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The effect of irrigation regimes and polymer on some physiological traits of forage Sorghum

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ABSTRACT

Sorghum is among the most important forages used in arid and semi-arid regions of south-eastern Iran, but its growth and yield are often constrained by water deficit and poor productivity of sandy soil. Irrigation water is becoming scarcer and more costly. Application of some materials such as Superabsorbent A200 polymer (SAP) in soil can increase soil water storage capacity and increase water use efficiency. The objective of present study was to investigate the effect of irrigation regime and different levels of SAP on dry matter and some physiological traits of sorghum×sudan grass in Zahedan, Iran during 2013. The experimental design was a split-plot with two factors including four irrigation regimes consisting irrigated with 40%, 60%, 80% and 100% crop evapotranspiration (ETc) as main plots and four amounts of SAP (0, 60, 120 and 180 kg ha^{-1}) as subplots in a completely randomized block design with three replications. The results indicated that the effect of irrigation and SAP in all traits were significant ($P<0.0001$) and also, revealed that the interaction effects of two factors were significant ($P<0.01$) except leaf area duration and relative water content traits. The results showed that water stress decreased chlorophyll index, leaf area duration, leaf area index, relative water content significantly, while the application of SAP decreased the negative effect of deficit irrigation. According to the results it could be concluded that supplying 80% water requirement the plant and 60 kg ha^{-1} SAP produced a desirable dry matter.

Keywords: Chlorophyll index, Leaf area duration, Leaf area index, Relative water content.

INTRODUCTION

Drought is one facing the most important problems of crops production in the world, specifically in the arid and semi-arid areas like Iran. As a result, the need for to enhance water use in forage production has became a major concern so as to decrease amount of irrigation and cost of water and energy. Speedfeed is a drought resistant summer annual [1,2], that able to maintain stomata opening in low levels of leaf water potential through osmotic adjustment [3,4]. Sorghum is adapted to the climatic conditions of Iran, particularly in tropical and arid areas such as Sistan and Baluchistan and southern provinces of Iran [5]. It is a drought resistant crop, much irrigation is need production. According to the research findings, it requires 330 li. Water to produce 1 kg of dry matter, while this amount for Corn is 368, Barely 434 and Wheat 514 lit [6]. Superabsorbent A200 polymers are made of hydrocarbon. These materials can absorb and retain water several times of their weights. When the environment dryness occurs, the polymer gradually releases water so the moisture is retained in the soil for a long-time without any need for applying irrigation water [7,8,9]. Thus, application of hydrophilic polymers can result in significant reduction of the required irrigation frequency particularly for sandy soil [10]. This is an important problem in arid and semi-arid regions, where the irrigation water is a scarce commodity and a short-term drought can cause plant losses. Thus, irrigation costs are minimized and water resources being saved [11]. Dry matter (DM) is affected by water deficit and when it is along with an increase in drought stress intensity, a significant decreasing in yield of DM is observed [12]. In drought stress conditions, reduction of the net photosynthesis decreased of DM production in leaf area unit [13]. Relative water content (RWC) has a close relation with water potential of plants [14,15]. Decreasing of the soil water potential can lead to decrease of the RWC and thus the plant photosynthesis decreases due to decrease of stomata conductivity and accessibility of plant to carbon dioxide. [16,17]. Drought stress directly affects on the leaf chlorophyll index (CI) and consequently on the yield [18]. Active oxygen causes damages to the cellular membranes under water stress conditions because of lipids proxidization [19]. leaf area and dry matter yield decreased with water stress [20]. The LAI and LAD were positively correlated with dry matter production [21]. LAD is one of the important physiological traits that have an implication on yield potential related to increasing assimilate availability [22]. It finally leads to decrease of the plant chlorophyll content. The objectives of this investigation were to determine the effects of Superab A200 and irrigation regime on the chlorophyll index, leaf area index, leaf area duration, relative water content and dry matter of sorghum.

MATERIALS AND METHODS

The field experiment was conducted in Dashtak, southeastern Iran (25°, 30' N and 58°, 47' E), with a mean annual rainfall of 120 mm with an arid and tropical climate. Before planting, soil samples were taken from the experimental site and were analyzed according to the procedure of [23]. Some physical and chemical properties of the soil are presented in Table 1.

