

II. REVIEW OF LITERATURE

The review of literature concerning this investigation will be divided into three parts as follows:

2.1. Role of irrigation treatments on maize.

2.2. Maize hybrids performance.

2.3. Effect of humic acid.

2.1. Role of irrigation treatments on maize

Maize requires 500-800 mm of water during its life cycle of 80-110 days for dry matter production (**Critchley and Klaus, 1991**). At the time of tasseling, maize requires 135 mm of water per month and this may increase up to 195 mm per month during hot windy conditions (**Jamieson et al., 1995**). The floral structure of maize is extremely sensitive to drought and temperature stress during anthesis (**Johnson and Herrero, 1981**).

Water deficit is one of the most common environmental stress factors experienced by plants. It interferes with both normal development and survival and productivity. However, plants can respond to drought stress at morphological, anatomical and cellular levels with modifications that allow the plant to avoid the stress or to increase its tolerance. The morphological and anatomical adaptation can be of vital important for some plant species but they are not a general response of all plants. By contrast the cellular responses to water deficit seem to be conserved in the plant kingdom.

Among various constraints responsible for average low maize yield per hectare, inadequate supply of water at critical development stages and high sensitivity of different maize cultivars to water stress are of immense importance. Water is also important for the plant for maintaining its turgidity. When the plant wilts, its turgor approaches zero, the cells begin to collapse and membranes suffer damage. Cells can recover after short drought periods; however, if damage is severe and extended, the cells may die. Maize breeders usually evaluate the genotypes under abiotic stress at the advance testing stage when the selection intensity is usually low; hence progress in breeding for tolerance to abiotic stress is poor. Water stressed experiments ranking differed significantly from experiment to experiment, because of the high interaction of genotype by environment, thus making it difficult to identify the suitable germplasm. Drought stress during pollination and kernel setting is believed to reduce the grain yield to considerable extent (**Harold, 1986**).

Grant et al. (1989) indicated that one corn growth stage that might be plausible for reduced water application is pre- anthesis. Never the less water deficits during vegetative growth have been found to be the less detrimental to yield than deficits at the flowering and grain filling stages.

El- Noemani et al. (1990) showed that water stress “irrigation every 18 days” significantly inhabited plant height in both seasons. All studied characters were significantly decreased owing to water stress. Also, **Sinclair et al. (1990)**

reported that severe water stress during the R1 (silking) to R3 (early grain –fill) reduced grain dry matter accumulation because of premature senescence.

Fehr (1991) reported that drought stress is one of the most important a-biotic stresses influencing performance of crop plants. Some cultivars perform similarly regardless of the productivity level of environment while the performances of others are directly related to the productivity potential of environment.

Schussler and Westgate (1991) showed that plant water deficit during flowering and early kernel growths, reduced the yield potential of maize by decreasing kernel number/ear.

Voetberg and Sharp (1991) suggested that osmotic adjustment due to increased proline deposition plays an important role in the maintenance of root elongation at low water potentials.

El- Naggat et al. (1992) mentioned that seasonal water consumptive use values, water use efficiency and maize production were increased by decreasing the depletion of available soil moisture.

Ibrahim et al. (1992) indicated that plant height, ear height, leaf area, number of ears/plant, grain yield/plant and grain yield/fed., were significantly increased with decreased irrigation period.

Nesmith and Ritchie (1992) stated that short time effect of the water deficit led to delaying leaf tip emergence and decreased production of leaf area. Long term consequences were manifested in the form of reduced final sizes of certain leaves and internodes, delays of tassel emergence, silk emergence the onset of grain filling by 25%. Decreased yield of deficit plant was attributed to a reduction in the number of well develop kernels. While the non-lethal water deficit prior to anthesis did not significantly affect the grain yield.

El- Sabbagh (1993) found that the mean values of protein percentage were increased by increasing depletion of soil moisture from 40 to 80 %, while irrigation after 40 % of depleting gave the highest values of protein yield/fed., and Zn content in grain of maize.

Salem (1993) concluded that ear length, number of kernels/row, ear weight, 100- kernels weight and grain yield/fed., were significantly increased with decreasing irrigation intervals up to 18 days. Whereas, number of ears/plant, ear diameter, number of rows/ear and shelling percentage were insignificantly affected by irrigation intervals in both growing seasons.

Dhillon et al. (1995) showed that maize is apparently more drought resistant in the early stages of growth than when fully developed. Extreme water stress at different stages of crop development has been reported to reduce the yield significantly.

Atta- Allah (1996) indicated that plant height, ear height, stem diameter, ear leaf area, number of ears/plant, number of rows/ear, grain yield/plant and

grain yield/fed., were significantly increased with shortening irrigation intervals from 20 to 10 days. The highest values of the mentioned traits were recorded with irrigation of maize plants 10 days intervals followed by 15 and 20 days intervals.

Jun-Chen and Dai-Junying (1996) found that water stress has been found to reduce leaf area, photosynthesis, leaf chlorophyll contents and consequently grain yield.

Ghali (1997) stated that corn production exhibited better growth when grown on sandy loam soil than when grown on sandy clay loam one. Moreover, minimizing water use through deficit irrigation during late season growth stage reduced the yield. Such reduction was less than that obtained when deficit irrigation was practiced during the critical period which is mid season growth stage.

Saied (1997) revealed that holding one irrigation at flowering or vegetative stages significantly decreased weight of 100 grains, leaf area and maize yield in both seasons. NPK concentration in maize grains and leaves were not significantly influenced by the concentration regime in both seasons except N concentration of maize leaves in the second season was significantly affected. The irrigation treatments that received all number of irrigations consumed more water than the other treatments while the minimum amount of water consumptive use and the highest values of water use efficiency were achieved through holding and irrigation at yield formation on vegetative stage. At the same time maize plants extracted about 70 % of water from the upper 30 cm layer of soil profile.

