Bulgarian Journal of Agricultural Science, 23 (No 3) 2017, 381–388
Agricultural Academy

PLANTS ADAPTATION TO DROUGHT ENVIRONMENT

ABDEL RAHMAN AL-TAWAHA*[1]; MUNIR AZIZ TURK[2]; YOUSEF M. ABU-ZAITOON[1]; SALEEM HMOUD ALADAILEH[1]; IBRAHIM MOHAMMAD AL-RAWASHDEH[1]; SULAIMAN ALNAIMAT; ABDEL RAZZAQ MOHAMMAD AL-TAWAHA[3]; MOHAMMAD H. ALU'DATT[2]; MOHAMMAD WEDYAN[4]

[1] *Al Hussein Bin Talal University, Department of Biological Sciences, Maan, P.O. Box 20, Jordan*
[2] *Jordan University of Science and Technology, Faculty of Agriculture, P.O. Box 3030, Irbid, Jordan*
[3] *Universiti Putra Malaysia, Faculty of Agriculture, Department of Crop Science, 43400 Serdang, Selangor, Malaysia*
[4] *The Hashemite University, Biological Sciences and Biotechnology Department, 330127, Jordan*

Abstract

Al-Tawaha, A. R., M. A. Turk, Y. M. Abu-Zaitoon, S. H. Aladaileh, I. M. Al-Rawashdeh, S. Alnaimat, A. R. M. Al-Tawaha, M. H. Alu'datt and M. Wedyan, 2017. Plants adaptation to drought environment. *Bulg. J. Agric. Sci.*, 23 (3): 381–388

Plant growth and productivity are adversely affected by drought. The sound of shortage of water on growth, yield and yield quality has been well deliberated in plants. In most cases growth, yield and yield quality are diminished under drought environments. There are four major strategic categories that represent the plant adaptation to desert, which include; lack water-escaping plants, lack water-evading plants, lack water-enduring plants and lack water-resisting plants. On the other hand, several controlling policies have been projected to compact with *drought stress* which including selection of crops and varieties, tillage and water conservation, moisture conservation through tephra covers, planting date, seed priming, nutrient management and water harvesting technique.

Key word: drought; seed priming; tephra covers; tillage; desert

Introduction

Drought has always been considered as a key issue that restricts plant growth and yield. *In Mediterranean* region it is expected to have longer and more severe drought periods in the near future**.** Plant growth and productivity is affected by many biotic and abiotic factors (Turk and Tawaha, 2002b; Musallam et al., 2004; Nikus et al., 2004; Al-Tawaha et al., 2005a; Al-Rifaee et al., 2007; Tawaha and Al-Ghzawi, 2013; Barłóg et al., 2016; Bazitov et. al., 2016; Bozhinova, 2016; Shafea and Saffari, 2016)

In study conducted by Shao et al. (2009) to sympathetic water deficit stress-persuaded variations in the rudimentary metabolic rate of higher plants-biotechnologically that can improve agriculture in the arid and semi-arid region. They reported that water shortage is the greatest significant environmental issue, harshly affect plant growth and limit it is productivity over any other environmental issue. Wery et al. (1994) reported that the harshness of drought is erratic as it depends on many issues such as occurrence and scattering of rainfall, evaporation rate, and the ability of the soil to store water. Even though crop reactions to water shortage are comparatively well recognized, it is affects plant by three main consequences: i. plant growth and physiology, ii. yield and iii. quality. This review represents a summary of the current work stated the specific properties and mechanisms of water shortage in crops and significant policies to overwhelmed the drought effects.

Effects of water shortage on crop growth and physiology

The effects of drought stress on growth have been well studied in crops. In most cases the growth of annual plants will

**Corresponding author*: abdeltawaha74@gmail.com

be diminished by drought more than that of perennial plants. Li et al. (2004) reported that the major effects of drought in crop plants are at the cellular level, division and expansion in a plant's growth is decreased. Farooq et al. (2008) found that water shortage can decline leaf growth, plant height and root growth. Taiz and Zeiger (2006) reported that drought can decrease germination and stand establishment as a result of limited the *imbibition* of water, declined energy source, and diminished enzyme actions. Hussain et al. (2009) reported that drought decline growth of sunflower (*Heliantus annuus* L.) because it decrease cell division and cell elongations. Kramer and Boyer, (1995) found that drought decrease leaf expansion, and inhibit branching and decrease the efficiency of photosynthesis. On the other hand, Nooden (1988) documented that drought stress can reduce photosynthetic rate and leaf area due to early senescence. The phenological traits such plant height, spike length, and days to heading are strongly affected by drought. Desclaux and Roumet (1996) reported that shortage of water can induce reproductive phase in many plants. Rahman et al. (2002) reported that water stress, decline sugar production and decrease photosynthesis rate. Similar result is reported by Malakouti and Tehrania, (2005) who found that water stress decreases photosynthesis rate in many crops. Dash and Mohanty, (2001) found that water stress induce significant injure of photosystems II, and also induce injury of photosynthetic pigments (Huseynova et al., 2009; Anjum et al., 2011; Kannan and Kulandaivelu, 2011). Drought stress has a great effect on chlorophyll content. In contrast, Mafakheri et al. (2010) observed that, Chl content decreased under drought stress. On the other hand, Kulshrehtha et al. (1987) reported absence of influence of water stress on Chl content in cereal plants. This variation may be due to differences in Chl synthesis between the genotypes. Some reports were also show that under drought stress the decrease of Chl b is higher than that of Chl a, as result of, transforming the ratio in favor of Chl a (Jaleel et al., 2009).