Table 1: Some physical and chemical properties of a representative soil samples in the experimental site before sowing (0-30 cm depth) in 2010

Soil properties	2013*
Silt	24.8
Sand	65.9
Clay	9.30
Texture	sandy – loam
Organic matter (%)	0.06
EC (1:1 extract) (ds m^{-1})	6.70
PH (1:1 suspension)	7.60
Total nitrogen (%)	0.16
Total $CaCo_3$ (%)	1.10
$NaHCO_3$-extractable P (mg L^{-1})	3.70
NaOAC-extractable K (mg L^{-1})	93.0

**Each value represents the mean of three replications.*

The experimental design was a split-plot with two factors including four irrigation regimes consisting irrigated with 40%, 60%, 80% and 100% crop evapotranspiration (ETc) as main plots and four amounts of SAP (0, 75, 150 and 225 kg ha^{-1}) as subplots in a completely randomized block design with three replications on sorghum×sudan grass (S*orghum bicolor* (L.) Moench×S. Sudanese (Piper) Stapf, variety ‘Speedfeed’) during 2010. The soil amendment used was a hydrophilic polymer, SAP produced by Rahab Resin Co. Ltd., under license of "Iran Polymer and Petrochemical Institute". The chemical structure of SAP is shown in Table 2 [24,25,26].

Table 2. The properties of Superab A200 Polymer

Appearance	White granule
Grain size (mm)	0.5-1.5
Water content (%)	3-5
Density (g cm^{-3})	1.4-1.5
pH	6-7
The actual capacity of absorbing the solution of 0.9 % NaCl	45
The actual capacity of absorbing tap water	190
The actual capacity of absorbing distilled water	220
Maximum durability (year)	7

Before seed planting, SAP was placed by hand where roots were expected to have greatest density (15-20 cm depth) in the middle of rows along the ridge, then the seeds were manually sown at the depths of 2-3 cm on the rows in early April. Plant density was at an average density of 34 plant m^{-2} (inter-row spacing and inter-plant spacing were 0.5 m and 0.06 m respectively). Soil preparation operations included plowing, disking and leveling which were carried out in early March. Thinning was done at 3-5 leaf stage and the seedlings distance along rows was set 6 cm. Water requirements were determined according to FAO method and using the evaporation pan data on base American A-class [27,28]. Daily evaporation and pan coefficient was calculated as follows:

$$ETc=KC(ETo) \qquad [1]$$

ETc: sorghum evapotranspiration
Kc: crop coefficients
ETo: evapotranspiration of the reference crop

Growing Degree-Days were calculated using Eq. [2], where Tmax and Tmin are the daily maximum and minimum temperatures respectively and B represents a base temperature value of 10°C [29].

$$GDD = \frac{T\max - T\min}{2} - B \quad [2]$$

Where Tmax and Tmin are the daily maximum and minimum temperatures respectively and B represents a base temperature value of 10°C [29]. The RWC was determined in the fully expanded topmost leaf one day before irrigation between 8 and 9 a.m. This was accomplished by excising three 1-cm disks of each sample leaf at 282, 444, 600, 766 and 907 GDD. The results were then averaged, resulting in a single value to represent that plot. The fresh weight of the samples was recorded and the samples were immersed in distilled water in a Petri dish. After 24 h, the leaves were removed, the surface water was blotted-off and the turgid weight recorded. Samples were then dried in an oven at 70°C to constant weight [18,30]. The RWC was calculated by Eq. [3] as follows:

$$RWC = \frac{Fresh\ \ Weight - Dry\ \ Weight}{Turgid\ \ Weight - Dry\ \ Weight} \times 100 \quad [3]$$

