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Surfactant effect on forage yield and water use efficiency for berseem clover and basil in intercropping and limited irrigation treatments

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ABSTRACT

Quantifying crop response to irrigation is important for establishing effective irrigation management strategies. The present study was conducted to evaluate the response of berseem clover and basil to limited irrigation in an additive intercropping system using a surfactant. The experimental treatments were carried out in split–split plots based on a completely randomized block design with three replications. The limited irrigation treatments comprised of replenishment of I_{100} full irrigation, I_{75} = 25% limited and I_{50} = 50% limited weekly evaporation and plant water requirements which were assigned to the main plots. The planting systems of sole berseem clover and sole basil culture along with additive inter cropping of berseem clover + 50% basil were assigned to the subplots. Water treatments of control (water alone) and water + surfactant were assigned to the sub-subplots. Results show that severely limited irrigation (I_{50}) dramatically reduced the forage yield of berseem clover and basil by 19.5% compared with the control (I_{100}). The severity of the adverse effects of limited irrigation stress decreased by the surfactant application in irrigation by water + surfactant (9.5% decrement compared to full irrigation). The highest irrigation water use efficiency (2.7 kg m^{-3}) was achieved in I_{50} treatment with an added surfactant. The highest total dry matter yield (berseem clover + basil dry matter) (9257.9 kg ha^{-1}) was obtained from additive intercropping of berseem clover 100% + basil 50% while irrigated by water + surfactant.

1. Introduction

Irrigation water use efficiency (IWUE), defined as the amount of biomass or grain produced per unit volume of applied water, provides a quick and simple measure of how well the available water can be converted into grain and thereby is the basic indicator of measuring the effectiveness of water-saving in agriculture (Sekhon et al., 2010). When water resource in a crop production is a limiting factor, a proper irrigation treatment is needed to enable maximum production per unit irrigation water volume. Deficit irrigation is one way of maximizing the IWUE (Bekele and Tilahun, 2007). The main objective of deficit irrigation is to increase the IWUE of crops by reducing the amount of water in irrigation or by reducing the number of irrigation events (Kirda, 2002). In recent years, the focus is shifting towards increasing productivity efficiency within the constraints of available limited water resources. As such, deficit irrigation is becoming a possible option, i.e., in irrigating crops, reducing water requirements while minimizing the adverse effects of extreme water stress on crop yield (Garg and Dadhich, 2014). In addition, water loss by evapotranspiration is very high during the growing season in semi-arid regions. Forage crops in these environments are often subjected to the detrimental effects of high temperatures and water deficits during the spring-summer period that seriously reduce the herbage and seed production. Therefore, it is necessary to know the allowable level of transpiration deficiency without significant reduction in crop yield. The monetary loss due to deficit irrigation yield reduction should be smaller than the benefits gained from the saved water which in turn could be normally used for other crops under traditional irrigation practices (Kirda, 2002).

Surfactant (wetting agent) application in the irrigation water increases moisture retention in soil (Leinauer, 2002). The increase in water retention under deficit irrigation treatments due to the application of surfactants can be explained by the mechanism in which the surfactant is applied. Surfactants reduce the surface

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tension of water and help water infiltrate into the pore spaces of soil. These pore spaces are not generally accessible to water without the surfactants (Leinauer, 2002). Surfactants also help maintain a uniform distribution of soil moisture and root zone moisture holding capacity and as a consequence improve crop yield under water deficit conditions (Wolkowski et al., 1985). Where the soil wettability is less than optimal, the use of surfactant in combination with appropriate irrigation and soil cultivation practices, improves the soil hydrological behavior resulting in an improved irrigation efficiency and water conservation (Kostka et al., 2007). By surfactant application in limited irrigation treatments, higher yields are produced. Economical evaluation has shown that using surfactants increases yield production cost in water repellant and wettable soils, however, the yield increment can compensate for the cost of surfactant and consequently a higher profit can be achieved (Chaichi et al., 2015). Therefore, by evaluating the effects of surfactant on forage and grain production of corn (Chaichi et al., 2015), fruits (McMillan et al., 2010) and potato (Oostindie et al., 2010) in different conditions, this study identifies the extent for the first time to which the water conservation in combination with surfactant utilization can be practiced based on yield data in an intercropping system.

Food strategies must not merely be directed at ensuring food security for all, but must also achieve the consumption of adequate quantities of safe and good quality foods that together make up a healthy diet. In this regard, cultivation and producing forage crops play key roles. However, the importance of these crops in producing protein and supporting food security have not been yet well appreciated. Berseem clover (*Trifolium alexandrinum* L.) is one of the best forage sources for feeding livestock. This plant is capable of producing 3.75 tons of dry forage and fix 100–200 kg of nitrogen/ha per year. Sweet basil (*Ocimum basilicum* L.) from the *Lamiaceae* family is a medicinal plant which is mostly used as an anti-spasm medicine for stomach gases, it is also appetizing, diuretic and adaptogenic and anti-inflammation.

