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Effects of surfactant and limited irrigation on forage yield and quality of alfalfa (*Medicago sativa* L.)

Sepideh Jafarian[1], Mohammad Reza Chaichi*[1], Mehrdad Moradi-ghahderijani[2]

[1]Department of Agronomy, Collage of Agriculture, University of Tehran, Karaj, Iran
[2]Department of Agronomy, Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran

***Corresponding author: rchaichi1023@gmail.com**

Abstract

To evaluate the response of alfalfa to limited irrigation and surfactant application, an experiment was conducted during 2013 and 2014 growing seasons. The experimental treatments were arranged as split plots based on a complete randomized block design with three replications. The limited irrigation treatments comprised of replenishment of 100%, 75% and 50% of weekly evaporation and plant water requirements (based on evapotranspiration and plant Kc value) assigned to the main plots. Water treatments of control (water alone) and water + surfactant (Golden Igrri Aid) were assigned to the subplots. The qualitative characteristics of alfalfa forage were recorded at 10% flowering stage. The result of the experiment showed that as the severity of limited irrigation increased crude protein percentage significantly increased, while the other traits were not affected under stress conditions. Additionally the forage yield followed a decreasing trend by enhancing the water scarcity. Surfactant application at limited irrigation treatments (75% and 50% irrigation), indirectly increased crude protein (CP) yield, reduced the neutral digestive fiber (NDF) and water soluble carbohydrate (WSC) percentage. The highest forage yield (7500 kg/ha) under limited irrigation treatments was achieved by providing of 75% weekly evaporation and plant water requirement + surfactant. Based on the results of this experiment, irrigation treatment of 75% weekly evaporation and plant water requirements + surfactant was best recommended and justified from agronomic and economical point of view.

Keywords: alfalfa, limited irrigation, surfactant, forage yield, forage qualitative traits, crude protein content.
Abbreviation: CP_ crude protein; NDF_ neutral digestive fiber; WSC_ water soluble carbohydrate.

Introduction

Drought and water shortage for human and agricultural consumption is a vital matter in arid and semi-arid regions of the world. According to some predictions, global warming and precipitation decrement will be more violent in the near future (Farre and Faci, 2006). Water is one of the most important factors contributing to crop yields and that is why conserving freshwater resources plays an important role in sustainable agriculture. Today most of the world freshwater resources are used on agricultural areas (60-80%), which makes many concerns for the future. So, more attention is needed to improve the management of water consumption in agricultural fields. Based on the research literature, it has been shown in economical evaluation aspects that using surfactant increased yield production cost, however, the grain yield increment could compensate surfactant price and consequently higher profit could be achieved (Chaichi et al., 2015). By inducing limited irrigation methods not only water consumption will be reduced but also the area under cultivation will be increased (Safai et al., 2011).

Environmental factors like soil water affects growth, yield, quality and nutritional value of crops. Among all environmental factors (biotic and abiotic stresses) challenging plants growth and yield, water stress is the most important factor that limits plant productivity especially in arid and semi-arid regions (Reddy et al., 2004). Water stress increases N concentration and protein content in cereals grain (Haberle, et al., 2008). Leaf area, dry matter, chlorophyll and essence content of peppermint (*Mentha piperita L)* significantly decreased under water stress (Mirsa et al., 2000).

The purpose of limited irrigation management is to maximize water use efficiency in crop yield and quality under deficit water conditions. To tackle and solve the problem of water scarcity in agriculture in the world and specifically in Iran, different methods such as using diverse substances in irrigation water could be useful. These substances (e.g. surfactants) reduce volume of water application, while increasing crop production efficiency. Surfactant is the abbreviation form of “Surface Active Agent”. It composes of two polar molecules which include a hydrophilic head (hydrophilic) and a hydrophobic tail (hydrophobic) (Turcios, 2007). The major effect of surfactant is on the surface tension of the air-water interface. Because of these characteristics by application of surfactant to water, the speed of water penetration into the soil will be increased. Economical evaluation have shown that using surfactant increased yield production cost, however, the yield increment could compensate surfactant price and consequently higher profit could be achieved. By surfactant application in limited irrigation systems, higher yields could be produced (Chaichi et al., 2015).