Effects of water stress on yield

Water stress is a core abiotic tension that limits plant growth and production (Forster, 2004). Barnabas et al. (2008) reported that universal hurts in crop yields from drought stress definitely turn outside the hurts from all other abiotic factors. Several researchers have found a reduction in number of grains per spike under drought stress in barley (Sanchez et al., 2002; Tawaha et al., 2006; Samarah et al., 2009) and in wheat (Garcia, 2003).

Nezami et al. (2008) indicated that drought stress decline phenological trait such as plant length, also they reported that water stress can decline biological yield and grain yield. In Pakistan, Ahmad et al. (2009) reported that plant height and yield of sunflower (*Helianthus annuus* L.) decreased with increasing water stress. Drought has adverse effect on vegetative and reproductive stages of crops. Mailer and Cornish (1987) found that drought has adverse effect during reproductive growth stage (flowering and fruiting) than the vegetative growth stage. Similar results have been reported by Richards et al. (2001). Previous study by Munier-Jolain (1998) reported that seed weight is decreased under water stress. In legume, Loss and Siddique, (1997) have shown that water stress during the reproductive stage of beans can decrease the number of flower per plant as well as of seed yield.

Abelardo and Antonio (2002) reported that pods per plant are the mostly affected yield components and during the stress period it decreased 63.3%. Similar results are reported by Lopez et al. (2008) who found that the reduction in grain yield is due to the reduction in the number of pods per plant.

Effects of drought stress on yield quality

It is very likely that the drought will have a major impact on carbohydrate accumulation. Stone and Nicolas, (1998) found a strong effect of carbohydrate accumulation in regulation of protein concentration, by letting more nitrogen concentration per unit of starch accrued in the grain.

The outcomes of water stress on protein concentration have been examined by several scientists. Dubetz and Bole (1973) reported that water stress during flowering and grain filling stage, frequently enhance protein level. Furthermore, abscisic acid and *water-stress induce* the appearance of proteins that are associated to the stress. Neslihan-Ozturk et al. (2002). Kim et al. (2000) reported that drought may decline photosynthetic rate, thus, declining the amount of assimilates obtainable for export to the sink organs. Moreover, it is well known that drought can also have an effect in carbohydrate metabolism in plant reproductive organs (Liu et al., 2004). On the other hand, Setter et al. (2001) found different levels of sucrose in maize ovaries between drought-stressed and well watered controls. Pallas et al. (1977) described that the peanut seeds formed under water stress had poorer germination rate. Results of some researchers clarified that this was mostly credited to inadequate calcium level that caused from debilitated calcium uptake under water stress conditions (Cox et al., 1976). Ali et al. (2009) even found seed oil contents under water stress are a common phenomenon and it is significantly decreased. In a study conducted by Nasri et al. (2008) the effect of micro and macro nutrient under water stress condition in rapeseed is evaluated. They found that drought stress caused an important decrease of seed oil content, and of oil yield of five rapeseed cultivars. Regarding the leaf chlorophyll content the results of some researchers clarified that water stress stimulates the decrease of leaf chlorophyll content. (Paknejad et al., 2007; Sun et al., 2011). The study of Tawaha et al. (2006) has shown that the accumulation of isoflavones (genistein, daidzein and glycitein) is enhanced under well-watered condition in synthesized soybean.

Major Categories That Represent Strategies of Adaptation to Desert

Drought-escaping plants

These are annual plants that are extremely dependent on autumn and winter rainfall. The main characteristic of this plants are their ability to complete its life cycle, from germination to the production of seed, within one growing season. There are almost evidences that appearance of annual species is contrariwise correlated to the amount and dependability of rainfall in the area (Schaffer and Gadgil, 1975). Went (1953) reported that the annual plants in the desert area are not able to germinate following a 10 mm rainfall: huge germination appeared only after a rainfall of 25 mm. This was recognized to ejection of natural *inhibitors* in the grain coats. The germination and the productivity of annual plants generally will be reduced by drought more than that of perennial plants. Beatley (1967); Mott (1972) all found that annual plants can grow well during wet years, and seed production can increase significantly if the soil remains moist until growth is completed. There are almost no evidences about the impacts of temperature on germination and growth of annual plant, Went (1953) note that very high and very low temperatures negatively affect the growth of annual plants and may even cause the plant irreversible damage. Some works were also performed measuring the optimal temperature for winter and summer annual plants (Shreve, 1942): this varies from 15-18°C for winter annual and 25-30°C for summer annual plant species(Went, 1953)

Drought-evading plants

They are deciduous perennial (non-succulent) plants such as (*Carex pachystylis, Rheum palaetinum, TuJipa amplyophylla*), which limited their cell division and cell expansion to period when water is available. Naturally such kinds of plant during drought period go dormant or die back. Evanari et al. (1982) described that the *Carex pachystylis* plant produces new rootlets in a short period of 12 hours after watering and quickly spread through the surface soils. The shoot development (leaf, flower and fruits) of these species occurs only after good development of root system and some causes the development of reproductive organs (flower and fruit) depend on the availability of moisture during their stage of growth, in other words the reproductive phase may be dispensed with in dry years (REF). Some perennial grasses such as Mitchell grasses (*Astrebla spp*.) have rapid growth rate. Walter and Breckle (1989) found that *Astrebla spp* is able to complete vegetative growth within two weeks and to produce ripe seed after six weeks.

