Chapter 1

Introduction

Cereals, products of grass family are the most important food crops and provides almost half of the calories to the mankind. Around a dozen cereals are human population food but 95 % of calories are contributed by wheat, rice and maize. Maize is the one among three most important cereal crops in the world. In terms of quantum, its the largest cereal grain produced in the world with a total production of ----- million tonnes. It is C_4 in nature and grown in a wide range of environments around the globe. It has wide adaptability which enables the plant to survive in temperate, tropical, sub tropical, arid and semi arid regions of the world.

Maize crop has significant contribution for food security in word both directly and indirectly. The large population in central Asia, Africa, South and North America, Middle East and Europe consume maize crop directly. Beside this, the use of maize crop varies from country to country due to its large number of domestic and industrial products. The maize flour and meal are the two most popular product. But the actual list of products made from maize is quite large including starch, sweeteners, syrup, beverages, glue, alcohol, ethanol and premium quality oil. Beside the corn kernel, the pith and rachis are used as fuel, soil mulch, soil conditioner and litter for poultry. The stalk is used as fodder after harvesting the cobs. Nutritionally the maize grain is a good source of energy providing 365 Kcal/100 grams of grain, with a grain composition of approximately 72% starch, 10% protein, 4% fat. Maize grain contain many minerals, fibre and B Vitamins but deficient in Vitamin B_{12}, Vitamin C, calcium, folate and iron (Ranum et al. 2014). Maize kernel has a range of colours from white to black but the most common are the yellow and white. Both these types of kernel colour are used extensively in the world, mainly the preference is social. For example most of the corn produced in United States is yellow but in Africa and central America is white due to social preference. One of the reason for preference of white products is manufacturing ease, the whiter the product the better it is. This preference leads to low consumption of β-Carotene, β-cryptoxanthin and vitamin-A precursors available in good proportion in orange and yellow corn. The feed industry however prefers yellow corn. Maize crop is a major source of fodder for livestock and feed for the poultry industry. Maize grain is sometimes classified on the basis of composition and size of endosperm as flint, dent, waxy, sweet, pop and pod corn.

Agriculture, in Pakistan is the main driving force for economy contributing 18.5% to Gross Domestic Product (GDP) and providing 38.5% employment in the country. Maize is the third most important cereal crop of the country after wheat and rice. The cultivated area under maize crop is 1.3 million hectares with a total production of 6.3 million Tons. Being the third most important cereal crop in the country, it contributed 2.6 % to value added in agriculture GDP and 0.5% to total GDP of the country. However, the direct consumption of maize by human population is non-significant and poultry which is the largest industry in the country is mainly dependent on maize crop (Saleem et al. 2017). The large demand of grain is the major driving force for the framers to cultivate maize crop. Around 70% of the total production is directly consumed by poultry, 20% goes to wet milling industry and the rest of the produced used for food and other uses WWW.PARC.pk Maize fodder is popular for livestock and demand for maize silage is also increasing very rapidly within the country and outside.

Corn is a popular street food in Pakistan consumed as boiled, roasted and steamed cobs largely available in the streets of the country. The use of corn kernels in the daily human consumption is increasing with the changing food habits due to use of soups, salads and snakes. In Pakistan maize is planted throughout the country right from the mountains of Gilgit Baltastan to sea shores of Sindh Province. However, the preference of crop varies depending upon competition among cash crops within that area. The diverse climate of the country allows two crops in a year. The major season is the Autumn season which starts from the month of July and terminates in November and the second season is Spring, which starts from February and terminates in June however maize crop remains in field from January to November. Maize crop is planted in almost all the provinces during Autumn season because most of the water demand is fulfilled by the Moon Soon rains, however the Spring season is only confined to those areas where the underground water is available to supplement irrigation along with the canal water. During this season as the crop progress the temperature frequently exceed beyond 40ºC and farmers have to irrigate the crop after 4-5 days to save it from high temperature during the months of May and June. The water availability is turning out to be the major limiting factor day by day for maize crop production in the country. The water availability is decreasing with every passing year and the demand for grain is increasing (Pakistan Economic survey). The picture is quite clear from the Table 1.1 that the available canal water is continuously decreasing and the threat of climate change is adding the severity of the problem.

