International Journal of Advance Research in Science and Engineering
Vol. No. 5, Issue No. 08 , August 2016
www.ijarse.com
IJARSE
ISSN 2319 - 8354

EFFECTS OF RISING TEMPERATURE ON EVAPOTRANSPIRATION AND ET CONTROL

Praveen Solanki[1], Rajeev Ranjan[2], Maitreyie Narayan[3], Surindra Negi[4]

[1,3,4]Ph.D. research scholar Dept. of Environmental Science

[2]Assistant Professor Dept. of Agrometeriology

G. B. Pant University Agriculture and Technology, Pantnagar (India)

ABSTRACT

Evapotranspiration (ET) is a significant water loss from drainage basins. Types of vegetation and land use significantly affect evapotranspiration, and therefore the amount of water leaving a drainage basin. Because water transpired through leaves comes from the roots, plants with deep reaching roots can more constantly transpire water. Through ET, forests reduce water yield, except in unique ecosystems called cloud forests. Trees in cloud forests collect the liquid water in fog or low clouds onto their surface, which drips down to the ground. These trees still contribute to evapotranspiration, but often collect more water than they evaporate or transpire.In areas that are not irrigated, actual evapotranspiration is usually no greater than precipitation, with some buffer in time depending on the soil's ability to hold water. It will usually be less because some water will be lost due to percolation or surface runoff. Climate change (rising temperature) is likely to require adaption of agricultural practices such as irrigation in India. Due to sandy soils with low water retention capacity and occasional insufficient rainfall, irrigation is a basic condition for agricultural production in the county. Transpiration rates go up as the temperature goes up, especially during the growing season, when the air is warmer due to stronger sunlight and warmer air masses. Higher temperatures cause the plant cells which control the openings (stoma) where water is released to the atmosphere to open, whereas colder temperatures cause the openings to close.

KEYWORDS: Evapotranspiration, precipitation, temperature, antitranspirant.

I. INTRODUCTION

Under dry land conditions soil moisture is the most limiting factor for cropproduction and simultaneously increase in temperature (as per the IPCC, 5^{th}AR (2014)**,** the averageglobal surface temperature has increased by nearly 1 ^{0}C over the past century and is likely to rise by another 1.4 to 5.8 ^{0}C over the next century) is more likely to affect the hydrological cycle. Water is lost as evaporation from soil surface and as transpiration from theplant surfaces. The combined loss of moisture through these two processes is knownas evapotranspiration.

Irrigated agriculture is dependent on an adequate water supply of usable quality. Water quality concerns have often been neglected because good quality water supplies have been plentiful and readily available. This situation is now changing in many areas. Intensive use of nearly all good quality water and extreme dry weather conditions are decreasing the quality water (Jagermeyr*et al*., 2015).

Low rainfall or failure of monsoon rain is a recurring feature in India. This hasbeen responsible for droughts and famines. The word drought generally denotesscarcity of water in a region. Though, aridity and drought are due to insufficientwater, aridity is a permanent climatic feature and is the culmination of a number oflong term processes (Bunce, 1997). However, drought is a temporary condition that occurs for ashort period due to deficient precipitation for vegetation, river flow, water supplyand human consumption. Drought is due to anomaly in atmospheric circulation.

In middle latitudes drought occurs under cool temperature conditions. This isdue to excessive transpiration and absence of absorption of moisture from thesoil, when the soil is in extremely low temperature conditions (Collatz*et al*., 1991).

II. EFFECTS ON EVAPOTRANSPIRATION

The rate of transpiration is fastest when air temperature is between 20°C to 30°C. At these temperatures the stomata apertures or opening are generally widest. In general, the stomata close at temperatures about 0°C and progressively increase in aperture up to about 30°C (Lu *et al*., 2000).

In addition, there are fleshy or relatively thick leaves, stems and fruits which, upon exposure to sunlight, results to internal temperatures which exceed that of surrounding air. The difference may reach 10°C. This wide difference in temperature would result to a steeper water potential gradient between the plant organ and the external environment. Consequently, it will favour rapid rate of transpiration (Atkin and Tjoelker, 2003).