Drought-enduring plants

This kind of plants has various morphological and physiological adaptations in root and shoot, to maintain growth even in times of extreme water stress. It has been experimentally shown that drought- enduring plants have extensive root system which includes most evergreen shrubs in the desert, such as in *Hammada scoparia* (*Chenopodiaceae*) in the Middle East. Some works were also performed by Phillips (1963), who found that depths of 53 cm are uncommon, for *Prosopsis* sp. Assessment of *photosynthetic potential* of leaves enduring plants tends to be considerably lower than that of deciduous plants (Fitter and Hay 1987). Armond et al. (1978), Mooney et al. (1978) all found that *Larrea divaricata* can remain active during the year and has the ability to keep-photosynthetic efficiency in good rates.

Drought-resisting plants

It is succulent perennials plant that developed water-storing tissue in their leaves, stem and roots. As a result of extreme size of the vacuole, the cells have a swollen form. In general, desert succulents have shallow root system, which let them to respond quickly to light rainfalls.Szarek and Ting (1975) detected that the *Opuntia basilaris* plant has stomata activity following a rainfall of only 6 mm on dry soil. Succulent stem adapted for desert environment and the main function of the stem are adapted for water storage and photosynthesize, also the surface of the stem are covered with waxy material to reduce water losses (REF). In general the succulent leaves are often reduced to spines, which provide shade (reduce heat load) in addition to protection. Nobel (1980) reported that cold temperature has adverse effect on the growth of desert succulents and freezing injure can happen to the top of the stem because of radiation heat loss. Results of some researchers clarified that desert succulents are not often killed by high temperatures; these are a *very* common of most cactus species that can survive temperatures over 60°C for short periods (Nobel and Smith, 1983; Smith, 1984).

Agronomic Approaches to Stress Management

Choice of crops and varieties

Plant breeders developed and advanced crops and varieties that can survive and grow well in a range of environments. For many years, the development of drought tolerant crop varieties has been one of the major strategies for organization water restriction in agriculture (Xoconostle-Cazares et al., 2010). Tawaha et al. (2006) stated that this can be reached through improvement of phenological and morphological characters that can play role in the modification of plant to drought region. .Previous studies (Hall, 2007; Cattivelli et al., 2008) showed that plant breeding activities have led to yield enhance in drought exaggerated environments for many crop such as maize, pearl millet, cowpea, groundnut and sorghum. Environmental factors and the genetic factor play significant role in the yield of major crops (Tawaha et al., 2006). Moreover, it is well known that selection of *short duration* crops was chosen because of the *importance* to combat drought and due to their ability to escape terminal drought (Tawaha et al., 2006). National and international research organizations such as ICARDA, ICRISAT, CIAT, IITA play important role to improve genetic yield potential of new cultivars under drought condition.

Tillage and water conservation

The purpose of tillage is to supply a favorable environment for crop growth and production. Van Duivenbooden et al. (2000) reported that conventional tillage in semi arid region is done with four main reasons (i) to organize seedbed, (ii) to help infiltration, (iii) to conserve water within the soil profile, and (iv) to avoid wind and water erosion of soil. In current periods, numerous reports have deliberated the role of tillage system on soil moisture conservation. Detailed reviews are found in Arshad and Gill (1997); Gauer et al. (1982); Lyon et al. (1998); Mesfine et al. (2005). The effects of tillage systems on the plant have been reported widely by Lyon et al. (1998). They mentioned that no tillage system stored the maximum quantity of water, while the conventional tillage stored a minimum amount. Previous studies using several years of experiments showed that minimum tillage for soil preparation played a significant role in the increasing soil water content (Larney and Lindwall, 1995). On the other hand, Phillips (1984) found that the conventional tillage system has greater evaporation in comparison to the no tillage system. Results of some researchers clarified non-significant differences in soil water content on silty loam among the conventional tillage, conservation tillage and no-tillage systems (Hussain et al.,1999).

Moisture conservation through tephra covers

In recent decades, several resources have been used as mulch, such as plastic plant residue, straw, etc. Several studies have demonstrated that application of surface-applied mulches has been associated with increasing water, heat energy and nutrient grade in soil, escaping soil and water loss, avoiding soil salinity (Bu et al., 2002). Li et al. (2000) reported various environmental factors which are induced by mulch such as soil temperature, soil moisture, soil salinity level, nutrients and soil texture. In arid and semi arid areas the tephra acts as mulch and have used to lower water loss from soils. Researchers have discussed the possibility of using crushed rocks added to soil as water conservation technique (Hartwell and Pember, 1908; Keller, 1948; Coleman, 1977). The tephra acts as mulch and was found to avoid soil salinity from running back to soil surface through dropping evaporation (Zhang et al., 1996). Fan et al. (2003) investigated the mulch on soil physical features and wheat yield, found that the salinity dose of the soil (0.44%) dropped to 0.07% after being mulched with straw for two growing seasons.

Planting date

In the arid and semi arid regions the selection of right planting date for a crop is one of the most significant factors in its production (Tawaha et., 2001; Tawaha and Turk., 2004; Tawaha et al., 2005; Tawaha et al., 2010). Moreover, it is well known that, early planting has been found to be more appropriate than the late planting, chiefly for the reason that the plants flower earlier and pods fill before the drought period, resulting into high yields (Tawaha and Turk, 2004). Early sowing of sesame result of more vegetative growth (plant height, stem diameter and branch number) (Bremner, 1966); which eventually, reflects in the leaf area index. Results of some researchers clarified that increasing crop growth and yield in initial seeding date has been documented by numerous workers (Kohn and Storrier, 1970; Doly and Marcellos, 1974; Degenhardt and Kondra, 1981;McDonald et al., 1983).