Intercropping is a way to increase diversity in an agricultural ecosystem. In addition, by using the intercropping system, the ecological balance, a better utilization of resources, higher quantity and quality of products, and less damage by pests and diseases are well achieved. Those systems, which are often without synthetic input and are based on an integrated management of local natural resources, theoretically offer numerous ecological advantages. Additionally, medicinal forage (intercropping of forage and medicinal crops) is considered as alternative forage sources to prevent contamination from diseases and improve growth and development in livestock.

Drought is known as one of the main natural hazards especially in arid and semiarid regions where there are considerable issues in regard to water resource management. In arid and semi-arid regions like Iran, less precipitation and high evaporation rates are the most important problems that are caused by high temperatures and low humidity of the air mass over the land. Because of this, we found that there is a necessary need to identify a good water management and good sowing pattern to catch the efficient IWUE for such a region. The specific objectives of the current study were: (1) to measure the effectiveness of water-saving in agriculture with considering the maximum production per unit irrigation water volume, (2) to evaluate the effects of wetting agents (surfactant) on total dry matter (berseem clover + basil dry matter) yield under limited irrigation systems, (3) To determine the result of interaction between three factors (limited irrigation treatments, cropping patterns and water treatment) on total dry matter yield, forage yield and IWUE of medicinal forage (berseem clover + basil). In short, the best intercropping patterns, the amount of required irrigation water and the best rate of surfactant were determined.

2. Materials and methods

2.1. Experimental site and climatic data

A series of 2-year (2013 and 2014) experiments was conducted at the Research Farm of the College of Agriculture and Natural Resources, University of Tehran, Karaj, Iran (N 35°56′, E 50°58′). The climate of this site is considered as arid to semiarid with a long-term (50-year) mean air temperature of 13.5 °C, soil temperature of 14.5 °C, and 262 mm of annual rainfall. The weather conditions at the experimental site during the two growing seasons are shown in Table 1.

2.2. Soil characteristics

The soil type at the site is classified as a Typic Haplocambid (Mirkhani et al., 2010) according to the United States Department of Agriculture classification (USDA, Soil Survey Staff, 1999). Prior to planting, soil samples were taken from 0 to 30 cm depth and analyzed for selected physical and chemical properties, including soil texture, soil acidity (pH), electrical conductivity (EC), total nitrogen (N), available phosphorus (P), and available potassium (K). Soil texture was determined using the hydrometer method. The soil pH and EC were measured by a pH-meter and EC-meter, respectively in 1:2.5 soil–water suspensions (Rhoades, 1996). Nitrogen content was measured by the Kjeldahl method (Bremner and Mulvaney, 1982). Available P was measured by the method of Olsen et al. (1954) and available K was determined by a flame photometer. The soil characteristics of the experimental site were performed before planting. The results of two years indicated: soil pH 8/7.9, EC = 1.86/1.96 (ds m^{-1}), total nitrogen (N) = 0.09/0.07(%), available phosphorus (P) = 8.87/9.0 (mg kg^{-1}), available potassium (K) = 225/202 (mg kg^{-1}), and the soil texture was clay loam for the whole period of 2013/2014, respectively.

2.3. Experimental Setup

The statistical design of the experiments was split–split plot based on a randomized complete block (RCB) design with three replications. The experimental treatments comprised of three levels of irrigation treatments, three sowing patterns and two types of water treatments. Different irrigation treatments were applied on the main plots as: the normal irrigation I_{100} (replenishment of 100% of weekly evaporation and plant water requirements), limited irrigations including I_{75} (replenishment of 75% of weekly evaporation and plant water requirements), and I_{50} (replenishment of 50% of weekly evaporation and plant water requirements). The subplots consisted of three sowing patterns including sole berseem clover, sole basil culture, and additive intercropping of berseem clover + 50% basil (safikhani et al., 2013). The sub-subplots were assigned to two types of water treatments of control (water only) and water + surfactant (1 ppm) irrigation. The study was performed in plot sizes of $4 \times 2 = 8$ m^2, which comprised of four rows of cropping 50 cm apart. The sole berseem clover and basil were sown at the rates of 30 kg and 5 kg per hectare (ha), respectively. In the additive intercropping treatment, basil was sown at 50% density of its normal sowing rate (2.5 kg ha^{-1}) with berseem clover at its normal rate of (30 kg/ha) on the same rows corresponding to the experimental plots. In additive intercropping system, the main crop (berseem clove) was sown at its normal density on rows of 50 cm apart. Then the second crop (basil) was sown at 50% of its normal density on rows 25 cm apart from the main crop (Safikhani et al., 2013).