Temperature as an environmental factor affecting transpiration also relates to water potential and relative humidity. The relationship of temperature (T, in °K), relative humidity (RH, in %) and water potential (Ψw, in pascal) is shown in the following mathematical equation provided by Hopkins (1995).

$$\Psi w = 1.06\ T \log(RH/100)$$

Applying the equation, an increase in temperature will decrease water potential. Thus at the same RH of 50%, Ψw at temperature of 20°C or 293.15°K is -93.5 MPa but lower (more negative, Ψw = -96.7 MPa) at higher temperature of 30°C. Increase in atmospheric temperature will therefore steepen further the plant-air water potential gradient.

Solar or thermal energy is necessary to evaporate the water from bothsoil and plant surfaces. Thus, of the total solar radiation intercepted by the leaf, only 1to 5% is used for photosynthesis and 75 to 85% is used for radiating the canopy surfacei.e., leaves and for transpiration. Hence, increased solar radiation increases atmosphericdemand and in turn evapotranspiration (Chartzoulakis*et al*., 200).

Increasing the temperature, increases the capacity of air to holdwater i.e., vapour pressure deficit is high, which means a greater atmospheric demandi.e., greater ET (Bunce, 1997).

Hot waves are very harmful during summer. These are experienced over Deccan andCentral parts of India during March to May. The harmful effects include shedding offruits, plants drying of water resources, loss of water by evaporation from irrigation channels, transpiration increases from plants beyond recouping levels, plants tend to wilt and die owing to rapid desiccation and ultimately hot winds cause shrivelling effect at milk stage of all agricultural crops (Souch*et al*., 1998).

Increase in the temperature results in opening of stomata.Temperature has significant effect on the permeability of the wall of the guard cellsand therefore greatly affects the osmatic phenomenon. This phenomenon isresponsible for the movement of guard cells (Bernacchi*et al*., 2001).

High air temperature, results in the desiccation of the crop plants also, injury caused because of short period fluctuation in air temperature is known as sunclad, the scorching of stem near the soil surface known as stem girdle is anotherinjury at high air temperatures, plant tissues escape from high heat by emission of long wave radiation,convection of heat, and transpiration (Hikosaka*et al*., 2006). However, transpiration is the most effective process in many natural situations; hence exposure of crop plants to temperatures over 45^{o}C for just 30 minutes can causesevere damage to the leaves of plants.The effect of high temperature is the disruption of cell metabolism, production of toxic substances, and damage to cellularmembranes due to higher rate of transpiration.

Higher rising temperature alters the water status by its influence on absorption,translocation and transpiration. The lag in absorption behind transpiration results inloss of turgor as a result of increase in the atmospheric dryness. Photosynthesis is reduced by moisture stress due to reduction in photosynthetic rate, chlorophyll content, leaf area and increase in assimilatessaturation in leaves. All most all metabolic reactions are affected by water deficits.Decrease in growth of leaves, stems and fruits maturity is delayed if drought occurs before flowering while it advances if droughtoccurs after flowering (Bjorkman*et al*., 1980).

Drought at flowering and grain developmentdetermines the number of fruits and individual grain weight, respectively. Panicleinitiation in cereals is critical while drought at anthesis may lead to drying of pollen.Drought at grain development reduces yield while vegetative and grain filling stagesare less sensitive to moisture stress (Borrell*et al*., 2006).

Because of high atmospheric temperature the atmospheric demand for moisture increases causing high evapotranspiration losses resulting in moisture stress. The effect on yield depends hugely on what proportion of the total drymatter is considered as useful material to be harvested (Brodribb and Jordan, 2008). If it is aerial andunderground parts, effect of drought is as sensitive as total growth. When the yieldconsists of seeds as in cereals, moisture stress at flowering is detrimental. When theyield is fibre or chemicals where economic product is a small fraction of total drymatter moderate stress on growth does not have adverse effect on yields.

The organic matter content in most of the soilsunder dry-land conditions is very low (< 1 %) due to high temperature and lowaddition of organic manures. Poor organic matter content adversely affects soilphysical properties related to moisture storage.Inoculating legumes with Rhizobium could not met with success for increasing'N' fixation under dry-land conditions probably due to unfavourable environment,especially prolonged soil moisture stress periods during crop season, hightemperature stress and deficiency of other nutrients (Fletcher*et al*., 2007).

Biofertilizers like Azospirillum commonly found in association with roots ofcereals and grasses. High N fixation capacity, low energy requirement and abundantestablishment in the roots of cereals and tolerance to high temperature (30-40° C)are responsible for its suitability to dry land conditions. It has been largely tested insorghum and bajra and can substitute up to 20 kg N/ha (Jochum*et al*., 2004).