El- Sheikh (1999) revealed that late – season water stress had more server effects on grain yield than early season water stress. Grain yield of synthetic varieties was not reduced severely even by the extreme drought stress compared with single crosses. It may be concluded that the synthetic cultivars may have a degree of stability in their performance under water stress treatment compared with other groups of hybrids.

Saleh (1999) reported that stem diameter and leaf area index was decreased from 10 to 20 days. As well as ear length, ear diameter, number of ears/plant, number of kernels/ear and grain yield/fed., were significantly decreased with irrigation intervals increased. But the greatest grain yield/plant was obtained from the irrigation every 10 days.

Kim et al. (2000) demonstrated that drought stress decreased photosynthetic rate and disrupted carbohydrates metabolisms in leaves and both may lead to a reduce amount of assimilate available for export to the sink organs and thereby increasing the rate of reproductive abortion.

Sinclair et al. (2000) stated that the decline in N₂ –fixation during water deficits and genotypes differences in sensitivity to drought may be associated with levels of nitrogen compounds such as amino acids in leaves and nodules of N₂ – fixing plants.

Fredrick *et al.* (2001) indicated that soil moisture stress affected growth and yield of soybean and the extent to which growth and yield criteria are affected depends upon the sensitivity of cultivated varieties and duration of water deficit.

Khan *et al.* (2001) stated that stem height was significantly affected by water stress. Maximum stem height was produced when six irrigations were applied and it was at par with 4 and 5 irrigations. However, it differed significantly with rest of the treatments. Minimum height was obtained when only one irrigation was applied which is statistically at par with 2 irrigations. Maximum stem diameter and leaf area were obtained in T0, which gradually decreased with increasing the water stress. Minimum stem diameter and leaf area was obtained when only one irrigation was applied. Maximum number of days was taken to complete flowering in treatments where six irrigations were applied while T5 treatment completed its flowering in minimum number of days. Number of grains per cob and 1000- grain weight was significantly affected by water stress. Number of grains per cob and 1000 grain weight decreased with decreasing number of irrigations. Maximum number of grains per cob was obtained when six irrigations were applied, however, minimum numbers of grains per cob were obtained when only one irrigation was applied. Grain yield was significantly affected by water stress. Maximum grain yield was obtained in treatments where six irrigations were applied which were followed by five, four, three and two irrigation treatments. Each of the above treatments produced significantly different grain yield as compared with other. So grain yield of maize decreased with increasing water stress.

Hussain *et al.* (2004) concluded that Water deficit is frequently the primary factor for crop production under arid and semi-arid conditions.

Wajid *et al.* (2004) stated that water stress effected nearly all the plant growth processes. However, the stress response depends upon the intensity, rate and duration of exposure and the stage of crop growth.

Fereres and Soriano (2007) revealed that in crop production, instead of achieving maximum yield from a unit area by full irrigation, optimum irrigation number or amount of irrigation water may be limited by allowing small yield decreases from a unit area but more area is irrigated with the same amount of irrigation water and water productivity can be optimized within the concept of deficit irrigation.

Ghooshchi *et al.* (2008) showed that water deficit significantly decreased yield. Water deficit at before silking, silking and filling growth stage decrease yield by 12.5, 42.0 and 22.5%, respectively. Data indicated that the most sensitive growth stage to water stress is silking growth stage and may be avoid of yield decreasing, contraception of water stress in this growth stage is necessary.

Hammed (2008) reported that characters of growth, relative water content, total water content, free water content, transpiration quotient and leaf water potential. Photosynthetic pigments, total soluble sugars, minerals (N, P, and K) contents in leaves, anatomical structure of stem as well as yield and its components were negatively affected by low water supplies, while the reverse

effect was observed in osmotic potential, bound water content, leaf water deficit, membrane integrity, water use efficiency, total carbohydrate and proline concentration.

Shirinzadeh et al. (2009) reported a decrease of maize grain yield by 40% due to drought stress at grain filling stage.

Fusheng et al. (2010) reported that the dry mass accumulation, crop water use efficiency and the activities of four maize on soil enzymes from jointing to grain filling stage of maize plants subjected to PRI and also different ratios of inorganic to organic N fertilization. Three irrigation methods i.e., conventional irrigation (CI), alternate PRI, (APRI) and fixed PRI (FPRI) which led to an increase of canopy water use efficiency by 7.4 % within the same irrigation method (CI, APRI, or FPRI).

Lamm and Aboukheira (2011) suggested that corn grower has great ability to handle early-season water stress, provided the water stress can be relieved during later stages. A critical factor in maximizing corn grain yields as affected by pre-anthesis water stress is maximizing the kernels/area. Maintaining a water deficit ratio (well-watered calculated corn water use / sum of irrigation and precipitation) greater than 0.7 to 0.8 or limiting available soil water depletion in the top 4 ft of soil profile to approximately 30% maximized the kernels/area. Some of these results contradict traditional irrigation guidelines.

Pejić et al (2011) indicated that maize is most sensitive to water stress in the flowering and pollination stage but less sensitive in the stages of vegetative growth, grain filling and maturity. Values of yield response factor in the growing period indicated that maize is moderately sensitive to soil water stress. The IWUE and ETWUE were in intervals of 0.47 to 3.00 and 0.67 to 2.34 kg/m³, respectively, mostly depending on the extent of favorable conditions of the season for maize production and irrigation water applied. The parameters IWUE and ETWUE could be used by maize growers as a guide in the study region in terms of optimum utilization of irrigation water for the planning, design and operation of irrigation projects and for improving the production technology of the crop.