Seed priming

Drought stress influences seed germination and seedling growth under arid and semi-arid environments. Al-Tawaha and Al-Ghzawi (2013) reported that both salinity and drought stress affected germination unfavorably as the effects of drought stress were more harsh than salinity stress. Seed priming was defined as pre-sowing treatments of the seed, the most seed priming methods hydro priming is the simple soaking of seeds in water) and osmotic priming (soaking seed in solutions of mannitol, potassium nitrate (KNO_3). Seed priming could be used to improve the seed germination under drought stress. Ashraf and Foolad (2005) indicated that seed priming is one of the approaches that can be taken to increase germination of many crops and under both stress and non-stress condition. Seed priming techniques play an important role for improving germination and it is uniformity and also, improve seedling establishment and stimulate vegetative growth (Ansari and Sharif-Zadeh, 2012; Ansari et al., 2012).

Nutrient management

At present, it is well known that under moisture stress conditions fertilizer increase crop yields under optimum moisture conditions (Turk and Tawaha, 2001; Tawaha and Turk, 2002; Turk and Tawaha, 2002; Tawaha et al., 2003; Turk et al., 2003). However, it has been found that under moisture stress conditions also mineral nutrients play a critical role in plant stress resistance (Marschnerm, 2012). Potassium plays a primarily critical function in plant growth and metabolism, and it donates extremely to the survival of plants that are under various water stress conditions (Pettigrew, 2008; Dong et al., 2010). Marschnerm (2012) reported that K+ plays essential role in stress resistance and decreased the incidence of diseases. Phosphorus is a major plant essential nutrient which effect on root growth, which, in sequence, assist in extracting more moisture and in the end leads to high yields under moisture stress environments (Lott et al., 2011). Phosphorus application enhanced drought tolerance in plant and increased flower formation and fruit production (Anonymous, 1988).

Water harvesting

The arid zone is characterized by extreme heat and insufficient, uneven precipitation and high potential evaporation over the crop-growing season. If the rain does occur in the arid and semi arid area, it is very important to be conserved and used efficiently (Oweis and Hachum, 2003). For this purpose the micro-catchments and macro-catchments techniques may be used for water harvesting in the arid and semi arid areas. Oeies and Hachum (2003) reported that supplemental irrigation and water harvesting that can improve farmers' income in dry environmental conditions. Nilsson (1988) reported that water harvesting in dry areas offers a number of environmental benefits such as decreasing flooding danger, decreasing soil erosion, **reducing water bills, suitable for irrigation, reduces demand on ground water, can be used for several non-drinking purposes**.

Conclusion

We conclude that plants have different strategies of adaptation to drought areas which include; lack water-escaping plants, lack water -evading plants, lack water -enduring plants and lack water -resisting plants. On the other hand, applying specific agronomic practices play an important role of adaptation to drought environment.

References

Abelardo, J. D and G. H Antonio 2002. Effects of planting date, genotype and their interactions on sunflower yield. I. determinats of oil corrected grain yield. *Crop Sci.,* 42: 1197-1201.

Ahmad, S. H., R. Ahmad, M. Y. Ashraf, M .Ashraf and E. A.Waraich, 2009. Sunflower (*Helianthus annuus* L.) response to drought stress at germination and seedling growth stages. *Pak. J. Bot.*, **41**(2): 647-654.

Ali, Q., M. Ashraf and F. Anwar, 2009. Physico-chemical attributes of seed oil from drought stressed sunflower (*Helianthus annuus* L.) plants. *Grasas y Aceites*., **60** (5): 475-481.

Al-Rifaee, M. K., A. Al-Yassin, N. Haddad and A. M. Al-Tawaha, 2007. Evaluation of chickpea breeding lines by examining their responses to sowing date at two Mediterranean climatic locations. *American-Eurasian Journal of Sustainable Agriculture*, 1 (1): 19-24.

Al-Tawaha, A. M. and A. A Al-Ghzawi, 2013. Effect of Chitosan coating on seed germination and salt-tolerance of lentil (*Lensculinaris* L.). *Res. on Crops,***14** (2): 489-491.

Al-Tawaha, A. M., S. Y. Shyam, M. Turk, M. Ajlouni, M. Abu-Darwish, A. M. Al-Ghzawi, M. Al-udatt and S. Aladaileh, 2010. Crop Production and Management Technologies for Drought Prone Environments. Chapter. In: Climate Change and Drought Management in Cool Season Grain Legume Crops, *Springer*.

Al-Tawaha, A. M., M. A. Turk, K. D. Lee, W. Z. Zheng, M. Ababneh, G. Abebe and I. W. Musallam, 2005. Impact of fertilizer and herbicide application on performance of ten barley genotypes grown in Northeastern part of Jordan. *International Journal of Agriculture and Biology*, **7** (2): 162-166.

Anjum, S. A, X. Xie and L.Wang, 2011.Morphological, physiological and biochemical responses of plants to drought stress. *Afr. J. Agr. Res.*, 6: 2026-2032.

Anonymous, 1988. Better Crops with Plant Food. *PPI*, Atlanta, USA, pp. 26.

Ansari, O. and F. Sharif-Zadeh, 2012. Osmo and hydro priming improvement germination characteristics and enzyme activity of Mountain Rye (*Secale montanum*) seeds under drought stress. *Journal of Stress Physiology & Biochemistry*, **8** (4): 253- 261.