All most all NPT (NEW PLANT TYPES) are photo insensitive and completely resistant to fluctuations in day length. Theycan be grown under all crop seasons provided inputs like fertilizers and irrigations are adequately madeavailable, so higher yields can be obtained. However, some of the NPTs are thermo-sensitive and areaffected by variation in temperature during season.

In India, maize cultivation extends from the hot arid plains of Rajasthan and Gujarat Extremelyhigh temperature and high humidity during flowering damage the foliage, deissicates the pollen andinterferes with proper pollination which results in poor grain formation (Souch, 1998).The high temperatures on bothends of wheat season restrict the cultivation of this crop in India. Too cooler months, hightemperatures in September do not permit good tillering of the crop. They also favour root rot andseedling blight. Hot summer during the grain ripening period hastens the maturity of the crop giving inferior quality of the crop.

The ions of primary concern are chloride, sodium and boron. Although toxicity problems may occur even when these ions are in low concentrations, toxicity often accompanies and complicates a salinity or water infiltration problem. Damage results when the potentially toxic ions are absorbed in significant amounts with the water taken up by the roots. The absorbed ions are transported to the leaves where they accumulate during transpiration (Wieringa, 1986). The ions accumulate to the greatest extent in the areas where the water loss is greatest, usually the leaf tips and leaf edges. The degree of damage depends upon the duration of exposure, concentration by the toxic ion, crop sensitivity, and the volume of water transpired by the crop. In a hot climate or hot part of the year, accumulation is more rapid than if the same crop were grown in a cooler climate or cooler season when it might show little or no damage.

Salts are added to the soil with each irrigation. These salts will reduce crop yield if they accumulate in the rooting depth to damaging concentrations. The crop removes much of the applied water from the soil to meet its evapotranspiration demand (ET) but leaves most of the salt behind to concentrate in the shrinking volume of soil water (Sheffieldand Wood, 2008).A toxicity problem is different from a salinity problem in that it occurs within the plant itself and is not caused by a water short-age. Toxicity normally results when certain ions are taken up with the soil-water and accumulate in the leaves during water transpiration to an extent those results in damage to the plant. The degree of damage depends upon time, concentration, crop sensitivity and crop water use, and if damage is severe enough, crop yield is reduced. The usual toxic ions in irrigation water are chloride, sodium and boron. Damage can be caused by each, individually or in combination.

The toxic ions sodium and chloride can also be absorbed directly into the plant through the leaves moistened during sprinkler irrigation. This occurs typically during periods of high temperature and low humidity. The leaf absorption speeds the rate of accumulation of a toxic ion and may be a primary source of the toxicity (Sherwood and Huber, 2010).The most common toxicity is from chloride in the irrigation water. Chloride is not adsorbed or held back by soils, therefore it moves readily with the soil-water, is taken up by the crop, moves in the transpiration stream, and accumulates in the leaves. If the chloride concentration in the leaves exceeds the tolerance of the crop, injury symptoms develop such as leaf burn or drying of leaf tissue.

III. CONTROL MEASURE

3.1 Methods of irrigation

Localized irrigation systems (drip, trickle or spitter) apply water on a daily or near daily basis at a very low application rate (2–8 litres per hour per emitter). The near daily replenishment of the water used by the crop keeps the soil moist and very near to or slightly above field water holding capacity. The irrigations should maintain a slight but nearly continuous downward movement of moisture and salts for excellent short-term salinity control. Irrigation efficiency can be close to 100 % during the cropping period, meaning that the crop evapotranspiration demand can be met essentially without losses due to runoff or deep penetration.

Irrigations to maintain high moisture content during the seedling stage of the crophave been found to be detrimental to the growth of jowar due to lowering of soiltemperature below the optimum and leaching of plant nutrients from the root zone.

Irrigation at 45th day even for rainfed crops which coincides with boot leaf ensuresgood yields.Decreasing the turbulent transfer of water vapour to the atmosphere bygrowing plants, raising wind breaks, straw mulches etc.Decreasing capillary conductivity by rapid drying of the surface soil layers.Decreasing the capillary flow and moisture holding capacity of the surfacesoil layers.For evaporation control, mostly mulches are used (Mott, 2007).