Human contribute to animal husbandry to meet a major part of the needs for food (animal protein) production. Alfalfa (*Medicago Sativa L.*) is known as one of the best sources among different forage crops for feeding livestock. This plant has a great nutritional value compared to other forage sources

(Khodabandeh, 2009). Forage plants account for a huge proportion in livestock diet (60-70% of the total dry matter intake). Livestock need the sufficient amount of fiber for the proper function of rumen. In this regard the importance of alfalfa as the best forage crop has been proven for Ruminant animals (Karimi, 1990). Alfalfa contains great amounts of minerals, protein, calcium, carotene, various vitamins and phosphorus which significantly contribute to livestock nutrition. All these characteristics along with alfalfa drought tolerance potential make it the best forage crop to be produced under limited water conditions in arid and semi-arid regions of the world. Despite numerous researches on alfalfa response to water deficit conditions, less attention has been paid to its forage quality in reaction to water additive substances such as surfactant under severe and moderate deficit irrigation treatments.

This experiment was conducted to evaluate the forage quality response of alfalfa to surfactant application under limited irrigation treatments.

Results and discussions

Total forage yield

As the severity of the limited irrigation increased, total forage yield followed a decreasing trend (Table 3). At moderate (I_{75}) and sever limited irrigation (I_{50}) treatments, the total forage yield increased by 11% and 13% compared to control (no surfactant application), respectively, when received surfactant. The good performance of water treatment I_{75} + surfactant application indicates that in a dry region like Karaj, by saving 25% of irrigation water, we are still able to gain almost the same forage yield as control with no water stress (I_{100} + no surfactant application) (Fig. 1). These results are supported by Jahanzad et al., (2013) and Chaichi et al, (2015) reporting on sorghum and corn, respectively.

Crude Protein (CP)

Across all water treatments by increasing the water scarcity, CP percentage followed an increasing trend (table 3). The highest and lowest percentage of CP was observed in I_{50} (27%) and I_{100} (24.3%) irrigation treatments, respectively which indicates the increased concentration of the cell sap under stress conditions. CP significantly decreased by surfactant application, specifically in limited irrigation treatments by almost 10%. Surfactant application in 50% limited irrigation treatment modified the adverse effect of stress condition by more water availability and enhanced alfalfa yield. This result might explain the lower CP percentage in surfactant treatment compared to control (no surfactant application) (Fig 2.). These results support the previous researches which showed as the water scarcity increase, CP percent increased (Keahavarz Afshar et al., 2012). It has been reported by Maleki Farahani and Chaichi (2013) that CP will be increased under water stress conditions. Also our results of crude protein increment with increase in water stress severity is in agreement with the results reported by Savin and Nicolas (1996) and Ozturk and Aydin (2004).

Neutral Detergent Fiber (NDF)

At I_{100} and I_{75} limited irrigation treatments, surfactant application significantly reduced NDF compared to control (no application). NDF decrement by surfactant application indicates the positive role of this substance to alleviate the forage quality under stress conditions specifically in I_{75} limited irrigation (Fig 3). It has been proven that forages with the lower NDF have the better quality and are more attractive for livestock. Water stress increased both acid detergent fiber (ADF), and neutral detergent fiber (NDF) of barely. Also it is shown that NDF would be increased in dry areas with greater temperatures (Maleki Farahani and Chaichi, 2013).

Water soluble carbohydrate (WSC)

WSC was not affected by limited irrigation systems across surfactant application treatments (Table 3). However, surfactant application, decreased WSC at 75% and 50% irrigation treatments compared to control (without surfactant) (Fig 4). WSC concentration decrement could be due to the yield increment under surfactant application compared to control. In control treatment (without surfactant) the yield of alfalfa was reduced under water stress conditions. This result explains the higher concentration of cell sap leading to enhanced WSC concentration in control (no surfactant) treatment. By surfactant application, more water for plants is available in moderate and severe limited irrigation treatments which enhance yield production and prevent cell sap concentration compared to control. Increasing the severity of water scarcity increased the percentage of WSC in control treatment (no surfactant application) which supports Keshavarz Afshar et al. (2012) findings.

Materials and Methods

Plant materials

In this experiment the widely cultivated native perennial alfalfa genotype (Hamedani) was used.