Ansari, O., H. R Choghazardi, F. Sharif Zadeh and H. Nazarli, 2012. Seed reserve utilization and seedling growth of treated seeds of mountain ray (*Seecale montanum*) as affected by drought stress. *Cercetări Agronomice în Moldova*, **2** (150): 43-48.

Armond, P. A., U. Schreiber and O. Bjorkman, 1978. Photosynthetic acclimation to temperature in the desert shrub, *Larrea divaricata. Plant Physiology,* 61: 411-15.

Ashraf, M. and C. M. Bray, 1993. DNA synthesis in osmoprimed leek (*Allium porrum* L.) seeds and evidence for repair and replication. *Seed Sci Technol.*, 3: 15-23.

Ashraf, M. and M. R Foolad, 2005. Pre-sowing seed treatment-a shotgun approach to improve germination growth and crop yield under saline and none-saline conditions. *Advan. Agron.*, 88: 223-271.

Arshad, M. A. and K. S. Gill, 1997. Barley, canola and wheat production under different tillage-fallow-green manure combinations on a clay soil in a cold semiarid climate. *Soil & Tillage Research*, 43: 263-275.

Barłóg , P., W. Grzebisz, K. Pepliński and W. Szczepaniak, 2016. Sugar beet response to balanced nitrogen fertilization with phosphorus and potassium. Part III. Dynamics of white sugar yield development. *Bulg. J. Agric. Sci.*, 22: 197-204.

Barnabas, B., K. Jager and A. Feher, 2008. The effect of drought and heat stress on reproductive processes in cereal. *Plant, Cell and Environment*, 31: 11-38.

Bazitov, R., V. Koteva, V. Bazitov and I. Gospodinov, 2016. The water defi ciency effect over maize yield cultivated for grain without irrigation in the region of South-Central Bulgaria. *Bulg. J. Agric. Sci.*, 22: 245-249.

Beatley, J. C., 1967. Survival of winter annuals in the northern Mojave Desert. *Ecology*, 48: 745-750.

Bozhinova, R., 2016. Heavy metal concentrations in soil and tobacco plants following long-term phosphorus fertilization. *Bulg. J. Agric. Sci.*, 22: 16-20.

Bremner, P. M and R. W. Radely, 1966. Studies in sesame agronomy. 2: The effect of variety and time of planting on growth, development and yield. *J. Agri. Sci.*, 66: 253-256.

Bu, Y. S, H. L Shao and J. C. Wang, 2002. Effects of different mulch materials on corn seeding growth and soil nutrients' contents and distributions. *J. Soil Water Cons.*, **16** (3): 40-42.

Cattivelli, L., F. Rizza, F. W. Badeck, E. Mazzucotelli, A. M. Mastrangelo, E. C. Franciab, A. Tondelli and A. M. Stanca, 2008. Drought tolerance improvement in crop plants: an integrated view from breeding to genomics. *Field Crop Res.*, 105: 1-14.

Coleman E., 1977. The Use of Ground Rock Powders in Agriculture. *Harborside*, Maine, p. 23.

Cox, F. R., G. A. Sullivan and C.K. Martin, 1976. Effect of calcium and irrigation treatment on peanut yield, grade and seed quality. *Peanut Sci.,* 3: 81-85.

Dash, S. and N. Mohanty, 2001. Evaluation of assays for the analysis of thermo tolerance and recovery potentials of seedlings of wheat (*Triticum aestivum* L.). *J. Plant Physiol.*, 158: 1153-1165.

Degenhardt, D. F. and Z. P. Kondra, 1981. The influence of seeding date and seeding rate on seed yield and yield components of five genotypes of *Brassica napus*. *Can. J. Plant Sci.*, 61: 175-183.

Desclaux, D. and P. Roumet, 1996. Impact of drought stress on the phenology of two soybean (*Glycine max* L. Merril) cultivars. *Field Crops Res*., 46: 61-70.

Doly, A. D. and H. Marcellos, 1974. Time of sowing and wheat yield in northern New South Wales. *Aust. J. Exp. Agric. Anim. Husb.*, 14: 93-102.

Dong H, X. Kong, W. Li, W. Tang, and D. Zhang 2010. Effects of plant density and nitrogen and potassium fertilization on cotton yield and uptake of major nutrients in two fields with varying fertility. Field Crop Res.119:106–113.

Dubetz, S. and S. B. Bole, 1973. Effect of moisture stress at early heading and nitrogen fertilizer on three wheat cultivars. *Can. J. Plant Sci.,* 53: 1-5.

Evanari, M., L. Shanan and N. Tadmor, 1982. The Negev: the Challenge of the Desert. *Harvard University Press*, Cambridge, p. 437.

Fan, Z. X., Z. F. Wang and F. S. Zhang, 2003. Effect of mulch on soil physical characteristics and wheat yield. *J. Wheat Res.*, **24** (3):18-20.

Farooq, M., T. Aziz, S. M. A Basra, M. A. Cheema and H. Rehamn, 2008. Chilling tolerance in hybrid maize induced by seed priming with salicylic acid. *J. Agron. Crop Sci.*, 194: 161-168.

Fitter, A. H. and R. K. M Hay, 1987. Environmental physiology of plants, 2nd ed., *Academic Press*, London, 423 pp

Forster, B., 2004. Genotype and phenotype associations with drought tolerance in barley 14 tested in North Africa. *Ann. Appl. Biol*., 144: 157-168.

Garcia, L., 2003. Evaluation of grain yield and its components in durum wheat under Mediterranean condition. *Agron. J.*, 95: 266-274.

Gauer, E., C. F. Shaykewich and E. H. Stobbe, 1982. Soil temperature and soil water under zero tillage in Manitoba. *Canadian Journal of Soil Science*, 62: 311-325.