Bouazzama et al. (2012) showed that the irrigation deficit accelerates the senescence of the sheets and reduces the leaf area index. The maximum values of this parameter reached at flowering under the full irrigation treatment (100 % ETc) are 5.1 and 4.8 during two seasons, respectively. Dry matter yields varied from 5.3 tons/ha under 40%ETc to 16.4 tons/ha under 100 % ETc in the first season whereas in the second season, it oscillated between 3.9 tons/ha under 20 % ETc to 12.5 tons/ha., under 100 % ETc. The actual evapotranspiration under 100 % ETc was 478 mm and 463 mm in the two seasons, respectively. According to the averaged values of two years, linear relationships have been evaluated between dry matter yield and water consumption ETa.

Ebtisam et al. (2012) showed that irrigation treatments of 75 % of ETo was the best on modified studied plant and soil characters especially WUE, which reflect maximizing production from water unite. HA application additions had a highly significant effect on improving soil characteristics such as aggregate size,

soil pH and EC as compared with control treatment. The HA2 was superior on increasing these values. HA treatments under different irrigation treatments had a positive effect on improving soil aggregates especially under I3 followed by I2 and lastly I1 irrigation treatments. While decreasing in irrigation quantity led to increase aggregates in the 1st depth than the 2nd one. Water treatment of 75 % is more closely to the crop water requirement of the maize plant. Increasing irrigation water treatments from 50 to 75 improved cob length , cob diameter and no. of grains row on cob by about 73, 84 and 38 %, respectively, while the change under 100 % irrigation treatments were 35, 65 and 28 % in the same order.

Ghalichechi et al. (2012) showed that there are significant differences in the level of 1% between the experimental conditions in terms of leaf chlorophyll content before the drought stress condition. There are also significant differences between genotypes in terms of leaf chlorophyll content before drought stress condition.

Grene (2012) reported that the context of the susceptibility of maize kernel to drought stress leading to embryo abortion, and the relative robustness of dividing vegetative tissue taken at the same time from the same plant subjected to the same conditions.

Khodarahmpour (2012) indicated that the importance to develop such cultivars that could perform better even under stress conditions. Drought stress is believed to be one of the most important environmental factors that reduce growth, development and production of plants. It can be said that it is one of the most devastating environmental stresses.

Lee (2012) stated that water deficit conditions prior to or during anthesis often results in the tassel emergence and anthesis before silk emergence. The resulting ears have few kernels develop near the base of the ear that ultimately lead to lower yield.

Salih and Falih (2012) showed that control treatment had highest consumptive water 610 mm, and decreasing to 538-574 mm at deficit irrigation treatments, The applied water reached to 620 mm for control treatment and decreasing to 539-576 mm at deficit irrigation treatments. This closeness between values of irrigation and ETa can be related to high irrigation efficiency and using of active deep according to the plant developing stages in this study because of the minimization of water losses as deep percolation. There is no significant difference in grain yield between the control treatment and deficit irrigation treatments at seedling, flowering and seed maturing stages. This result pointed that stages are low sensitive to water stress. The field and crop water use efficiencies values reduced when deficit irrigation was applied at vegetative growth stage, and increased when deficit irrigation was applied at seedling, flowering and grain maturity stages in comparison with full irrigation treatment.

Aslam et al. (2013) reviewed that today, the world is facing many problems for crop production among them drought is the most dangerous. The threat of drought to food security in future especially related to maize production. Water is a cooling agent plays an important role in the functioning of plant body. Drought

stress have deleterious effects on the seedling establishment, vegetative growth, photosynthesis, root growth, anthesis, anthesis-silking interval, pollination and grain formation in maize crop. The deleterious effects of drought can be mediated by application of nutrients which may enhance tolerance to drought stress. Among the nutrients potassium can enhance the tolerance in maize plant for drought stress. The application of potassium enhanced root growth and stem elongation. Similarly, potassium increased leaf water potential, osmotic potential and turgor potential under drought stress.

Sara et al. (2013) stated that under full irrigation conditions, the highest grain yield tons/ha was obtained. Reduction of irrigation water amount of 20% and 40% of full corn requirement resulted in a 21.6% and a 40.4% reduction of corn grain yield.

Soltani et al. (2013) showed that water deficit stress had significant effects on grain yield. Water deficit stress at vegetative phase had significant effect on leaf solution proteins and reduced it in stress treatments when compared with control. At the end of each phase of stress, water deficiency induced significant increase of Proline in leaves. Water deficit stress led to significant decrement of chlorophyll content in examined cultivars. Water deficiency had significant effect on free amino acid content of leaf at the end of reproductive stress.

Benjamin et al. (2014) reported that there was no significant correlation between water deficit stress and shoot or root biomass at the V6 growth stage. At the V12 and R1 growth stages, there were negative, linear correlations among water deficit stress and both root biomass and shoot biomass. The proportional decrease of shoot biomass was greater than the proportional decrease in root biomass, leading to an increase in the root: shoot ratio as water deficit stress increased at all growth stages..

Gohari (2014) showed that maximum seed yield value of 2345 kg/ha., was recorded for the 6 days irrigation interval treatment. Amount of water use efficiency on seed yield on irrigation management in the range 0.47 - 0.71 kg/m³ was variable. Maximum Leaf relative water content of 96.8 % was in the 6 days irrigation interval.