3.2 Use of mulches (**)

Mulch is any covering material applied on the soil surface to reduceevaporation losses. This material may be grown and maintained in place, or anymaterial grown and modified before placement or any material processed ormanufactured and transported before placement.

Types of mulches

Soil mulch or dust mulch: Soil mulch is a thin layer of loose soil surface that canbe created by frequently stirring the soil with surface tillage implements like danthis, gun takas. Soil mulch of surface 5-8 cm dry soil effectivelyreduces the evaporation losses by obstructing the raise of soil moisture throughcapillary action. The soil mulch also prevents deep cracks in soils by reducing the direct action of atmosphere and hence evaporation is alsoreduced. The repeated intercultivations done in rabi crops even in the absence ofweeds help in reducing evaporation losses. Among the different mulches soil mulch isthe cheapest.

Straw and stubble mulch: Straw and other crop residues like stubbles, groundnutshells, cotton stalks etc; can be used as mulches on soil surface for moistureconservation. Straw mulches reduce both the amount of energy absorbed by the soiland its movement above the soil and hence reduce evaporation. However,the availability of adequate crop residues is a problem for use as mulches.

Plastic mulches: Plastic mulches are very effective as mulches for evaporationcontrol provided cost is not a limiting factor. The plastic mulches may be either whiteor black. Black plastic mulches will absorb the solar radiation and enhance the soiltemperature for hastening the germination of winter crops like wheat; barley etc.,White plastic mulches will reflect the incident radiation and reduce evaporation ofsoil moisture.

Chemical mulches: Chemicals like hexadeconol, a long chain alcohol when mixedwith surface 5 mm of soil can reduce evaporation by about 40%. The surface layer ofa treated soil dries out more rapidly than that of untreated soil, creating a diffusionallayer to evaporation.

Vertical mulching: It is a technique wherein trenches of 40 cm wide, 15 cm deepare dug at 2 to 4 m interval across slope and filled with stubbles or organic wastes toa height of 10 cm above soil surface. Runoff is checked, collected in the shallowtrenches and redistributed to adjoining soil layers and infiltration is increased inblack soils.

Live mulching: Is the term used to describe the covering of soil surface throughthe plant canopy in intercropping system.Eg.Sorghum + forage cowpea, sorghum + sword bean.

Pebble mulch: Where small pebbles like stone are placed on the soil surface. This mulching will be successful in dry-land fruit tree culture. The pebblesplaced on the basis of trees not only reduce evaporation but also facilitateinfiltration of rain water into the basin.Mulching is more advantageous during rabi/summer months than in kharifseason. Organic mulches particularly under receding soil moisture conditionsincrease crop growth by conserving soil moisture.

Soil temperature: The effects of mulches on soil temperature are highly variableand depend up on the type of mulch material. White or reflective type of plastic mulches generally decreases soil temperature, while black plastic mulches mayincrease soil temperature. Crop residues moderate temperature by decreasing it insummer and by increasing in winter season. This is due to combined effect ofradiation interception and evaporative cooling. The sugarcane trash mulch willenhance the germination of sugarcane setts during summer by temperaturereduction.

IV. ADAPTATION STRATEGIES (**)

Reducing losses due to transpiration

Nearly 95% of water absorbed by the plant is lost in transpiration. Hencetranspiration reduction is needed for maintaining favourable water balance in theplants. Transpiration has become unavoidable evil as the stomata, which allow CO_2exchange also allows water vapour transfer into the atmosphere.

There are four principles of transpiration control

1. By increasing leaf resistance to water vapour transfer by application ofmaterials, which tend to close or cover stomata (ex: both stomatal closingand film forming type of antitranspirants).
2. By reducing amount of energy absorbed by leaf surface (Eg: leafreflectants).
3. By reducing top growth of plants (Eg: Growth retardants).
4. By increasing air resistance to water vapour transfer by shelter belts/wind breaks

The transpiration losses can be controlled by use of antitranspirants, use ofwind breaks/shelter belts and efficient weed control.

Anti-transparent: Any material that is applied on transpiring plant surfacefor reducing water loss is called antitranspirants. The antitranspirants are alsoknown as transpiration suppressants. The best anti transpirants reduce transpirationlosses up to 30-40%.

There are four types of anti transpirants.