Hall, A. E., 2007. Sahelian Droughts: A Partial Agronomic Solution. www.plantstress.com

Hartwell, B. L. and F. R. Pember, 1908. Experiments with feldspathic rock as a source of postassium. *Roy. Inst. Agric. Ex. Station Bull.* 129: 27.

Huseynova, M., S. Y.Suleymanov, S. M. Rustamova and J. A. Aliyev, 2009. Drought-induced changes in photosynthetic membranes of two wheat (*Triticum aestivum* L.) cultivars. *Russ. Biokhimiya,* 74: 1109-1116.

Hussain, I., K. R. Olson and S. A. Ebelhar, 1999. Impacts of tillage and no-till production of maize and soybean on an eroded Illinois silt loam soil. *Soil & Tillage Research*, 52: 37-49.

Hussain, M., M. A. Malik., M. Farooq, M. B. Khan, M. Akram and M. F. Saleem, 2009. Exogenous glycinebetaine and salicylic acid application improves water relations, allometry and quality of hybrid sunflower under water deficit conditions. *J. Agron. Crop Sci.*, 195: 98-109.

Jain, M., S. Tiwary and R. Gadre, 2010. Sorbitol-induced changes in various growth and biochemicalp arameters in maize. *Plant Soil Environ.,* 56: 263-267.

Jaleel, C. A., P. Manivannan and A. Wahid, 2009. Drought stress in plants: a review on morphological characteristics and pigments composition. *Int. J. Agr. Biol.,* 11: 100-105.

Kannan, N.D., and G. Kulandaivelu, 2011. Drought induced changes in physiological, biochemical and phytochemical properties of Withania somnifera Dun. J. Med. Plants Res. 5: 3929-3935.

Keller, W. D., 1948. Native rocks and minerals as fertilizers. *Science Monthly*, 66: 122-130.

Kim, J. Y., A. Mahé, J. Brangeon and J. L. Prioul, 2000. A maize vacuolar invertase, IVR2, is induced by water stress. Organ/tissue specificity and diurnal modulation of expression. *Plant Physiology*, 124: 71-84.

Kohn, G. D. and R. R. Storrier, 1970. Time of sowing and wheat production in southern New South Wales. *Aust. J. Exp. Agric. Anim. Husb.*, 10: 604-609.

Kramer, P. J. and J. S. Boyer, 1995. Water relations of plant and soil. *Academic Press*, San Diego, p. 495.

Kulshrehtha, S., D. P. Mishra and R. K. Gupta, 1987. Changes in contents of chlorophyll, proteins and lipids in whole chloroplasts and chloroplast membrane fractions at different water potential in drought resistant and sensitive genotypes of wheat. *Photosynthetica*, 21: 65-70.

Larney, F. J. and C. W Lindwall, 1995. Rotation and tillage effects on available soil water for winter wheat in a semi-arid environment. *Soil & Tillage Research*, 36: 111-127.

Li, K. J., W. Z. Jia and H. E Feng, 2004. The technology of irrigation with slightly saline water in Heilonggang region of East Hebei. *Chin. J. Agric. Technol. Popular.*, 3:55-56.

Li, S. Q. and N. J. Lan, 1995. Achievements and progresses in the research of wheat mulched by plastic films. *Gansu Agri. Sci. Technol.*, 5:1-3.

Liu, F., C. R Jensen and M. N. Andersen, 2004. Drought stress effect on carbohydrate concentration in soybean leaves and pods during early reproductive development: its implication in altering pod set. *Field Crops Research*, 86 (1):1-13.

Lopez-Raez, J. A., T. Charnikhova, V. Gomez-Roldan, R. Matusova, W. Kohlen, R. De Vos, F. Verstappen, V. Puech-Pages, G. Becard, P. Mulder and H. Bouwmeester, 2008. Tomato strigolactones are derived from carotenoids and their biosynthesis is promoted by phosphate starvation. *New Phytol.*, 178: 863-874.

Loss, S. P. and K. H. M Siddique, 1997. Adaptation of faba bean (*Vicia faba*, L.) to dry land Mediterranean-type environment. I. Seed yield components. *Field Crops Research*, 54: 17-28.

Lott, J. N. A., J. Kolasa, G. D. Batten and L. C. Campbell, 2011. The critical role of phosphorus in world production of cereal grains and legume seeds. *Food Security*, 3: 451-462.

Lyon, D., W. W. Stroup and R. E Brown, 1998. Crop production and soil water storage in long-term winter wheat-fallow tillage experiments. *Soil & Tillage Research*, 49: 19-27.

Mafakheri, A., A. Siosemardeh, B. Bahramnejad, P. C. Struik and Y. Sohrabi, 2010. Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars. *Aust. J. Crop Science*, **4** (8): 580-585.

Mailer, R. J. and P. S.Cornish, 1987. Effects of water stress on glicosinolate and oil contents in the rape (*Brassica napus* L.) and turnip rape (*B. rapa* L.). *Australian Journal of Experimental Agriculture*, 27: 707-711.

Malakouti, M. J and M. M. Tehrani, 2005. Effects of micronutrient on the yield and quality of agricultural products: Micronutrient with macro-effects. *Tarbiat Modares University Press*, Tehran, Iran, p. 445.

Mambetnazarov, A. B., 2016. Features of water consumption of cotton on irrigated lands of Karakalpakstan. *Bulg. J. Agric. Sci.*, 22: 250-252.