2.2. Maize hybrids performance

El- Karamity and Atta- Allah (1997) reported that the highest grain yield and its components were recorded with S.C. 10 hybrid irrigated with fresh water over the season, followed by three irrigated with drainage water after receiving two irrigation with fresh water. So, one- third of fresh water could be drainage water in irrigation with no significant yield losses. The lowest values for the studied were produced by Giza 2 cultivar, irrigated with drainage water over the whole growing season. The highest grain protein was obtained by S.C. 10 hybrid irrigated with drainage water over growing seasons, while the highest oil percent was recorded with Giza 2 irrigated with drainage water.

Moursi (1997) reported that maize genotypes differed significantly under water stress in number of rows/ear, ear weight number of kernels/row, 100 – kernel weight and grain yield.

El-Sayed (1998) evaluated 18 open pollinated population of maize under different moisture regimes. Based on high absolute yield the local cultivars Giza 2 and the CIMMYTS drought tolerant population DTF-2 were considered as the most drought resistance genotypes.

El- Sheikh (1999) revealed that grain yield of hybrids S.C.10 and TWC 73 four double cross was less than single crosses exhibited sever reduction in the early season stress treatment (skipping the second irrigation 80 days from planting). Reduction in grain yield as a percentage of the control were 5 % and 16 % in the first season, 8 % and 22 % in the second season for early and the season stress treatments, respectively the most sensitive period was flowering stage therefore, tolerant cultivars would be affected by reduction in kernel dry matter accumulation and in sequent kernel weight.

Ansari (2006) stated that yield and yield components of corn will decrease tangibly due to moisture stress and product amount reaches below its potential, but this yield drop has no uniform and characteristic trend. All 3 cultivars exhibited almost the same sensitivity to water stress.

Golabadi et al. (2006) reported that performance of crop cultivars across diverse environments and its response to different kinds of biotic and abiotic stresses is an important concern of plant breeders. Based on this emphasis is always given to yield performance under water deficit conditions.

Shoachosseini et al. (2008) detected that rate of precipitation has decreased significantly, resulting in lowering of the levels of undergrounds water and in water shortage on most irrigated fields in the province. Water shortage, on one hand, and cultivation of mere late – maturing cultivar 704, on the other hand, resulted in decreased grain yields within different regions of the province. It is necessary, therefore, to perform some experiments on different cultivars under moisture stress conditions.

Mohammad and Heidari (2008) stated that decreasing water potentials, total soluble protein content first increased, and then decreased in the roots and leaves of both varieties. The decrease in total soluble protein content in the roots of both varieties was equal, but in the leaves of cv. 301 it was greater than in cv. 704. In drought conditions the decrease in root and shoot fresh weight in cv. 704 was greater than in cv. 301. With water potential –1.76 MPa, the accumulation of dehydrin-like 38, 50, 57, and 65 KDa M.W. root proteins and 15, 17, 20, 27, 30, 37, 54, and 59 KDa M.W. leaf proteins increased. However, the expression of 15, 19, and 27 KDa M.W. root proteins, and 22 KDa M.W. leaf protein was induced in both varieties. The accumulation of dehydrin-like proteins in the roots and leaves of cv. 704 was higher than in cv. 301. There was no relationship between protein changes and drought tolerance.

Moussa and Abdel-Aziz (2008) concluded that the stress tolerance mechanism exists at seedling stage of maize genotypes. The Giza 2 is comparatively tolerant to water stress with higher increase in proline accumulation, and photosynthetic efficiency. The higher membrane stability index and high water retention capacity might have also imparted water stress tolerance in Giza 2. Further, Trihybrid 321 was also able to resist water stress to some extent via the above adjustments.

Farhad et al. (2011) reported that water deficit affects plant growth, yield and eventually leads to a considerable crop failure. Although maize (*Zea mays* L.) is susceptible to water deficit there was a marked genotypic variation in rooting density, morphological and physiological characteristics in maize. A green house experiment was conducted to study the response of spring maize plant growth to soil moisture content under controlled conditions. The seeds of eight maize hybrids (FH 421, FH 810, Pioneer 32-F-10, Pioneer 32-W-86, Monsanto 919, Monsanto 6525, NK 8441 & SS 5050) were sown in pots having the capacity of eight kg soil. The two field capacities (75% & 100%) were maintained after the reduction of 30% soil moisture. Monsanto 919 performed better in both levels with maximum plant height, leaf area per plant, water potential, osmotic potential, turgor potential and minimum relative saturation deficit, while maize hybrid FH 810 remained sensitive at deficit irrigation (75% field capacity).

Tollefson (2011) showed that successful drought resistant genotypes improved commercial maize yields under water limiting conditions by up to 15% and, importantly, yields under water sufficient conditions were only marginally less than control hybrids.

Aghaei et al. (2012) revealed that SC704 could be suitable hybrid for Moghan region as well as limited irrigation condition. Mean comparison of the genotypes showed that the hybrids had high value for the all traits excluding number of kernel row per ear as compared with parental lines. It is worth mentioning that in view of this trait just line K74/1 was superior from hybrids, whereas the rest of the lines valued less than hybrids. This is indicative of the importance should be given to the production of hybrid varieties in the present condition. In general, in terms of the grain yield and yield components, in both irrigation conditions hybrid SC704 had the most heterosis in comparison with other hybrids.

Araus et al. (2012) stated that plant breeders and major seed companies have developed maize genotypes with enhanced yields in water deficient environments. Phenotypic traits, such as silking, yield, grain number, carbon allocation to roots, leaf rolling and leaf chlorophyll content, were used to select stress tolerant maize germplasm.