Stomatal closing type: Transpiration mostly occurs through stomata on the leafsurface. Some fungicides like PMA (phenyl mercuric acetate) and herbicides likeatrazine in low concentrations serve as anti transpirants by closing of stomata. PMAis known to inhibit mesophyll photosynthesis. Though the success was reported fromglasshouse studies, their effectiveness under field conditions is limited.

Film forming type: The plastic and waxy materials, which form a thin film on theleaf surface, retard the escape of water due to formation of physical barrier. Thesuccess of these chemicals is limited since they also reduce photosynthesis. Thin film forming type: HexadeconolThick film forming type: Mobileaf, Polythene S-60.

Leaf reflectant type: These are the white materials, which form a coating on theleaves and increase leaf reflectance (albedo). By reflecting the radiation they reduceleaf temperatures and vapour pressure gradient from leaf to atmosphere and hencereduces transpiration. About 5% of kaolin spray reduces the leaf temperature by 3-4°C and decrease in transpiration by 22 to 28 per cent. Celite and hydrated lime arealso used as reflectant type of anti transparent.

Growth retardant type: These chemicals reduce shoot growth and increase rootgrowth and thus enable the plants to reduce transpiring surface and resist droughtconditions. They increase root/shoot ratio.Eg :Cycocel – (2-chloroethyl) Trimethyl ammonium chloride (CCC), Phosphon–D,Maleic Hydrazide (MH). Antitranspirants generally reduce photosynthesis. Therefore, their use islimited to save the crop from death under severe moisture stress.

Use of wind breaks and shelterbelts: Wind breaks are any structures thatobstruct wind flow and reduce wind (hot wind) speed while shelterbelts are rows of treesplanted for protection of crops against wind and high temperature. Theprotection offered by the shelterbelts is dependent on the height of central tree rowin the shelterbelts. Generally, shelterbelts give protection from desiccating winds tothe extent of 5 to 10 times their height on windward side and up to 30 times onleeward side. Due to reduction in wind speed, evaporation losses are reduced andmore water is available for plants. The beneficial effect of shelterbelts is seen moreclearly in drought years. In addition, shelterbelts reduce wind erosion.

Effective weed control: Weeds transpire frequently greater amount of waterper unit of dry matter production than the crop plants. Therefore controlling weedsespecially at early stages of crop growth will be most effective means of increasingthe amount of water available for crops. This is the most useful method to reducetranspiration losses.

V. CROP ADAPTATION STRATEGIES

The ability of crop to grow satisfactorily under water stress is called droughtadaptation. Adaptation is structural or functional modification in plants to surviveand reproduce in a particular environment.Crops survive and grow under moisture stress conditions mainly by threeways: (i) escaping drought, (ii) drought resistance and (iii) avoiding stress.

Escaping Drought-Evading the period of drought is the simplest means of adaptation of plants todry conditions. Many desert plants, the so called ephemerals, germinate at thebeginning of the rainy season and have an extremely short life period (5 to 6 weeks)which is confined to the rainy period. These plants have no mechanism forovercoming moisture stress and are, therefore, not drought resistant. In cultivated crops, the ability of a cultivar to mature before the soil dries isthe main adaptation to growth in dry regions. Certain varieties of pearlmillet mature within 60 days after sowing. Short duration pulses like cowpea,greengram, blackgram can be included in this category (Nan*et al*., 2011).

Drought Resistance-Plants can adapt to drought either by avoiding stress or by tolerating stressdue to different mechanisms. These mechanisms provide drought resistance.

Avoiding Stress-Stress avoidance is the ability to maintain a favourable water balance, andturgidity even when exposed to drought conditions, thereby avoiding stress and itsconsequences. A favourable water balance under drought conditions can be achievedeither by: (i) conserving water by restricting transpiration before or as soon as stressis experienced; or (ii) accelerating water uptake sufficiently so as to replenish thelost water.

VI. UTILIZATION OF CO_2 FERTILIZATION

Water deficit stress can occur as precipitation does not adequately compensate for an increased evaporative demand due to a temperature rise. This stress could cause a decline in yield or require more irrigation to maintain yields. This negative effect of increased temperature may be counteracted by effects of elevated CO_2 on crop tolerance to water stress. Increased atmospheric CO_2 levels have important physiological effects on crop plants such as an increase in photosynthetic rate. Depending on the inclusion and exclusion of CO_2-fertilization effect, an increase, or a decrease is reported to occur in crop yields (Wassen and Joosten,1996).