Site Description

A 2-yr (2013 and 2014) experiment was conducted at the Research Farm of the College of Agriculture and Natural Resources, University of Tehran, Karaj, Iran (N35°56’ N, E50°58’ E). The climate type of this site is considered as arid to semi-arid with long-term (50-yr) air temperature of 13.5°C, soil temperature of 14.5°C, and 262 mm of annual rainfall. The weather condition at the experimental site during the two growing seasons is shown in Table 1.

According to the USDA classification (Soil Survey Staff, 1999), the soil at the site is classified as a typic haplocambid (Mirkhani *et al*., 2010). Prior to planting, soil samples were taken from 0 to 30 cm soil depth and analyzed for selective physical and chemical properties which have been mentioned in Table 2. In Table 2. N, P and K are the abbreviation of total nitrogen, available phosphorus and available potassium, respectively.

Experimental design and factors

The statistical design of the experiment was split plot based on a randomized complete block design (RCBD) with three replications. The experimental treatments comprised of three levels of irrigation systems and two types of water treatments. Main plots were allocated to irrigation treatments comprised of normal irrigation (replenishment of 100% of weekly evaporation and plant water requirements) (I_{100}) and limited irrigation treatments including I_{75} (replenishment of 75% of weekly evaporation and plant water requirements) and I_{50} (replenishment of 50% of weekly evaporation and

Table 1. Monthly relative humidity, evaporation, precipitation and mean air temperature during 2013 and 2014 growing seasons.

Month	Relative Humidity (%)		Evaporation (mm)		Precipitation (mm)		Mean Air Temperature (ºC)	
	2013	2014	2013	2014	2013	2014	2013	2014
May	45.3	37.9	7.8	10	21.2	18.4	18.7	22.1
June	38.2	30.7	13.2	13	1.5	11.6	24.1	26.2
July	39.5	30.9	14.0	14	0.0	8	27.1	28.7
August	42.2	27.0	9.9	12	3.9	0.0	25.3	28.5
September	32.7	33.7	9.9	11	0.0	0.0	25.3	24.0

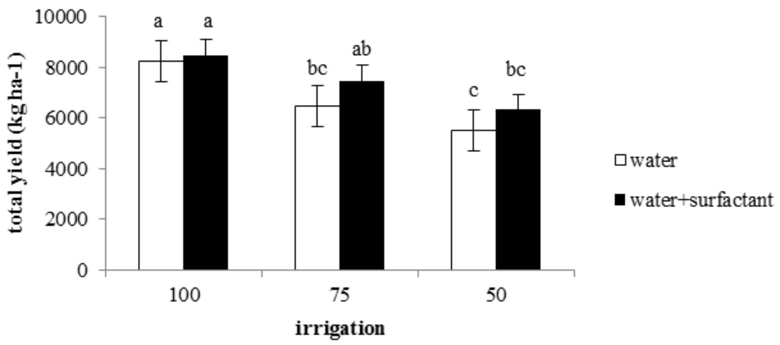

Fig 1. The interaction of irrigation treatments and water treatments (with and without surfatant) on the total yield of alfalfa (*Medicago sativa L.*) (means 2013 and 2014).

Table 2. General properties of the soil of the experimental site (depth of 0 – 30 cm).

Year	Soil texture	pH	EC (ds m^{-1})	Total N (%)	Available P	Available K
					-------------mg kg^{-1}------------	
2013	Clay loam	8	1.86	0.09	8.87	225
2014	Clay loam	7.9	1.96	0.07	9.0	202

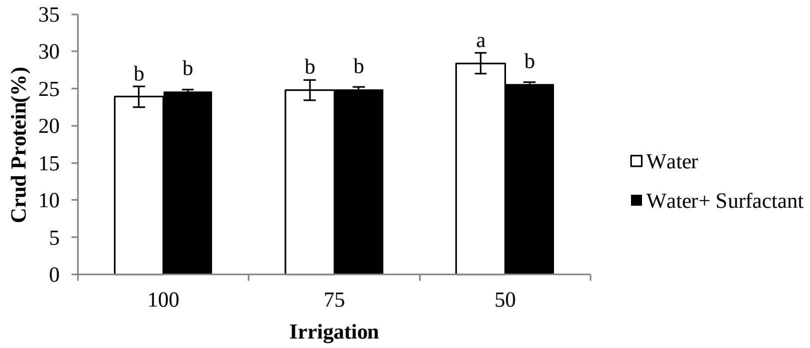

Fig 2. The interaction of irrigation and water treatments (with and without surfatant) on the CP of alfalfa (*Medicago sativa L.*) (mean 2013 and 2014).

