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Performance of ornamental plants under deficit irrigation

M.K. Suleiman, N.R. Bhat and R.R. Bellen

Aridland Agriculture and Greenery Department, Kuwait Institute for Scientific Research, Email: mkhalil@kisr.edu.kw

Abstract

To promote efficient use of expensive water resource as well as to maintain soil productivity and health in Kuwait, it is important to ascertain plant performance with regard to different irrigation regimes. A study was conducted to determine the effects of induced water stress on the growth and greenery impact of four ornamental plants *viz. Vitex agnus castus* (VA), *Caesalpinnia mexicana* (CM), *Myoporum parifolium* (MP) and *Rosmarinus officinalis* (RO), grown under the harsh arid climate of Kuwait. Acclimatized plants of these species were planted at KISR's Urban Demonstration Garden site in Salmiya in July 2002. Plants were subjected to water stress by irrigating them at the rate of 25, 50 or 100 % of the daily evapotranspiration rates during that month (3.75, 7.5 or 15.0 mm/d). The irrigation was adjusted according to average monthly ET rates. Growth and visual greenery impact data were recorded at weekly intervals during the first 87 days after planting and then, at monthly intervals. Soil moisture was determined at weekly intervals using field tensiometers and oven-dry method prior to irrigation application. Plants that received 7.5 or 15.0 mm/day irrigation grew faster than those that received 3.75 mm/d. Plant canopy appeared to be more sensitive to water stress than the height.

Key words: Ornamental plants, drought, deficit irrigation, water stress, plant growth, irrigation water

Introduction

The Kuwait Institute of Scientific Research developed the National Greenery Plan (NGP) in 1996 to provide an integrated framework for the present and future greenery activities in the country, enhance the quality of the environment, promote the sustainable use of national resources, especially of water and land, and to preserve the quality of the environment for the present and future generations (KISR, 1996). Its main goal is to green and beautify the country without depleting the land and water resources. Currently, landscape and greenery plants are irrigated far in excess of their daily water requirement to compensate for extreme arid conditions and low water retention capacities of the soils. When the national greenery plan is fully implemented, the demand for the irrigation water is expected to increase approximately 124 million gallons per day. While supplemental irrigation has contributed to an increase in greenery development, it has led reduce avoidable wastage of expensive water resources and salinization of arable lands. Consequently, it has threatened the long-term sustainability of greenery plant production activities in the country.

The elimination of unnecessary irrigation application improves the water use efficiency, maintains soil health and optimizes the plant growth and development. Some researchers have looked into the suitability of employing crop water stress index (CWSI) as a criterion for irrigation scheduling and to improve water-use efficiency (Irmak *et al.*, 2000). In these studies, water stress was imposed through different irrigation regimes based on ET values or soil moisture holding capacity of the soil. Sensitivity to water stress varied with plant type, variety and the phonological stage. Pittenger *et al.* (2001) compared four irrigation regimes (50, 40, 30 and 20% of real-time ET_0) in six landscape ground cover species (*Baccharis pilularis, Drosanthemum hispidum, Vinca major, Gazania rigens, Potentilla tabernaemontani* and *Hedera helix*) and found that the response to irrigation treatment was species dependent. *B. pilularis, S. hispidum* and *G. helix* maintained minimal acceptable visual quality with applied water equal to 20% ET_0, while *V. major* required a minimum of 30% ET_0. Acceptable visual quality of *G. rigens* and *P. tabernaemontani* were not maintained in any treatment. Thus, it is possible to grow plants successfully and produce visually acceptable impacts even with less water if irrigation water application is precisely matched with plant's requirement at different stages of growth and during different time of the year. Studies presented in this paper were designed to ascertain the response of four potential plant species to deficit irrigation levels.

Materials and methods

Four proven adaptable plant species, two each from the shrub (*Vitex agnus castus,* VA and *Caesalpinia mexicana,* CM)) and ground cover (*Myoporum parvifolium*, MP and *Rosmarinus officinalis,* RO) categories were selected for the drought stress study. Hardened plants in 10 cm plastic containers were used as test plants. Planting materials of these species were raised through rooting of terminal cuttings taken from mother plants in the Ahmadi Bio Park.