Ghalichechi et al. (2012) showed that significant differences was observed after the drought stress condition in the level of 1% in experimental conditions, environmental conditions, genotype and also the interaction of genotype × environment conditions. The results of the comparison indicated that genotype 6 had the highest chlorophyll content before the drought and genotype 1 was awarded the lowest chlorophyll content.

Khodarahmpour (2012) reported that hybrid K3651/1 × K166B produced the highest germination percentage, germination rate, root length, seedling length and seed vigour, hence hybrid K3651/1 × K166B performed better than others. Many reports indicated that germination percentage and seed vigour can be utilized as screening criteria for stress tolerance. In the present study the findings were very similar to the previous case in which germination decreased due to the increase in PEG-6000 concentration. This study strongly supports the assertion that germination indices can be utilized to screen corn hybrids for drought tolerance at germination and early seedling growth stage. Growth of plants in arid and semi-arid land was dependent upon plants susceptibility to drought stress and also related to the ability of seeds to achieve optimum germination under these unfavorable conditions. Therefore, it is necessary to identify hybrids tolerance to drought at the primary growth stage. Taking all traits into account, this study found that K3651/1 × K166B was the most tolerant hybrid to water stress conditions.

Maryam et al. (2012) showed significant difference for plant height, leaf to stem ratio (dry), dry forage yield of hybrids ($P < 0.05$) and the number of leaves, leaf area index, dry weight per ear ($P < 0.01$), while among the studied hybrids, no significant difference was observed for leaf dry weight and shoot dry weight. Also, all traits except number of leaves showed a significant difference ($P < 0.01$) to drought stress. Increment of irrigation from normal to severe stress reduced dry and fresh forage yield (44% and 27%, respectively).

Wegary et al. (2012) stated that in general, the inbred lines used in this study were found to be useful sources for genetic variability for the development of new genotypes for stress tolerance and the study confirmed the possibility of achieving good performances across stress and non-stress conditions in QPM germplasm.

Barnaby et al. (2013) stated that maize hybrids varying in drought tolerance were treated with water stress in controlled environments. Experiments were performed during vegetative growth and water was withheld for 19 days beginning 17 days after sowing. Genotypic comparisons used measured changes of leaf water potential or results were expressed by time of treatment. Total dry matter of the drought tolerant hybrid on the final harvest was 53% less than that of the intermediate and susceptible maize hybrids when plants were water sufficient. This showed that maize hybrids selected for extreme drought tolerance possessed a dwarf phenotype that affected soil water contents and leaf water potentials. Changes of shoot and root growth, leaf water potential, net photosynthesis and stomatal conductance in response to the time of water stress treatment were diminished when comparing the drought tolerant to the intermediate or susceptible maize hybrids. Genotypic differences were observed in 26 of 40 total foliar metabolites during water stress treatments. Hierarchical clustering revealed that the tolerant maize hybrid initiated the accumulation of stress related metabolites at higher leaf water potentials than either the susceptible or intermediate hybrids. Opposite results occurred when changes of metabolites in maize leaves were expressed temporally. The above results demonstrated that genotypic differences were readily observed by comparing maize hybrids differing in drought tolerance

based on either time of treatment or measured leaf water potential. Current findings provided new and potentially important insights into the mechanisms of drought tolerance in maize.

Khalili *et al.* (2013) stated that drought stress is an abiotic factor affecting growth and yields of crop plants and one of the most important limiting factors for corn growth and productivity. Condition represented the effects of irrigation treatment were significant on number of rows in ear, number of seeds per row, 100- seeds weight, biological yield, harvest index and seed yield. Control treatment showed the maximum value for all mentioned factors. Effect of cultivar was significant on all of studied traits in probability different levels. The maximum of three levels of water deficit stress as first factor (50 mm, 100 mm and 150 mm evaporation from class A pan) related to KSC720 cultivar. Interaction of irrigation and cultivar was significant on harvest index and seed yield. With increase severity of drought stress had decreased seed yield and harvest index. Difference between cultivar in control level was little and with increase of drought stress this difference had expanded.

Rasheed and Ayat-Ur-Rahman (2013) reported that the average grain yield for drought stress treatment during flowering, at Peshawar, ranged between 2961 and 6000 kg ha⁻¹ observed for parental hybrids ICI-974 and P-3025, respectively. Similarly maximum (6453 kg ha⁻¹) and minimum (3038 kg ha⁻¹) average grain yield for water stress treatment at grain filling was noted for modified hybrids WD-2x8 and P-3025. Maximum grain yield of 10678 kg ha⁻¹ at Pirsabak, for water stress treatment at flowering was displayed by hybrid P-3025 while minimum grain yield of 6265 kg ha⁻¹ was observed for hybrid WD-2x8. Similarly hybrid P-3025 and modified hybrid WD-2x8 produced maximum and minimum average grain yield of 11255 and 7086 kg ha⁻¹, respectively, at Pirsabak for drought stress treatment at grain filling stage. It could be concluded that modified double cross maize hybrids were less affected by drought stress conditions as compared to their respective parental hybrids and that modified hybrids were high yielding as compared to parental hybrids under drought stress condition.

Roth *et al.* (2013) reported that maize improvement in drought-stress tolerance poses a great challenge as the global need for food, fiber, and fuel increases. Seed companies are developing and promoting drought-tolerant hybrids, but their physiological drought-tolerance mechanisms are not well understood. They revealed that drought and non-drought-tolerant hybrids did not markedly differ in grain yield or most other traits. In both seasons, grain yield was impacted most by N rates. A complex N rate effect on photosynthesis and transpiration was tightly related to water supply (i.e. higher N had positive impact under non-drought conditions). Hybrid differences in photosynthesis and transpiration were not significant at the leaf-scale, but one drought-tolerant hybrid had lower estimated cumulative A and E at the season-long canopy scale. Under the non-drought and specific-drought conditions in these single-location trials there was no indication that designated drought-tolerant hybrids were more tolerant to high crowding intensity and/or low N stresses.

