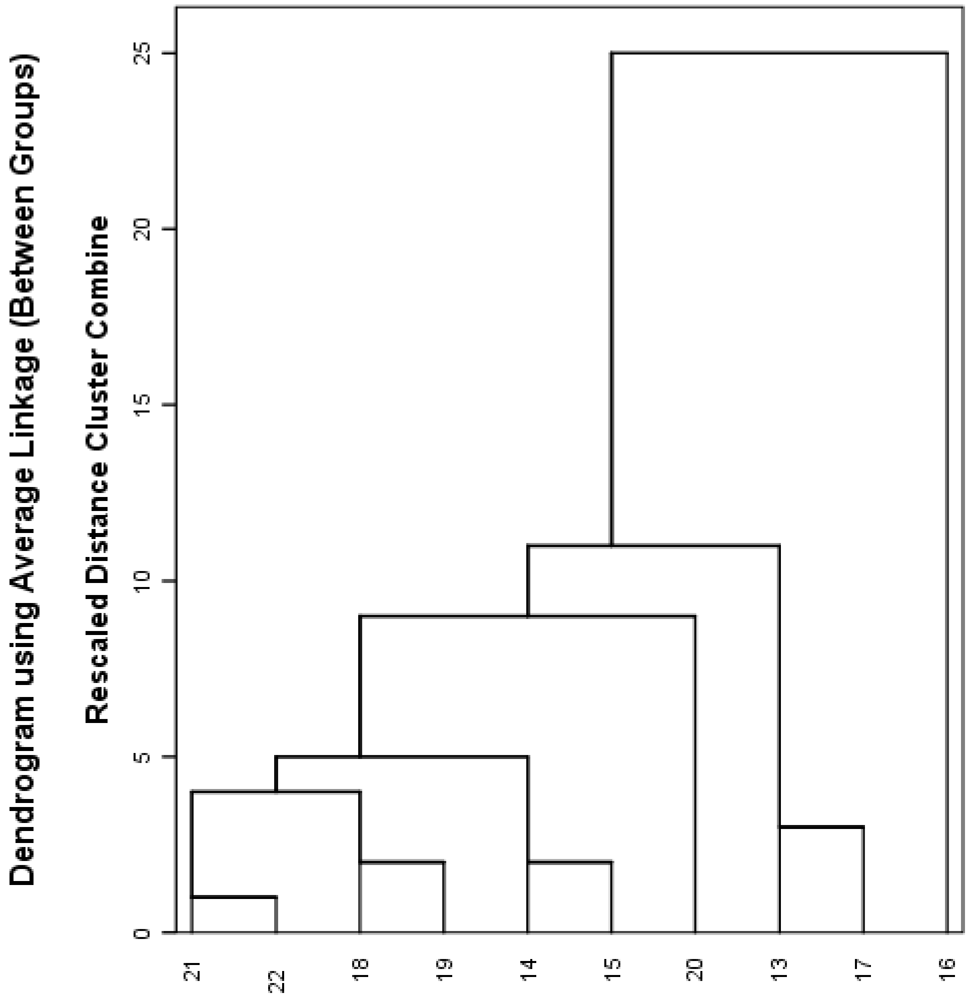

Figure 4.9. Dendogram for 10 einkorn (*Triticum monococcum* subsp. m*onococcum*) wheat populations (Salt Treatment)

4.3.2 Discussion

One of the most sensitive growth stages of the crops is germination. Biotic and abiotic stresses during the germination stage hurt crop development and reduce the production yield. Salt stress, one of the serious stress on sensitive plants, especially for their germination and seedling stages, is the most focusing stress source by researchers. When the salt concentration in the soil increases, the plant germination decreases (Khan et al., 2000). Because of decreased water intake and osmotic limitations, and Na^+ and Cl^- ion toxicity around the seed during the stress prevents the plant germination (Murillo-Amador et al., 2002; Rahman et al., 2008; Sabir and Ashraf, 2007; Shokohhifard et al., 1989).

All 22 wheat cultivar and differed for GR, CL, SL, RL, FW, RDW, and RFDWR but not GP and SRLR (Table 4.13). This was parallel to Biabani et al. (2013), who reported significant differences for germination rate, shoot length, root length, in bread wheat cultivars and also to Mahmoodzadeh et al. (2013) who reported differences for germination, germination speed, and germination percentage in bread wheat cultivars.

Highly significant ($P<0.01$) blocking for GR, GP, CL, SL, RL, and SRLR; significant ($P < 0.05$) for RFW and RFDWR, and non-significant for RDW and for all cultivars except non-significant GP and SRLR ($P<0.01$) exposed that completely randomized block design (RCBD) with a factorial restriction, was a worthy choice. RCBD behaved the same by Biabani et al. (2013) but not by Abdelkader et al. (2015), in whose studies significant but lower genotype differences was observed. Higher significant differences among salt doses and cultivars for most of the characters was because of effective blocking. No cultivar by dose interaction in this experiment within the treatments. However, Biabani et al. (2013) determined significant cultivar by salt interaction for shoot length, dry shoot weight, and germination rate.