The study was conducted at KISR's Urban Demonstration Gardens site in Salmiya. The climate of the study site is characterized by harsh summers and mild winters. Temperature extremes are high, with means during the warmest and coolest months ranging between 46.2ºC and 6.9ºC. Winter brings occasional frost. Rainfall is minimal, not exceeding 115 mm yr^{-1}, but evaporation is very high, averaging 14.1 mm d^{-1}. The relative humidity is low, and strong, dry and hot northwesterly winds prevail during summer particularly in June and July.

Soil in the study site is sandy in texture, alkaline, high in calcareous materials ($CaCO_3$) and low in organic matter and plant nutrients.

Underground water resources are limited and brackish in nature with total dissolved solids (TDS) concentrations ranging from 3.0 to 10.0 g L^{-1}.

Planting holes of appropriate sizes (*i.e.*, 60 x 60 x 60 cm for shrubs, and 30 x 30 x 30 cm for ground covers) were prepared as per the planting plan. After putting plants in these holes, holes were backfilled with a 1:1 (v/v) mixture of soil and sphagnum peat moss and pressed lightly to provide adequate anchorage for the plants.

Irrigation water was applied through drip system comprising of a sixteen-station timer, polyethylene pipes and one emitter per plant. Soil in the testing area was watered uniformly to attain field capacity until the seedlings had fully established. Then, predetermined quantities of water were applied to each plant daily as per treatment. The total amount of water applied to each treatment is calculated average ET estimates. Soil samples were taken weekly from each irrigation treatment for moisture content analysis, using the oven drying procedure.

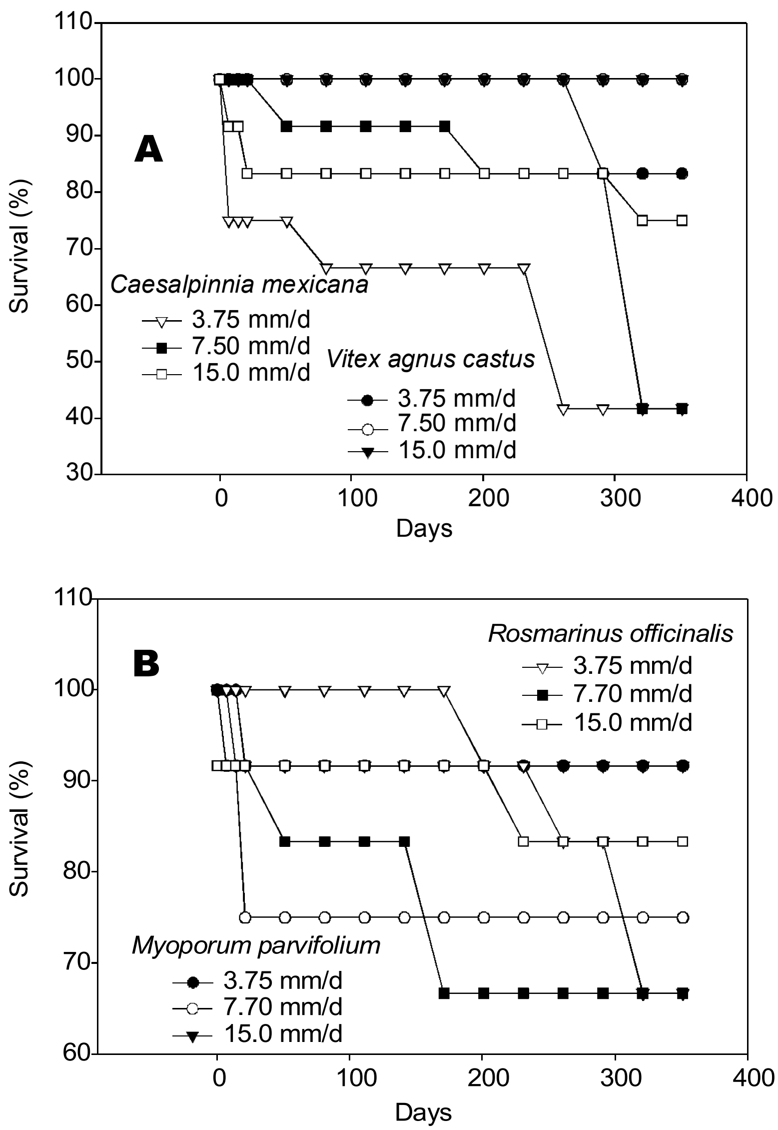

Fig. 1. Survival percentage at different irrigation levels and intervals (A) *Vitex agnus castus* and *Caesalpinnia mexicana* (B) *Myoporum parvifolium* and *Rosmarinus officinalis*

Water stress was applied by irrigating the plants at 25, 50 and 100% of average evapotranspiration rates (ET_p). ET_p values estimated in the earlier project were used to calculate the amount of water to be applied in each irrigation treatment (Taha *et al.*, 1988).