Table: 1.1. Water availability million acre feet in last fifteen years

Period	Summer	Winter	Total	%age incr/decr.
2003-04	65.9	31.5	97.4	-5.9
2004-05	59.1	23.1	82.2	-20.6
2005-06	70.8	30.1	100.9	-2.5
2006-07	63.1	31.2	94.3	-8.9
2007-08	70.8	27.9	98.7	-4.6
2008-09	66.9	24.9	91.8	-11.3
2009-10	67.3	25.0	92.3	-10.8
2010-11	53.4	34.6	88.0	-15
2011-12	60.4	29.4	89.8	-13.4
2012-13	57.7	31.9	89.6	-13.4
2013-14	65.5	32.5	98.0	-5.3
2014-15	69.3	33.1	102.4	-1.1
2015-16	65.5	32.9	98.4	-4.9
2016-17	71.4	29.7	101.1	-2.3
2017-18	70.0	24.2	94.2	-9
2018-19	59.6	24.8	84.4	-18.5

The uncertainty in weather is rather aggravating the water availability situation from bad to worse. Pakistan is among of top countries which are expected to be affected by the climate change (--------). The variability in rain fall patterns has increased during the past few years and is expected to increase even more. Similar is the situation with the heat wave days which increased up to five times during the last thirty years. The uncertainty in heat waves and precipitation patterns are leading to uncertainty in river flow, resulting in floods and dry spells. It is expected that a rise in temperature by 3-5 degrees by the end of this century may affect the crop yield. The increase in temperature will increase the evapo-transpiration rate in crop plants resulting in yields and crop losses. The decrease in yield would affect the equilibrium of supply and demand leading to food security issues. Only the climate smart cultivars which can use the available water efficiently and economically will be able to withstand these climatic changes. Maize is C_4 in nature and requires reasonable quantity of resources to yield good and out of all the resources water is most important input. Yield in corn is affected greatly due to water availability and intensity of water stress.

The water shortage affect the plant at cell, tissue and organ level. Plant growth is affected due to the reduced cell elongation, leaf area, and plant height. Poor water availability results

closure of stomata which reduces CO_2 exchange, resulting in decreased photosynthetic rate. Consequently, reactive oxygen species (ROS) are produced which react with the structural and functional proteins, cell organelles and membranes Taiz & Zeiger, 2006; Hussain *et al.,* 2008, Saleem et al., 2016a,b). An important factor which is least studied under drought is the reduced uptake of nutrients which results in poor flowering, pollen abortion, reduction in number and size of grain. The drought stress at vegetative stage limits the organ growth, process of photosynthesis, translocation of photosynthetes from source to sink and ultimately their conversion to yield (Yebei, *et al.,* 2018). Maize crop is relatively tolerant to water stress at earlier growth stage but at later stages stress reduces yield at large (Saleem et al., 2011). Both intensity and duration of water shortage affects the growth and yield in corn plant at every growth stage (-----). Pakistan lies in semi-arid climate and in most parts of the country the rain water is not sufficient for maize crop production and the water availability is decreasing drastically hence, the only solution to sustain maize is the development of climate smart genotype which could yield better under low water availability. This can only be achieved by the targeted breeding for drought tolerance.

The basic prerequisite for any breeding program is the availability of genetic variability in germplasm (Salman et al. 2011) and potential use of this variably for the development of efficient genotypes which could perform well under the given environment. Although, significant efforts have been made through the conventional breeding and biotechnology to breed stress tolerant germplasm but the success is just limited. Drought tolerance is multi-genic response in which many genes and factors together give a combined effect towards drought tolerance. The knowledge regarding the nature of gene action is essential for the plant breeds and enables them to optimize their breeding plan. The understanding of the genetic effects responsible for the expression of a trait are important for variety development and this expression can change with the change in environment (Hussain et al 2016) and the Generation Mean Analysis can provide useful information for the assessment of quantitative trait (Frank and Hallauer 1997, Zdunic et al. 2008, Hussain et al. 2016). The yield stability, potential and drought tolerance are the complex quantitative interactions directly influenced by the genotypic and environmental interaction. The phenotypic performance of the traits can be best evaluated by the Generation Mean Analysis (Kearsey & Pooni, 1996; Sharma & Sain, 2004, Saleem et al. 2016a). This not only provides information on direct effects i.e. additive [d] and dominance [h] but also gives a comprehensive

picture of epistatic effects i.e: dominance × dominance [l], additive × additive [i] and dominance × additive [j]. The information generated through this study will be helpful in estimating the performance of parents and their crosses and provide guideline for selecting and designing a maize breeding program. The present findings suggests that physiological and morphological traits are the indicators of stress tolerance, their utilization in breeding high yielding drought tolerant maize germplasm can gear up the breeding for stress tolerance.