Control in this experiment always had the highest GR, GP, CL, SL, RL, SRLR, FW, RDW, and RFDWR. The lower the salt dose the better the characters during the germination developed in the experiment: GR and GP between 0-0.20M; CL, SRLR, RFW, and RDW between 0-0.15M; SL and RFDWR between 0-0.20M. Decrease in GR, GP, and RFDWR started at 0.25M. CL, SRLR, RFW, and RDW started to worsen at 0.20M, GP and RFDWR at 0.25M (Table 4.14).What that meant was we obtained a good curve for salt doses to observe their effects clearly. This results were opposite to what Mahmoodzadeh et al. (2013) determined, in which doses in their experiment were so cultivar dependent and doses between 0-20 (dsm^{-1} NaCl) did not differ from each other. Our findings, on the other hand, fit well what Benlioğlu and Özkan (2015), Biabani et al. (2013), and Karakullukçu and Adak (2008) reported. Biabani et al. (2013) successfully obtained significant but lower salt doses and a good curve for shoot length, root length, shoot fresh weight, and shoot dry weight, root fresh weight, root dry weight, vigor index, mean germination time, and germination rate of the cultivars. The decreasing in fresh and dry weight of chickpea under salt stress was also clear (Karakullukçu ve Adak, 2008).

Bread wheat cultivars and einkorn populations fluctuated from each other to the most extent for all germination characters deliberated ($P<0.05$). Bread wheat cultivars and einkorn populations settled in the same groups in numerous circumstances (Table 4.15), though some individual cultivars or populations performed differently for some characters. Even population assembly of einkorn populations did prompted uniform germinations as modern improved bread wheat cultivars did. While some bread wheat cultivars showed the highest others showed lower values for some characters. That was the same as in the studies of Abdelkader et al. (2015), Biabani et al. (2013), and Mahmoodzadeh et al. (2013). Population-14, Population-1, Gün-91, Gerek-79 had higher values for GR and GP. Gerek-79, Momtchill, Demir-2000, Bayraktar-2000, and Pehlivan had the longest CL, which might be good for drought as well (Farhad et al., 2014).

Pearson linear correlation coefficients (r; Kalaycı, 2006) reflected linear correlations at different significance levels (Table 4.16). The highest correlations ($r=0.900-1.000$) were between SL-RFDWR, RL-RDW, and RFW-RDW. Higher significant relationships ($r=0.700-0.890$) were among GP-RDW, CL-RDW, CL-RFW, CL-SRLR, CL-RL, RL-SRLR, SRLR-RDW, and SRLR-RFW. The lower relationships ($r=0.260-0.490$) existed among only GR-RFDWR, GR-SL, and RL-RFDWR. The lowest linear relationships of 0.000-0.250 did not happen among any of the character pairs. Most germination characters as expected were interrelated to each other. No research, which studied correlations among germination characters, up to date, unfortunately was reached.

A significant coefficient, which was ≥ 0.3 (Hair et al., 1987) observed was 0.356 for RDW, 0.335 for RL, 0.310 for SRLR, and 0.309 for RFW, of which these 4 characters formed PC1. Wheat root as expected was the most vital character during germination against the salt as it was designated by root related RDW, RL, SRLR, and RFW. SL and RFDWR had 0.613 in PC2. GR had 0.779 and GP had 0.633 PC3. First three PCs had a sum of 90.525%. The highest was PC1 (71.946%), PC2 the second (11.098%), and PC3 the lowest (7.481%), (Table 4.5). The first three PCs were also upper for spike characteristics of bread, durum, emmer, and einkorn wheat entries studied by Karagöz and Zencirci (2005).

That an overall dendogram clearly grouped bread wheat and einkorn entries (Figure 4.7) revealed that bread wheat cultivars differed from einkorn populations for characters given. Population-21, Population-22, Population-18, Population-19, Population-14, Population-15, and Population-20, Population-13, Population-17, and Pandas were in the first group. The second main group had commonly bread wheat cultivars and an einkorn: Population-16. Karagöz and Zencirci (2005), separated for 8 einkorn populations and two durum wheat cultivars (i.e. Kızıltan-91 and Kunduru-1149) based on their some spike characteristics. That also supported our results.

Two sub dendograms were formed for bread wheat cultivars. The first one had seven cultivars: Kenanbey, Momtchill, İkizce-96, Pandas, Gün-91, Flamura-85, and Gerek-79. The second subgroup consisted of five cultivars: Kıraç-66, Bayraktar-2000, Tosunbey, Demir-2000, and Pehlivan (Figure 4.8). Germination characters of bread wheat cultivars failed to fall into clear-cut groups under salt stress. This is most likely because of no selection pressure was applied during the breeding cycle against the salt.

Average based dendograms grouped einkorn populations into two groups except Populations-16, which remained alone. Other populations: Population-21, Population-22, Population-18, Population-19, Population-14, Population-15, and Population-20 were in one sub-sub-group and Population-13 and Population-17 in the other sub-sub group. Karagöz and Zencirci (2005) also similarly set two dendograms for spike characteristics of einkorn populations.

5. CONCLUSIONS AND RECOMMENDATIONS

Wheat, which is a well-known stable crop around the Earth. It is under the attacks of cold, drought, and salt stresses. These stresses are the important factors for modern, hulled, and wild wheat species due to the increased climatic changes day-by-day.

With increased likely environmental stress risks because of existing or expected fast climatic changes, new genetic resources against these stresses have become an important issue to look for. In that context, hulled wheats are considered the essential sources nowadays. Though, stresses may hit wheat at every development stage, germination and the early crop development stages are the most vulnerable stages in wheat and these stress factors easily damage them, seriously worsen development, and sharply decrease yield and quality. Therefore, the studies about the reactions of various wheat species and/or genotypes against cold, drought, and salt stress at germination stage are good approaches to overcome these stresses on these days. Expected that einkorn wheats may provide novel tolerance sources so that their genetic, biochemical and physiological basis against the stress could be effectively benefited in the future.

The mechanism against cold, drought and salt stresses in wheat have not fully known or completely explained yet. Determination of new genetic materials, developing new laboratory and field techniques with interdisciplinary research against cold, drought, and salt stresses would bring more information, more tolerant / resistant gene pools and improved cultivars with higher and more quality yields.

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