Experimental plants were sprayed with fast release fertilizer, potassium nitrate every two weeks. Agriformâ, a slow release fertilizer containing 21-0-10 NPK was applied after the establishment of seedlings in the field. Diazioneâ at 0.02% of active ingredient was applied to control ants and grasshoppers in the experimental site.

There were twelve treatment combinations (four species and three irrigation levels) that were arranged in a randomized complete block factorial design with three replications and four plants per treatment. The observations recorded at regular intervals included seedling survival (the number of living plants on each of the observation dates), plant height (measured from soil surface to the tip of the uppermost leaf), plant canopy at the widest point and the plant physical condition. The soil moisture percentage in the upper 30 cm layer of the soil was determined at weekly intervals using tensiometers and oven-drying technique.

Results and discussion

Response of the individual plant species to three irrigation levels was assessed based on seedling survival, average seedling height and canopy and compared with soil moisture regimes in the root zone during corresponding periods.

Seedling survival: Although all seedlings established initially, some died after the start of irrigation treatments (Fig. 1). VA survived throughout the entire experiment without any seedling deaths. However, on the 261^{st} day after planting, the highest seedling mortality (58.34%) was observed in the 3.75 mm/d treatment in CM, and in RO the highest mortality rate was 8.34% on the 21^{st} day of seedlings planting in the 3.75 mm day^{-1} treatment. Finally, RO recorded the highest mortality rate (33.34%) on the 321^{st} day of seedlings planting. The seedling survival did not change after this period.

Seedling height: Plant species grew at different rates. VA grew at 12.26% in 3.75 mm day^{-1} treatment, 24.74% in the 7.5 mm day^{-1} treatment and 29.3% in the 15mm day^{-1} treatment in the 351 day period. Height increments in other species were 6.66, 67.5, and 77.45% in 3.75, 7.5 and 15 mm day^{-1}, respectively in CM. Likewise, MP recorded 25, 48.22 and 60%, and RO recorded 80.87, 54.16 and 113.92% in 3.75, 7.5 and 15mm day^{-1} treatments, respectively (Fig. 2). The lower level (3.75 mm) adversely affected the average height in all species beyond 60 days of planting. However, there was no difference between 7.5 mm and 15.00 mm irrigation levels. Significant irrigation x species interaction was noticed only at later stages of plant growth.

Seedling canopy: Seedling canopy was influenced both by species and irrigation levels (Fig. 3). Plants irrigated at the 7.5 or 15.0 mm/ d had the greatest canopy. However, the irrigation x species interaction was not evident throughout the study. Among species, VA grew faster than other species.