plant water requirements). Sub plots were assigned to water treatments of control (water alone irrigation) and water + surfactant (1 ppm) irrigation. The study was carried out in plot sizes of 4 x 2 = 8m^2, which consisted of 4 rows of cropping, 50cm apart. The Alfalfa (domestic Hamedani genotype) was cultivated at the rate of 25 kg of seed per hectare. To prepare a suitable seedbed, the land was cultivated by a deep plough in autumn and a light one in the spring of each year. The final preparation was achieved after 2 vertical and horizontal disks were applied. Seedbed preparation was accomplished on 1st May, 2013 and 3rd May, 2014 for the first and second experimental periods, respectively. The vermi-compost (2 tons ha^{-1}) fertilizer was incorporated into the soil before land cultivation. Before sowing, the alfalfa seed was inoculated by biological fertilizer comprised of a mixture of different probiotic bacteria (20cc bacterial solution per 1kg seed) according to Somasegaran and Hoben (1994). The blend bio-fertilizer comprised of different probiotics of Azotobacter + Azosperilium + Mycorrhiza + Bacilus and Rhizobium bacterial, was provided by the Soil Microbiology Lab. of Department of Soil Science, College of Agriculture, University of Tehran.

Irrigation

In both years, all experimental plots were irrigated normally until plants reached full establishment (4-6 leaf stage). Times

Table 3. Crude Protein (CP), Dry Matter Digestibility (DMD), Water Soluble Carbohydrates (WSC), Acid Detergent Fiber (ADF), ASH and Neutral Detergent Fiber (NDF) of alfalfa as affected by limited irrigation and water treatments.

Treatments	Total forage yield (kg ha^{-1})	CP (%)	DMD (%)	WSC (%)	ADF (%)	ASH(%)	NDF (%)
Irrigation treatments							
100%	8354.8a	24.3c	67.5a	11.4a	33.1a	7.8a	53.3a
75%	6970.3b	24.9b	65.9a	11.4a	33.7a	7.8a	51.8a
50%	5921.7c	27.0a	65.8a	10.6a	30.6a	6.5a	51.7a
Water treatments							
Water	6543.40b	25.0a	67.2a	11.1a	31.9a	7.8a	53.2b
Water+ surfactant	7421.25a	25.70a	65.6a	11.2a	33.0a	7.7a	51.3a

Different letters on each column indicates significant difference at $P \leq 0.05$.

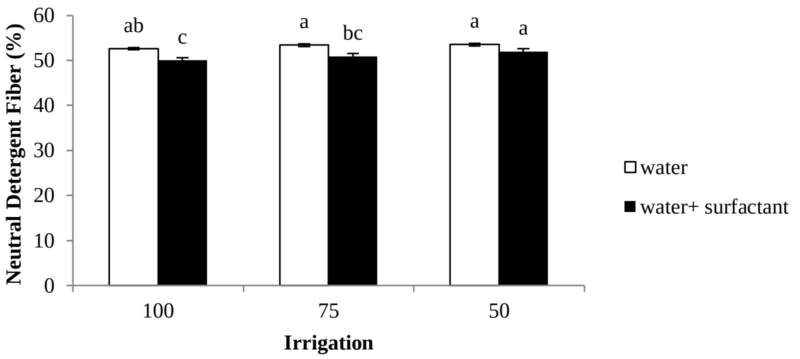

Fig 3. The interaction of irrigation systems and water treatments (with and without surfatant) on the NDF of alfalfa (*Medicago sativa L.*) forage (mean 2013 and 2014).