Sara et al. (2013) stated that under the highest mean of grain yield (17.3 ton/ha) belonged to maize hybrid 704. Grain yield of hybrid 647 was significantly less than that of hybrid 704 while hybrid 400 was not significantly different from 2 other hybrids in terms of grain yield under water deficit.

Soltani et al. (2013) showed that water deficit stress and cultivar had significant effects on grain yield. Water deficit stress at vegetative phase had significant effect on leaf solution proteins and reduced it in stress treatments in compared with control. At the end of each phase of stress, water deficiency induced significant increase of Proline in leaves. Water deficit stress led to significant decrement of chlorophyll content in examined cultivars. Water deficiency had significant effect on free amino acid content of leaf at the end of reproductive stress.

2.3. Effect of Humic acid on maize

Humic acid (HA) is one of the most important components of bio liquid compound, because of its molecular structure; it provides numerous benefits to crop production. It helps break up clay compacted soils, assists in transferring micronutrients from the soils to the plant, enhances rates, improves water, air and roots penetration, and stimulates development of microflora population in soils. Humic acid is not a fertilizer but considered as a compliment to fertilizers. Humic acid essentially helps the movement of micronutrients from soil to plants. (**Mackewiak et al., 2001**).

Liu et al. (1998) reported that plant's root growth was dependent on the plant's air system, but since the root plays an important role in raw material supply, the root and air system have a mutual relationship. The root's growth is affected by the environmental factors, provided other factors such as humidity, temperature and soil's nutritional substances exist especially humic acid.

Herrmann et al. (2000) stated that the positive effect of HA and organic fertilization on the yield capacity of soil consists of many components. First, these components concern nutrient supply to plants, second, physical soil properties are affected resulting in difference in roots penetration, gas exchange and water supply.

Sharif et al. (2002) observed non significant changes in micronutrients concentration in maize leaves with addition of HA ranging from 0 to 300 mg/kg in pot experiments but when the concentrations were converted to total nutrient accumulation, the effect of HA treatments was significant.

Zimmer (2004) stated that humic acid is a vital factor for main finance of soil fertility and plant growth because it possesses strange chemical and physical characteristics by means of which it interacts with various soil components and it is main portion of soil organic matter.

Delfine et al. (2005) reported that the foliar application of humic acid caused a transitional production of plant dry mass with respect to unfertilized control and split soil N application. This effect was also evident for grain yield,

spike fertility and grain protein content during the two years of the study. Humic acid never affected photosynthesis or stomatal conductance, while Rubisco activity and leaf protein content showed intermediate responses between unfertilized control and split soil N application. They concluded that humic acid had limited promoting effects on plant growth, grain yield and quality, and photosynthetic metabolism of durum wheat crops grown in a typical Mediterranean-type agro-ecosystem of southern Italy, with respect to split soil N application.

Islam et al. (2005) stated that humic have antimicrobial activity by inhibiting the bacterial and fungal growth. Thus decreases levels of mycotoxins in feed.

Kaya et al. (2005) reported that humic and fulvic acids, deriving from coal or soil, exhibit action similar to extracts from seaweeds, although a bigger importance in the development of the plant root system are ascribed to them. Humic acids are considered to be compounds increasing permeability of cellular membranes in plants.

Kolsarici et al. (2005) discussed that 60 g humic acid per 100 seeds produced the highest values for the all criteria and they recommended that this ratio could be used for all cultivated sunflower varieties.

Sangeetha et al. (2006) reported that the humic substance the major component of soil organic matter have both direct and indirect effects on plant growth.

Ali et al. (2009) determined the effects of soil and foliar application of humic acid substance on dry matter and some nutrient elements uptake of wheat grown under 3 calcareous soil conditions. The highest dry weight and nutrient uptake were obtained at 1 g/kg humus treatment. Foliar application of the humic acid had statistically significant effect on Mg, Fe and Mn uptake. Humic acid raised the dry weight and N, P, K, Ca, Mg, Na, Fe, Cu, Zn and Mn uptake of plants at non limed pots and the amounts were found high at 0.1 % doses of humic acid. The second dose 0.2 % was found much more effective on dry weight and nitrogen uptake at high lime conditions.

Akinci et al. (2009) reported that humic acids promote the conversion of mineral nutrients into forms available to plants. It also stimulates seed germination and viability, and its main effect usually being more prominent in the roots. Humic acid (HA) caused significant increase of root fresh and dry weights by 30.1% and 56.6% of broad bean roots, respectively. Flame photometer and atomic absorption spectrophotometer analyses revealed that K content was major nutrient among the tested elements. Humic acid increased the contents of Na and K significantly. The content of Ca and Fe was not significantly increased whereas Cu, Mn and Zn content decreased under HA treatment.

Bakry et al. (2009) recorded a significant increase in maize vegetative growth characters (plant height and leaf contents of chlorophyll (a) and (b) and ear characters and grain yield (ear length, ear diameter, row number/ear and grain

quality parameters (weight of 100 grains) due to humic acid application (spraying plants with 50 mg k- humate/l) three times once every month starting from sowing.