McDonald, G. K., B. G. Sutton and F. W. Ellison, 1983. The effect of time of sowing on the grain yield of irrigated wheat in the Namoi Valley, New South Wales. *Aust. J. Exp. Agric. Anim. Husb.*, 34: 229-240.

Mesfine, T., G. Abebae and A. M. AL-Tawaha, 2005. Effect of reduced tillage and crop residue ground cover on yield and water use efficiency of sorghum (*Sorghum bicolor* (L.) Moench) under semi-arid conditions of Ethiopia. *World Journal of Agricultural Sciences*, 1 (2): 152-160.

Mooney, H. A., O. Bjorkman and G. J. Collatz, 1978. Photosynthetic acclimation to temperature in the desert shrub *Larrea divaricata. Plant Physiology,* 61:406-10.

Mott, J. J., 1972. Germination studies on some annual species from an arid region of Western Australia. *Journal of Ecology,* 60: 293-304.

Munier-Jolain, N. G., N. M. Munier-Jolain., R. Roche, B. Ney and C. J. Duthion, 1998. *Exp. Bot.*, 49: 1963-1969.

Musallam, I. W., G. Al-Karaki, K. Ereifej and A. M. Tawaha,. 2004. Yield and Yield Components of Faba Bean Genotypes Under Rainfed and Irrigation Conditions. *Asian Journal of Plant Science*, **3** (4): 439-448.

Nasri, M., M. Khalatbari, H. Zahedi, F. Paknejad and H. R. Tohidi-Moghadam, 2008. Evaluation of micro and macro elements in drought stress condition in cultivars of rapeseed (*Brassica napus* L.). *American Journal of Agricultural and Biological Sciences,* **3** (3): 579-583.

Neslihan-Ozturk, Z., V. Talam, M. Deyholos, C. B. Michalowski, D. W. Galbraith, N. Gozukirmizi, R. Tuberosa and H. J. Bohnert, 2002. Monitoring large-scale changes in transcript abundance in drought- and saltstressed barley. *Plant Molecular Biology*, 48: 551-573.

Nezami, A., H. R Khazaei, Z. Boroumand, A. Rezazadeh and A. Hosseini, 2008. Effects of drought stress and defoliation on sunflower (*Helianthus annuus* L.) in controlled conditions. *Desert*, 12: 99-104.
http://jdesert.ut.ac.ir

Nikus, O, M. A. Turk and A. M. Al-Tawaha, 2004. Yield response of sorghum (*Sorghum bicolor* L.) to manure supplemented with phosphate fertilizer under semi-arid Mediterranean conditions. *International Journal of Agriculture and Biology*, 6 (5): 889-893.

Nilsson, A., 1988. Groundwater Dams for Small-Scale Water Supply. *Intermediate Technology Publ.*, London.

Nobel, P. S. and S. D. Smith, 1983. High and low temperature tolerances and their relationships to distribution of agaves. *Plant, Cell and Environment,* 6: 711-719.

Nooden, L. D.,1988. The phenomena of senescence and aging. In: L. D. Nooden, A. C. Leopald (Ed.) Senescence and Aging in Plants. *Academic Press*, San Diego, pp. 1-50.

Oweis, T and A. Hachum, 2003. Improving Water Productivity in the Dry Areas of West Asia and North Africa. Water Productivity in Agriculture: Limits and Opportunities for Improvement. CABI, Wallingford, UK, p.183.

Paknejad, F., M. Nasri, H. R. T. Moghadam, H. Zahedi and M. J. Alahmadi, 2007. Effect of drought stress on chlorophyll fluorescence parameters, chlorophyll content and grain yield of cultivars. *J. Biological Sci.*, **7** (6): 841-847.

Pallas, J. E., J. R. Stansell and R. R. Bruce, 1977. Peanut seed germination as related to soil water regime during pod development. *Agron. J.*, 69: 381-383.

Pettigrew, W. T., 2008. Potassium influences on yield and quality production for maize, wheat, soybean and cotton. *Physiol. Plantarum*, 133: 670-681.

Phillips, R. E., 1984. Soil moisture. In: R. E. Phillips and S. H. Phillips (Eds.), No-tillage Agriculture: Principles and Practices, *Van Nostrand-Reinhold*, New York.

Phillips, W. S., 1963. Depths of roots in soil, *Ecology,* 44: 424.

Rahman, M. T., M. T. Islam and M. O. Islam, 2002. Effect of water stress at different growth stages on yield and yield contributing characters of transplanted Aman rice. *Pak. J. Biol. Sci.*, 5: 169-72.

Richards, R. A., A. G. Condon and G. J. Rebetzke, 2001. Application of physiology in wheat breeding, Mexico, *D. F. CIMMYT*, pp. 88-100.

Samarah, N. H., N. Haddad and A. Alqudah 2009. Yield potential evaluation in chickpea genotypes under late terminal drought in relation to the length of reproductive stage. *Italian J. Agron*., 3: 111-117.

Sanchez, D., J. Garcia and M. Antolin, 2002. Effects of soil drought and atmospheric humidity on yield, gas exchange, and stable carbon isotope composition of barley. *Photosynthetica*, 40: 415-421.

Setter, T. L., B. A. Flannigan and J. Melkonian, 2001. Loss of kernel set due to water deficit and shade in maize: carbohydrate supplies, abscisic acid, and cytokinins. *Crop Science,* 41: 1530-1540.