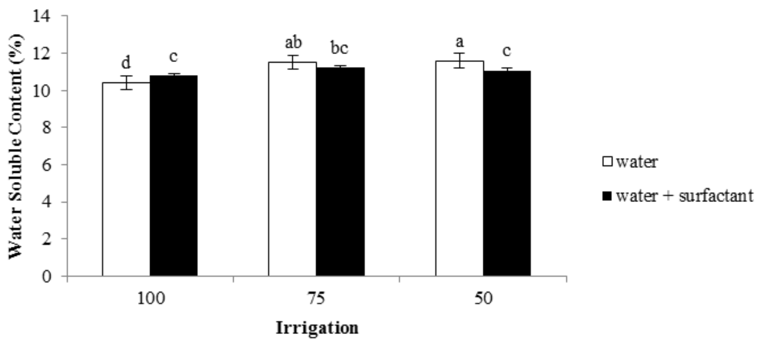

Fig 4. The interaction of irrigation systems and water treatments (with and without surfatant) on the WSC in alfalfa (*Medicago sativa L.*) forage (mean 2013 and 2014).

of irrigation in the normal irrigation regime were scheduled based on the common practice in the area, which consisted of irrigating at 7 day-intervals. At the trigger of the second step of irrigation (limited irrigation), all experimental plots were protected by pile of soil to preserve the measured irrigated water during the seasons. Likewise, the timing of the irrigation treatments (IR_{100}, IR_{75} and IR_{50}) were scheduled once a week and started on 22nd May and 25th April in 2013 and 2014 (when plants reached 4 to 6-leaf growth stage), respectively.

Actual crop water requirements for alfalfa were determined according to the crop evapotranspiration (ETc), estimated from the potential evaporation (ETo), and using the crop coefficients (Kc) by the following equation:

$$ETc = ETo \times Kc \qquad \text{Eq. (1)}$$

Where ETo was calculated by the Penman–Monteith method (Allen *et al.*, 1998) using daily data of synoptic weather station at Research Farm of College of Agriculture located in Karaj, Iran. The Kc is defined as the ratio of the crop evapotranspiration rate to the reference evapotranspiration rate. The mean localized step-wise Kc for alfalfa was 0.9 in Karaj according to FAO, 2012 report. The water requirement for individual plots was measured in gallon per week then it was converted to liter per week. The volume of water applied for each treatment at weekly intervals was calculated by the following equation:

$$I_n = \frac{0.623 \times A \times K_c \times ETo}{IE} \qquad \text{Eq. (2)}$$

Where I_n is the volume of irrigation water (gallons), 0.623 the constant of equation, *A* the canopy surface area (sq. ft.) in each plot, Kc the crop coefficient, ETo the accumulative weekly potential evaporation and IE the irrigation efficiency. The surface area of each plot was 8 m^2 and the irrigation use efficiency was assumed 80% in both years (Howell, 2003). A counter meter was used for accurate water measurements in irrigation treatments and control. The total amount of irrigation water used during the plant life cycle were as follows: IR_{100} =5150m^3 ha^{-1}, IR_{75} =3910m^3 ha^{-1} and IR_{50}

2575 m^3 ha^{-1} during the first year, and $IR_{100} =$ 9000 m^3 ha^{-1}, $IR_{75} =$ 6750 m^3 ha^{-1} and IR_{50} =4500 m^3 ha^{-1} during the second year for normal, moderate and severe limited irrigation treatments, respectively. To reach the physiological maturity the different irrigation regimes continued until 25th Aug. and 8th Sep. in 2013 and 2014, respectively. In this study non-ionic surfactant (10% alkyl polyglycoside, 7% EO/PO block copolymer and 83% water) was applied at the rate of 1 ppm which was added to the corresponding irrigation water treatments all through the growing season (Karcher and Landreth, 2003).

Measurements of yield and forage quality parameters

Alfalfa forage yield and qualitative characteristics were recorded at 10% flowering stage. All the qualitative traits were measured by Near-Infrared Spectrometer device (NIR) to determine chemical composition of hay samples. This system is based on infrared radiation absorption and reflection technology in 2500 -700 nm wave lengths. In this way the light reflected on the body and the energy reflected from the sample is measured. The calibration of NIR is done by SESAME2 software based on forage legume data (Jafari et al., 2003).

Statistical analysis

Data were analyzed with SAS software (V9.2). Mean comparison implemented using Duncan's multiple range test at the 95% level of probability. All differences reported are significant at $P \leq 0.05$ unless otherwise stated. Graphs were designed by using Microsoft Office Excel.

Conclusion

Limited irrigation has adverse effect on alfalfa forage quantity and quality. Surfactant application can modify the adverse effects of water scarcity on forage characteristics which frequently happens in arid and semi-arid regions. Application of surfactant help to decrease the negative forage quality parameters (e.g. NDF) by providing more water for alfalfa under water stress conditions and it can be the best solution to increase forage yield and quality beside water conservation.