VI. STRATEGIES FOR DROUGHT MANAGEMENT (*)

The different strategies for drought management are discussed under thefollowing heads.

Adjusting the plant population: The plant population should be lesser indryland conditions than under irrigated conditions. The rectangular type of plantingpattern should always be followed under dryland conditions. Under drylandconditions whenever moisture stress occurs due to prolonged dry spells, underlimited moisture supply the adjustment of plant population can be done by the followings.

Increasing the inter row distance: By adjusting more number of plants withinthe row and increasing the distance between the rows reduces the competitionduring any part of the growing period of the crop. Hence it is more suitable forlimited moisture supply conditions.

Increasing the intra row distance: Here the distance between plants is increased by which plants grow luxuriantly from the beginning. There will be competition for moisture during the reproductive period of the crop. Hence it is less advantageous as compared to above under limited moisture supply.

Mid-season corrections: The contingent management practices done in thestanding crop to overcome the unfavourable soil moisture conditions due toprolonged dry spells are known as mid-season conditions.

Thinning: This can be done by removing every alternate row or every third rowwhich will save the crop from failure by reducing the competition.

Spraying: In crops like groundnut, castor, redgram, etc., during prolonged dry spells the crop can saved by spraying water at weekly intervals or 2 per cent urea atweek to 10 days interval.

Ratooning: In crops like sorghum and bajra, ratooning can practiced as mid-season correction measure after break of dry spell.

Weed control: Weeds compete with crop for different growth resources ore seriously under dryland conditions. The water requirement of most of the weeds ismore than the crop plants. Hence they compete more for soil moisture. Therefore theweed control especially during early stages of crop growth reduces the impact of dry spell by soil moisture conservation.

Water harvesting and lifesaving irrigation:The collection of runoff water during peak periods of rainfall and storing in different structures is known as water harvesting. The stored water can be used for giving the lifesaving irrigation during prolonged dry spells.

Avoiding Stress-CRI: In wheat, the first node of crown is formed near the soil surface irrespective of the depthof sowing. Crown roots start developing at this node. Depending upon temperature, CRI takesplace 15-21 DAS. Plants at his stage are very sensitive to soil moisture stress. Hence, there is aneed for adequate moisture at this stage (Longobardiand Villani, 2013).

VII. CONCLUSION

Global climate change may have serious impacts on water resources and agriculture in the future. Water deficit stress can occur as precipitation does not adequately compensate for an increased evaporative demand due to a temperature rise. This stress could cause a decline in yield or require more irrigation to maintain yields. In the future, water demand for irrigation will increase due to decreasing precipitation. Changes in climatic conditions and CO_2 concentration would result in changes in crop yields. Hence, methods of irrigation and its scheduling, use of mulches, anti-transparent, use of wind breaks and shelterbelts, crop adaptation strategies against high temperature and agronomic practices can play vital role in reducing the adverse effect of rising temperature on evapotranspiration.

REFERENCES

[1]. **Prabhakara, R. and Yellamanda, R. (AGRO 102). "Dryland Farming and Watershed Management. Lecture Notes- Dept. of Agronomy. Acharya N. G. Ranga Agricultural University.

[2]. *Pratap, K. R. and Radha, K. M. Principles of Agronomy and Agricultural Meteorology Credit Hours: 3(2+1) Acharya .N.G.Ranga Agricultural University, Rajendranagar, Hyderabad.

[3]. Atkin, O. K. and Tjoelker, M. G. (2003).“Thermal acclimation and the dynamic response of plant respiration to temperature”.Trends Plant Sci. 8, 343–351.

[4]. Bernacchi, C. J., Singsaas, E. L., Pimentel, C., Portis, A. R., and Long, S. P. (2001). “Improved temperature response functions for models of Rubisco-limited photosynthesis”. Plant, Cell and Environment. 24, 253–259.

[5]. Bjorkman, O., Badger, M. R. and Armond, P. A. (1980).“Response and adaptation of photosynthesis to high temperature. In: Turner, N.C., Kramer, P.J. (Eds.), Adaptation of Plants to Water and High Temperature Stress. John Wiley & Sons, New York, pp. 233–249.

[6]. Borrell, A., Jordan, D., Mullet, J., Henzell, B. and Hammer, G. (2006).“Drought adaptation in sorghum. In: Ribaut, J.M. (Ed.), Drought Adaptation in Cereals”. The Haworth Press, Binghamton, USA, pp. 335–399.