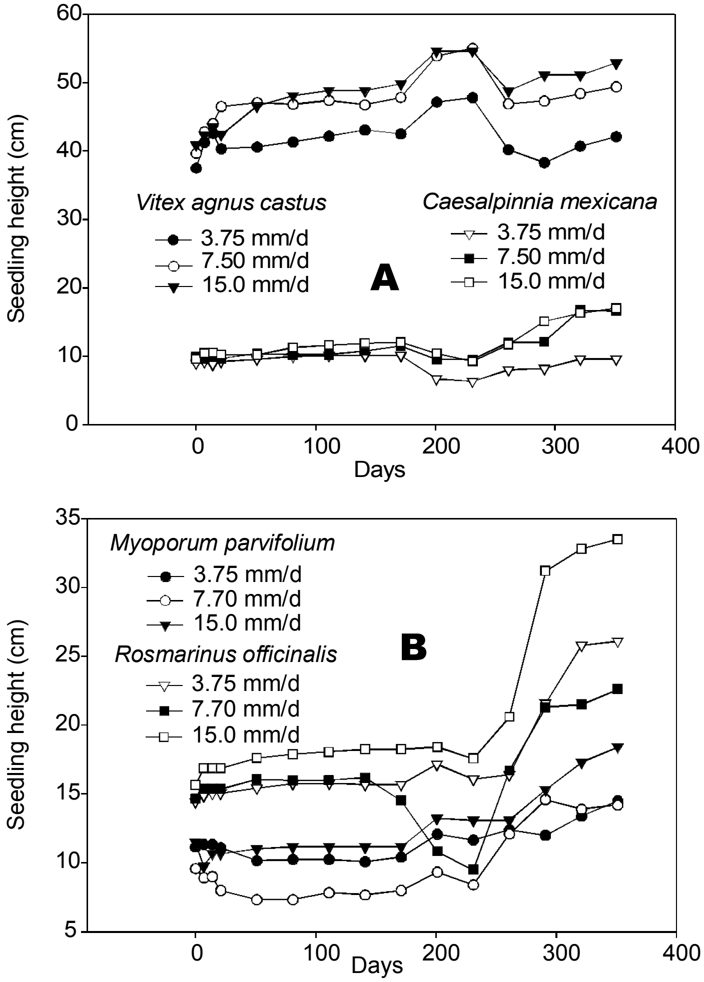

Fig. 2. Seedling height at different irrigation levels and time intervals (A) *Vitex agnus castus* and *Caesalpinnia mexicana* (B) *Myoporum parvifolium* and *Rosmarinus officinalis*

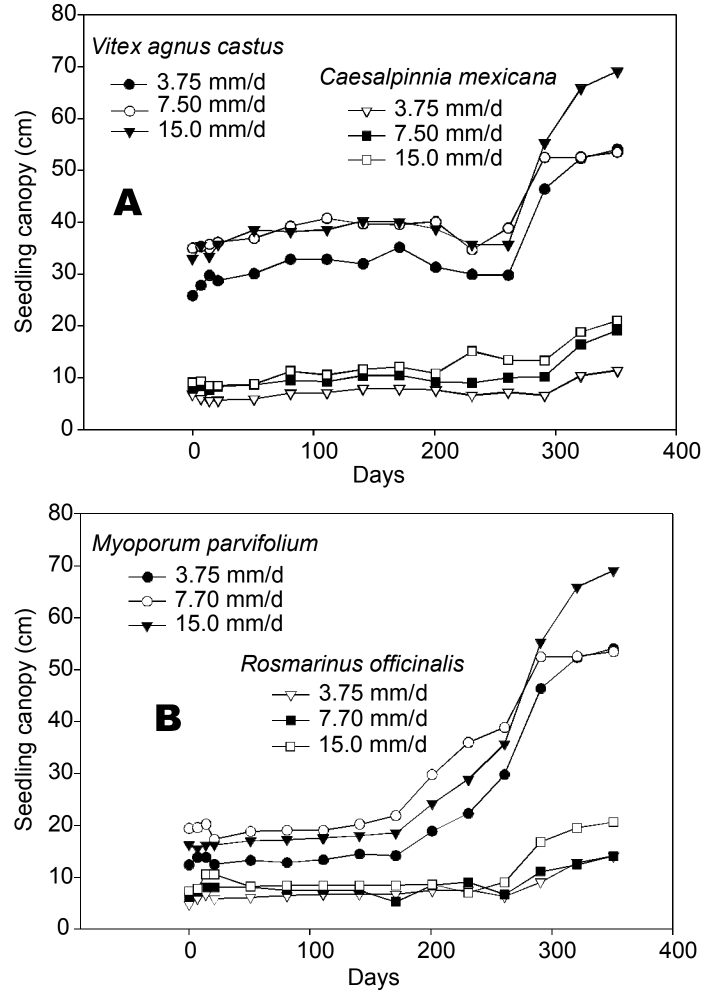

Fig. 3. Seedling canopy at different irrigation levels and time intervals (A) *Vitex agnus castus* and *Caesalpinnia mexicana* (B) *Myoporum parvifolium* and *Rosmarinus officinalis*

Soil moisture: The soil moisture fluctuated between 1.07 and 6.82% and was not influenced by either the species or the irrigation level (Fig. 4).

Biomass Production: The biomass production in *Vitex agnus castus* and *Caesalpinnia mexicana* (both form the shrub category) was highest in the 7.5 mm day^{-1} irrigation level. However, it varied in the groundcover category where in *Myoporum parvifolium* the production was higher in the 15 mm day^{-1} irrigation level, and in *Rosmarinus officinalis* there was hardly any difference between the 3.75, 7.5 and 15 mm day^{-1} irrigation level (Table 1).