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References

Allen RG, Pereira LS, Raes D, Smith M (1998) Crop evapotranspiration. FAO Irrigation and Drainage Paper 56, FAO, Rome, Italy.

Chaichi MR, Nurre P, Salven J, Rostamza M (2015) Surfactant application on yield and irrigation water use efficiency in Corn under Limited Irrigation. J Crop Sci. 55(1):386-393.

Farre I, Faci JM (2006) Comparative response of maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* L. Moench) to limited irrigation in a Mediterranean environment. Agric Water Manage. 83: 135-143.

Haberle J, Svoboda P, Raimanova I (2008) the effect of post-anthesis water supply on grain nitrogen concentration and grain nitrogen yield of winter wheat. Plant Soil Env. 54:304–312.

Howell TA (2003) Irrigation efficiency. p. 467-472. *In*: B.A. Stewart, T.A. Howell (ed.). Encyclopedia of Water Science. Marcel Dekker, New York.

Jafari AV, Connolly A, Walsh EK (2003) A note on estimation of quality in perennial ryegrass by near infrared Spectroscopy. Agri Food Res. 42: 293-299.

Jahanzad E, Jorat M, Moghadam H, Sadeghpour A, Chaich MR, Dashtaki M (2013) Response of a new and a commonly grown forage sorghum cultivar to limited irrigation and planting density. Agric Water Manage. 117:62–69.

Karcher DE and Landrerth JW (2003) Weting agents decrease wilt symptoms and water repllency on a Sand-Based putting green. AAES research series 520. Hortic Studies. 44-46.

Karimi H (1990) Agriculture and modification of forage plants. Fourth edition. University of Tehran Press. 414 pages.

Keshavarz Afshar R, Chaichi MR, Moghaddam H, Ehteshami MR (2012) The effect of limited irrigation systems, biological and chemical fertilizers on qualitative and quantitative characteristics of Forage turnips. J Crop Sci. 43(3):391-403.

Khodabandeh N (2009) forage farming. First Edition. Agric Sci Publication. 307 pages.

Maleki Farahani S, Chaichi MR (2013) Whole Forage Barley Crop Quality as Affect ed by Different Deficit Irrigation and Fertilizing Systems. Comm Soil Sci Plant Anal. 44: 20, 2961-2973.

Mirkhani R, Roozitalab MH, Khaleghpanah N, Rezaei N, Teimori S (2010) Physico-chemical characteristics and clay mineralogy composition of selected soils in arid and semiarid regions of Iran. 5-8 August 2010. 21st Australian Clay Minerals Conference- Brisbane, QLD, Australia.

Mirsa A, Strivastava NK (2000) Influence of water stress on Japanese mint. J Herbs Spices Medic Plants. 7: 51-58.

Ozturk A, Aydin F (2004) Effect of water stress at various growth stages on some quality characteristics of winter wheat. J Agron Crop Sci. 190:93–99.

Reddy AR, Chaitanya KV, Vivekanandan M (2004) Drought induced responses of photosynthesis and antioxidant metabolism in higher plants. J Plant Physiol. 161: 1189-1202.

Safai L, Zeinali H, Afuni D (2011) Assessing the genetic diversity of agronomic traits in different genotypes of fennel (*Foeniculum vulgare* Mill.). J Res Genet Plant Breed Pasture Forestry. (in Persian).19 (1):167-180.

Savin R, Nicolas ME (1996) Effects of short periods of drought and high temperature on grain growth and starch accumulation of two malting barley cultivars. Aust J Plant Physiol. 23:201–210.

Soil Survey Staff (1999) Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys, USDA-NRCS Agric. Handb, 436. U.S. Gov. Print. Office, Washington, DC.

Somasegaran P, Hoben HJ (1994) Hand book for rhizobia: Methods in legume-Rhizobium technology. New York: Springer-Verlag, USA.

Steduto P, Hsiao CT, Fereres E, Raes D (2012) Irrigation and drainage paper: Crop yield response to water. FAO, Rome.

Turcios MA (2007) MS thesis. California state polytechnic university, Pomona,CA. USA.