[7]. Brodribb, T. J. and Jordan, G. J. (2008).“Internal coordination between hydraulics and stomatal control in leaves”.Plant Cell Environ. 31, 1557–1564.

[8]. Bunce, J. A. (1997). “Does transpiration control stomatal responses to water vapour pressure deficit”.Plant Cell Environ. 20, 131–135.

[9]. Bunce, J. A. (1997). “Does transpiration control stomatal responses to water vapour pressure deficit”.Plant Cell Environ. 20, 131–135.

[10]. Chartzoulakis, K., Bosabalidis, A., Patakas, A. and Vemmos, S. (2000). Effects of water stress on water relations, gas exchange and leaf structure of olive tree. ActaHorticulturae, 537: 241–247.

[11]. Collatz, G. J., Ball, J. T., Grivet, C. and Berry, J.A. (1991). “Physiological and environmental regulation of stomatal conductance, photosynthesis and transpiration: a model that includes a laminar boundary layer”. Agric. For. Met. 54, 107–136.

[12]. Fletcher, A. L., Sinclair, T. R. and Allen, L. H. (2007). “Transpiration responses to vapor pressure deficit in well watered ‘slow-wilting’ and commercial soybean”. Environ. Exp. Bot. 61, 145–151.

[13]. Hikosaka, K., K. Ishikawa, A. Borjigidai, O. Muller, Y. and Onoda, V. (2006). “Temperature acclimation of photosynthesis: mechanisms involved in the changes in temperature dependence of photosynthetic rate”. J. Exp. Bot. 57, 291-302.

[14]. Hopkins, R. D. (1995). “Canopy temperature and crop water stress”. Advances in Irrigation / Daniel H. (ed.). New York, USA, p. 43–85.

[15]. IPCC 5th A. R. (2014). “Climate Change 2014”: The Scientific Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

[16]. Jagermeyr, J., Gerten, D., Heinke, J., Schaphoff, S., Kummu, M. and Lucht, W. (2015). “Water savings potentials of irrigation systems: global simulation of processes and linkages”. Hydrol Earth Syst Sci. 19:3073–3091.

[17]. Jochum, A. M., Camino, E. R., De Bruin, H. A. R. and Holtslag, A. A. M. (2004). “Performance of HIRLAM in a semiarid heterogeneous region: evaluation of the land surface and boundary layer description using EFEDA observations”. Mon Wea Rev. 132:2745–2760.

[18]. Longobardi, A. and Villani, P. (2013).“The use of micrometeorological data to identify significant variables in evapotranspiration modelling”.Procedia Environmental Sciences. 19: 267–274.

[19]. Lu, Z. M., M. A. Quinones, E. and Zeiger.(2000). “Temperature dependence of guard cell respiration and stomatal conductance co-segregate in an F-2 population of Pima cotton”.Aust. J. Plant Physiol. 27, 457-462.

[20]. Mott, K. A. (2007). “Leaf hydraulic conductivity and stomatal responses to humidity in amphistomatous leaves”.Plant Cell Environ. 30, 1444–1449.

[21]. Nan, L., Chen, S. P. and Wilske, B. (2011). “Evapotranspiration and soil water relationships in a range of disturbed and undisturbed ecosystems in the semi-arid Inner Mongolia, China”. Journal of Plant Ecology. 4: 49–60.

[22]. Sheffield, J. and Wood, E. (2008).“Projected changes in drought occurrence under future global warming from multi-model, multi-scenario, IPCC AR4 simulations.ClimDyn. 31:79–105.

[23]. Sherwood, S. C. and Huber, M. (2010). “An adaptability limit to climate change due to heat stress”. ProcNatlAcad Sci. 107(21):9552–9555.

[24]. Souch, C., Susan, C., Grimmond, B. and Wolfe, C. P. (1998). “Evapotranspiration rates from wetlands with different disturbance histories: Indiana Dunes National Lakeshore”. Wetlands. 18:216–229.

[25]. Wassen, M. J. and Joosten, J. H. J. (1996).“In search of a hydrological explanation for vegetation changes along a fen gradient in the Biebrza Upper Basin (Poland)”.Vegetatio. 124:191–209.

[26]. Wieringa, J. (1986). “Roughness-dependent geographical interpolation of surface wind speed averages. Quart J Roy Meteorol Soc. 112:867–889.