Kasim et al. (2009) stated that under acid condition, organic based liquid N fertilizers (fulvic acid or both, humic and or fulvic acids) increased accumulation of NH_4^+ in soil. The presence of carboxylic groups in humic molecules increased NH_4^+ retention with increasing soil's stock labile carbon. However, low percentage of these acids reduced their full effect on dry matter production. The availability of nitrate was not statistically different for all treatments. Low soil pH could have reduced nitrification processes and simultaneously soil NO_3^- content. Liquid form of humic and/or fulvic acids could play an important role in enhancing urea efficiency. However, their contribution needs to be studied in detail in relation to humic molecules characteristics. This study had a potential in the development of liquid and foliar organic fertilizers.

Katkat et al. (2009) proved that humic substances significantly affect an increase in seed germination energy, the intensification of seedling growth, the growth of root weight and shoot development.

Puglisi et al. (2009) stated that his work highlights the importance of applying advanced biological and biotechnological methods to notice changes occurring in plant rhizodeposition and rhizosphere microbial activity. Moreover, it suggests correlations between the molecular properties of humic matter and their effects on microbial communities in the rhizosphere as mediated by maize root exudation.

Savov et al. (2009) reported that all of the examined preparations increase the protein content of corn. Regarding Kn 509, humic and enzyme preparations increase the protein production per unit of area from 17 to 19 %, and regarding the Kn M 625 hybrid – from 9 to 17%.

Verlinden et al. (2009) indicated that the effect of humic substances on maize yield was limited, probably due to the rather high nutrient status of both soils. Finally, the formal meta-analysis showed a consequent increase in nitrogen and phosphorus uptake of all studied crops as well. The effect on potassium and magnesium uptake was also mainly positive, while sodium and calcium uptake were not affected in most of the experiments.

Eslah (2010) revealed that the effect of humic acid on the vegetative growth of cowpea plant i.e. plant height, number of branches, fresh weight, leaf area/plant, total pods yield, N, P, K uptake and K/Na, Ca/Na ratio. Also N, P, K, protein and carbohydrate content in cowpea seeds showed significant increase with increasing the rate of humic acid application from 0, 3, 4.5 up to 6 kg/fed. 4. The interaction between cultivars and water salinity with humic acid application showed no statistical differences in both seasons.

Ghorbani et al. (2010) detected that usage of humic acid in addition to enhancement in maize's performance, gave us better results by reducing the usage of chemical fertilizers because of its variant physiological effects; it is also used

as a substance with natural sources that stabilize and increase agricultural production.

Gulser et al. (2010) stated that applications of humic acid and calcium nitrate significantly affected pepper seedling growth. 1000 and 2000 mg kg⁻¹ humic acid and 50 mg kg⁻¹ calcium nitrate applications increased fresh and dry leaf weight, fresh and dry root weight, stem diameter, root length and shoot length. The highest rates of humic acid (4000 mg/kg) and calcium nitrate (100 and 150 mg/kg) decreased these criteria of pepper seedling under the saline soil condition.

Khaled and Fawy (2011) observed that salinity negatively affected the growth of corn; it also decreased the dry weight and the uptake of nutrient elements except for Na and Mn. Soil application of humus increased the N uptake of corn while foliar application of humic acids increased the uptake of P, K, Mg, Na, Cu and Zn. Although the effect of interaction between salt and soil humus application was found statistically significant. The interaction effect between salt and foliar humic acids treatment was not found significant. Under salt stress, the first doses of both soil and foliar application of humic substances increased the uptake of nutrients.

Matysiak et al. (2011) showed that different action of tested substances on maize depending of application method. Seaweed extracts induced seed germination than humic substances. Joint seed and foliar application and double foliar application promote shoot and root growth.

Nikbakht et al. (2011) reported that HA had no effect on yield of milk thistle and decreased pumpkin yield. HA treatment decreased oil content of both species. Regarding to oil quality, gas chromatography results indicated that oils unsaturation degree was improved by HA application. It could be concluded that although HA had no positive effect on yield and oil content, it was worthy in enhancement of nutritional value of the oils.

Rajpar et al. (2011) stated that humic acid efficiently improves soil fertility and crop productivity, especially on poorly fertile and alkaline-calcareous soils. The growth, yield and oil content of three mustard varieties viz., S-9, P-78 and AH-2001 were observed under varying levels of humic acid application to a poorly fertile and alkaline-calcareous soil. The humic acid was applied to soil at the time of sowing at 0, 3.17, 6.35, and 9.35 kg per acre. Overall varieties, compared to control, the application of humic acid at 6.35 kg acre⁻¹ positively affected almost all the growth and yield parameters. The variety S-9 responded comparatively better to all the application rates of humic acid than its other two counterparts.

Tahir et al. (2011) reported that significant differences among HA levels were recorded for wheat growth (plant height and shoot weight) and N uptake. On an average of both soils, the largest increases in plant height and shoot fresh and dry weights were found with HA2 (60 mg kg⁻¹ soil), being 10%, 25%, and 18%, respectively, as compared to the control without HA (HA0). Both soils responded positively towards HA application. The wheat growth and N uptake in the non-

calcareous soil were higher than those of the calcareous soil. The HA application significantly improved K concentration of the non-calcareous soil and P and NO_3^- of the calcareous soil. The highest rate of HA(90 mg kg^{-1} soil) had a negative effect on growth and nutrient uptake of wheat as well as nutrient accumulation in soil, whereas the medium dose of HA(60 mg kg^{-1} soil) was more efficient in promoting wheat growth.