Shafea, L. and M. Saffari, 2016. Evaluation of grain filling rate and path analysis in different combinations of nitrogen and zinc in maize. *Bulg. J. Agric. Sci.*, 22: 60-64

Shao, H. B., L. Y. Chu, C. A. Jaleel, P. Manivannan, R. Panneerselvam and M. A. Shao, 2009. Understanding water deficit stress-induced changes in the basic metabolism of higher plants-biotechnologically and sustainably improving agriculture and the ecoenvironment in arid regions of the globe. *Crit. Rev. Biotechnol.*, 29: 131-151.

Shreve, F., 1942. The desert vegetation of North America. *Botanical Review*, 8: 195-246.

Schaffer, W. and M. Gadgil, 1975. In: M. Cody and J. Diamond (Eds.) The Ecology and Evolution of Communities, *Harvard Univ. Press*, Cambridge, MA, pp. 142-157.

Smith, S. V., 1984. Phosphorus versus nitrogen limitation in the marine environment. *Limnology and Oceanography,* 29: 1149-1160.

Stone, P. J. and M. E. Nicolas, 1998. Comparison of sudden heat stress with gradual exposure to high temperature during grain-filling in two wheat varieties difference in heat tolerance. II. Fractional protein accumulation. *Aust. J. Plant Physiol.,* 25: 1-11.

Sun, C., H. Cao, H. Shao, X. Lei and Y. Xiao, 2011. Growth and physiological responses to water and nutrient stress in oil palm. *Afr. J. Biotechnol.*, 10: 10465-10471.

Szarek, S. R. and I. P. Ting, 1975. Photosynthetic efficiency of CAM plants in relation to C3 and C4 plants. In: R. Marcelle (Ed.), Environmental and Biological Control of Photosynthesis. *Junk*, The Hague.

Taiz, L. and E. Zeiger, 2006. Plant Physiology, 4th Ed., *Sinauer Associates Inc. Publishers*, Massachusetts.

Tawaha, A. M. and Al-A. A Ghzawi, 2013. Effect of Chitosan coating on seed germination and salt-tolerance of lentil (*Lensculinaris* L.) *Res on Crops,* 14 (2): 489-491.

Tawaha, A. M. and M. A. Turk, 2002. Lentil (*Lens culinaris* Medic.) productivity as influenced by rate and method of phosphate placement in a Mediterranean environment. *Acta Agronomica Hungarica*, **50** (2): 197-201.

Tawaha, A. M. and M. A Turk, 2004. field pea seeding management for semi-arid Mediterranean conditions. *Journal of Agronomy and Crop Science*, 190: 86-92.

Tawaha, A. M., V. P. Singh, M .A.Turk and W. Zheng 2003. A review on growth, yield components and yield of barley as influenced by genotypes, herbicides and fertilizer application. *Research on Crop*, **4** (1).

Tawaha, A. M., M. A Turk. and K. D. Lee, 2005. Adaptation of chickpea to cultural practices in a Mediterranean type environment. *Research Journal of Agriculture and Biological Science*, **1** (2): 152-157.

Tawaha, A. M., M .A.Turk and G. A Maghaireh, 2001. Morphological and yield traits of awnless barley as affected by date and rate of sowing under Mediterranean condition. *Crop Research*, 22 (3) 311-313.

Turk, M. A. and A. M. Tawaha, 2001. Common vetch (*Vicia sativa* L.) productivity as influenced by rate and method of phosphate fertilization in a Mediterranean environment. *Agricultura Mediterranea*, 131: 108-111.

Turk, M. A. and A. M. Tawaha, 2002a. Impact of seeding rate, seeding date, rate and method of phosphorus application in faba (*Vicia faba* L. Minor) in the absence of moisture stress. *Biotechnology, Agronomy, Society and Environment*, 6 (3): 171-178.

Turk, M. A. and A. M. Tawaha, 2002b. Irrigated winter barley response to seeding rates and weed control methods under Mediterranean environments. *Bulgarian Journal of Agricultural Science*, **8** (2-3): 175-180.

Turk, M. A., A. M. Tawaha and M. Shatnawi, 2003. Lentil (*Lens culinaris* Medik) Response to plant density, sowing date, phosphorus fertilization and Ethephon application in the absence of moisture stress. *Journal of Agronomy and Crop Science*, **189** (1): 1-6.

Van Duivenbooden, N., M. Pala., C. Studer, C. L. Bielders and D. J. Beukes, 2000. Cropping systems and crop complementarity in dryland agriculture to increase soil water use efficiency: a review. *Netherlands Journal of Agricultural Science*, 48: 213-236.

Walter, H. and S. W. Breckle, 1989. Ecological systems of the geobiosphere. III Temperate and polar zonobiomes of northern Eurasia. *Springer, Berlin, Heidelberg,* New York, 581 pp.

Went, F. W., 1953. The Effect of Temperature on Plant Growth. *Annual Review of Plant Physiology,* 4 (June 1953): 347. Abstract.

Wery, J., S .N. Silim, E. J Knights, R. S. Malhotra and R. Cousin, 1994. Screening techniques and sources and tolerance to extremes of moisture and air temperature in cool season food legumes. *Euphytica*, 73: 73-83.

Xoconostle-Cazares, F. A., L. Ramirez-Ortega, R. Flores-Elenes and M. Ruiz-Medrano, 2010. Drought tolerance in crop plants. *Am. J. Plant Physiol.,* 5: 1-6.

Zhang, Z. H., S. H. Yan and Y. H. Hu, 1996. Effects of mulch on soil water and salt moving in coastal saline soil. *Chin. J. Soil Sci.*, **27**(3): 136-138.

Received December, 26, 2016; accepted for printing May, 3, 2017