The efficiency with which irrigation water is stored, distributed and used throughout the world is generally low with only 30 to 50% of water used to produce dry matter. The main purpose of modern irrigation system is to deliver water, in a specified quantity and at a specified time and place, for irrigation. Adequate control and accurate measurement of water flowing from storage to delivery are necessary for successful water management. Day to-day management of water requires that daily water-use be known and compared against plant requirements. This can be accomplished only by knowing, with reasonable accuracy, the amount of water being delivered, withdrawn by plants and lost by other processes (surface runoff, drainage and evaporation). Considerable quantities of water can be saved by minimizing surface runoff and drainage and by upgrading measurement techniques.

Although increasing irrigation frequency produced higher biomass and seed yields, several researchers have shown that deficit or minimal irrigation applications are associated with the highest water-use efficiencies and sustainable yields. Therefore, there has been an increasing interest in the crop water stress index (CWSI) as a potential tool for quantifying water stress and irrigation scheduling (Irmak *et al.*, 2000). A number of studies have been carried out to quantify water stress and to develop parameters for irrigation scheduling to optimize biomass production, yield and visual landscape effects. Water stress is imposed through different irrigation regimes based on ET values or available soil moisture holding capacity. Sensitivity to water stress vary with crop type, variety and the phonological stage. Diouf *et al.* (2001) showed that corn (Variety Synthetic – C) was sensitive to water deficits during the flowering stage. The relative water content, leaf water potential and crop water stress were less sensitive (showed low rate of decrease) to water deficits during the flowering phase than during the vegetative phase. The gaseous exchange, stomatal conductance and transpiration

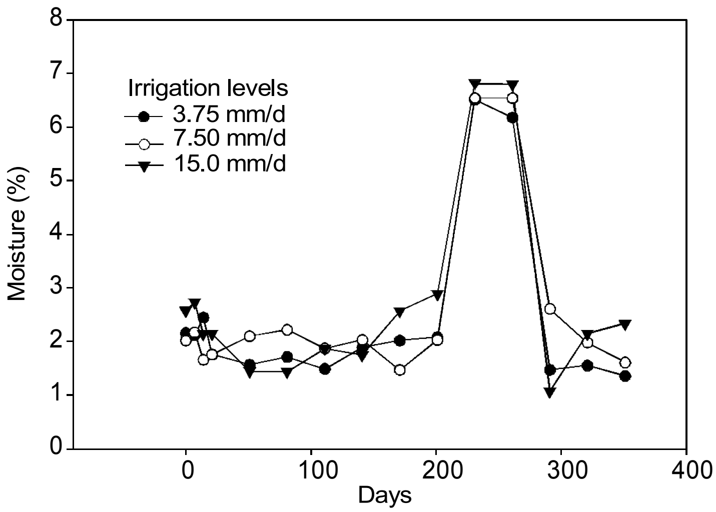

Fig. 4. Soil moisture regime at different irrigation levels

Table 1. Plant biomass means of the irrigation study

Specie	Irrigation level(mm d^{-1})	Plant fresh weight (g)	Plant dry weight (g)
Shrubs			
Vitex agnus castus	3.75	26.80	20.95
	7.50	30.90	23.35
	15.00	23.70	20.05
Caesalpinnia mexicana	3.75	20.10	16.60
	7.50	22.55	17.85
	15.00	19.75	17.10
Groundcovers			
Myoporum parvifolium	3.75	83.85	29.90
	7.50	56.20	24.95
	15.00	82.60	32.65
Rosmarinus officinalis	3.75	23.65	18.80
	7.50	23.30	18.85
	15.00	22.00	18.65

were more sensitive to water deficit during reproductive phase. Moreover, significantly less yield and WUE were observed during this phase of development.

The present study conducted for assessing the effects of water stress on vegetative growth and physical condition of four introduced ornamental plants revealed that main (irrigation levels and species) effects were significant but their interaction were non-significant. Among the species, *Vitex agnus castus* was most sensitive to water stress. Plants watered at the rate of 7.5 or 15.0 mm day^{-1} were growing faster than those that received lower amounts of water (3.75 mm day^{-1}). Plant canopy appeared to be more sensitive to water stress than the height in all test plants.

Acknowledgements

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