Turan et al. (2011) examined the effect of soil application of humus substances on dry weight and the nutrient uptake of selected elements in maize grown under salt stress in greenhouse condition. Sodium chloride was added to the soil to obtain 0, 15, 30, 45 or 60 mM NaCl. Three different doses of solid humus (0, 1 or 2 g/kg) were applied to the soil one month prior to planting. High levels of salt (45 and 60 mM NaCl) had negative impacts on dry weight and the N, P, K, Ca, Mg, Fe, Cu, Zn and Mn uptake of the maize plants. The highest mean dry weight, Mg and Mn uptake were observed for 0.1 g humus/kg treatment and the highest mean Cu content was in the 2 g humus/kg treatment.

Delkhoshi and Jalilian (2012) stated that row number per ear, ear diameter, number of grain per ear, 1000-grain weight, seed yield, biomass yield and harvest index of corn plants in both pre-sowing seed treatment and spraying methods have significant differences compared to mean control value. Maximum (4.76 cm) and minimum (4.1 cm) ear diameter was obtained in plants that treated with Humax as pre-sowing seed treatment and control plants, respectively. Results showed that the plants treated with Humax in foliar application and pre-sowing seed treatment had a maximum row number per ear and the control plants had the minimum of it. Application of Humax in both methods causes the highest number of grain per ear and the lowest belonging to the control. Plants treated with Humax showed the increase in 1000-grain weight in both pre-sowing seed treatment and foliar application method. The highest grain yield observed in plants treated with Nitroxin at pre-sowing seed treatment method and the lowest mean value of it obtained by control. The highest (30554 kg/ha) mean value of biomass yield was obtained from the plants that sprayed with Humax fertilizer. Generally, application of Humax as with pre-sowing seed treatment and foliar application lead to increase in yield and yield components of maize.

Khanghah et al. (2012) indicated that the application of liquid humic fertilizer can positively affect the maize biological yield and some agronomic traits i.e., length of ear, number of grains/ear, grain weight/ear, grain weight, ear weight.

Rezazadeh et al. (2012) concluded that the consumption of humic acid in seedling and flowering stages of maize var. KSC704 could raise up forage yield and reduce the chemical pollution of soil.

Wafaa (2012) reported that application of humic acid and calcium forms significantly affected maize dry weight and nutrients uptake except Mn and Zn uptake. The salts at no humic acid applications caused plant death, but no plant death was obtained in humic application (1.0 and 2.0g kg^{-1}) doses in all salts type. The effects of salts in nutrient uptake were significant. Application of humic acid (1.0 and 2.0g kg^{-1}) doses and calcium sulphate (CaSO_4) increased dry weight and

the N, P, K, Fe and Zn uptake of the maize plants. The soil pH was significantly decreased with application of humic acid. Also, the soil pH was significantly decreased with application of CaSO₄ compared with control. EC decrease significantly with application of humic acid (2.0 and 3.0g kg⁻¹) doses.

Anita Osvalde et al. (2013) reported that pre-plant and foliar humic substances (HS) tested was hardly effective in preventing nutrient (S, Zn, B) deficiencies limiting onion yield. Moreover, HS induced changes that significantly reduced nutrient status of organically grown onion and had detrimental effect on yield. Although one-year results did not suggest a benefit from HS application, further studies are necessary to evaluate the possible effectiveness of peat and vermin compost extracts on onion production in Latvia.

Attia et al. (2013) found that soaking seeds before planting in humic acid plus foliar spraying plants with humic acid enhanced maize growth, subsequently produced the highest means grain yield and its attributes in both seasons.

Balbaa and Awad (2013) showed that humic acid application resulted in significant decrease in days to 50% tasseling and sliking but did not affect plant height and ear height.

Daur (2013) indicated a better performance of FYM than HA with significant differences in many parameters including plant height, leaf area index, chlorophyll content, biological yield, grain yield, and N content of grains of the different N levels, the best performance was observed for 100 kg N/ha. The results show that 18 Mg FYM with 100 kg N ha⁻¹ may be recommended as good sources for wheat fertilization. However, more research is needed to evaluate the effectiveness of HA as an organic fertilizer and to compare higher HA rates with FYM.

Daur and Bakhshwain (2013) observed that significant differences were observed for all the studied parameters across the HA levels. Based on this study, application of 25 kg of HA/ha., may be recommended to improve growth and quality of maize fodder in similar environmental conditions. Further research is required in diverse plant environments to determine economically feasible application level of HA while comparing it with other manures and organic fertilizer sources.

Mehdi et al. (2013) reported that statistically significant interactions between irrigation methods × humic acid on root yield of sugar beet and irrigation levels × humic acid on root yield. Results also showed that WUE and Total WUE were affected by irrigation methods, so that IFI method could enhance water saving by 35 %. For RY, WSY, the best results were obtained from humic acid with irrigation (76.94 and 7.94 ton ha⁻¹, respectively). Furthermore, WUE, RY and TDM and WSY were affected by stress levels.

Osman et al. (2013) observed that in most cases, foliar application of humic and fulvic acids together led to significant increases of plant height, number of tillers/m², 1000 grains weight (g), grain, straw rice yield and N, P & K content of grain and straw as well as NO₂ and NO₃ of grain and straw, whereas, the lowest

significant ones were obtained for control treatment (without foliar application of organic acids) in both seasons.

Aisha et al. (2014) reported that increasing rate of humic acid increased growth characters, yield characters and increase the percentage of protein, N, P, K, carbohydrate and Fe contents of turnip root tissues. The highest values of the growth characters, roots characters and the percentage of protein, N, P, K, carbohydrate and Fe content (ppm) in turnip root tissues were associated with plants received higher compost level (20 m³/fed.) with higher level of humic acid (6 L/fed.).