The Chlorophyll Index was measured using the Minolta SPAD-502 meter, Tokyo, Japan on three parts of each measured leaf (tip, middle and bottom) from three plants from each plot in the fully expanded topmost leaf one day before irrigation at 282, 444, 600, 766 and 907 GDD. The results were then averaged, resulting in a single value to represent that plot [18,31]. LAI was measured after flowering was at a 10% level by measuring the leaf area of five plants per treatment. The LAI was calculated by Eq. [4] as follows [32]:

$$LAI = \frac{Leaf\ \ area(m^2)}{Land\ \ area(m^2)} \quad [4]$$

LAD was measured after flowering was at a 10% level by Eq. [5] as follows [32]:

$$LAD = \frac{(LAI_1 + LAI_2) \times (t_2 - t_1)}{2} \quad [5]$$

where
LAI_1 = Leaf area Index at t_1
LAI_2 = Leaf area index at t_2
t_1 = time of first observation
t_2 = time of second observation

Statistical analysis was carried out by SAS software, version 9.2 for a split plot randomized complete block design. The analysis of variance for each variable was performed with the PROC GLM. The graphs were designed by using Sigma plot software.

RESULTS AND DISCUSSION

Relative water content

The irrigation regime and SAP levels had a significant effect on RWC at 1% probability level, but the interaction effect of the two factors was not significant (Table 3). The results showed that the highest amount of RWC was achieved form high amounts of polymer (180 kg ha^{-1}) and also under the condition 100% ETc, but the lowest amount of RWC was related to the treatment of 40% ETc without using polymer (Figure 1). Krieg (1992) reported that the RWC in sorghum decreased with an increase in water stress. Mao et al. (2011) showed that RWC increased with increasing amount of polymer in the soil.

Table 1. Degree of freedom and Probability level for the effect of irrigation regime and polymer on dry matter and some physiological traits in forage sorghum during 2013 season.

		Probability level				
S.O.V	**df**	**Leaf area index**	**Leaf area duration**	**Relative water content**	**Chlorophyll index**	**Dry matter**
Block	2	0.79	0.42	0.12	0.19	0.17
Irrigation	3	0.0001	0.0001	0.0008	0.004	0.0001
Linear(L)	1	0.0001	0.0001	0.0002	0.0008	0.0001
Quadratic(Q)	1	0.5	0.14	0.38	0.39	0.89
Cubic(C)	1	0.006	0.007	0.04	0.75	0.0006
Polymer	3	0.0001	0.0001	0.0001	0.0001	0.0001
Linear(L)	1	0.0001	0.0001	0.0001	0.0001	0.0001
Quadratic(Q)	1	0.31	0.8	0.53	0.11	0.6
Cubic(C)	1	0.002	0.001	0.019	0.38	0.5
Irrigation × Polymer	9	0.01	0.056	0.7	0.0008	0.005
CV%		7.4	6.4	4.56	4.53	10.86

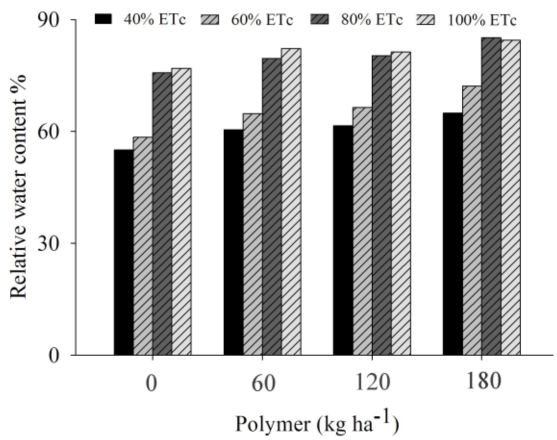

Figure 1. Effect of water stress and polymer (A200) on relative water content.

Leaf area index

The results obtained showed that irrigation regime and SAP levels had significant difference at 1% probability level on LAI and also the interaction effect of the two factors was significant (Table 3). The results showed that the highest amount of LAI was achieved form high amounts of polymer (180 kg ha^{-1}) and also under the condition 100% ETc, but the lowest amount of LAI was related to the treatment of 40% ETc without using polymer (Figure 2). Islam et al. (2011) showed that leaf area did not changed under low application of superabsorbent polymer but increased remarkably following SAP application at medium and high rate by 18.9 and 32.5%, respectively. LAI was significantly correlated (Table 4) with RWC (0.87).

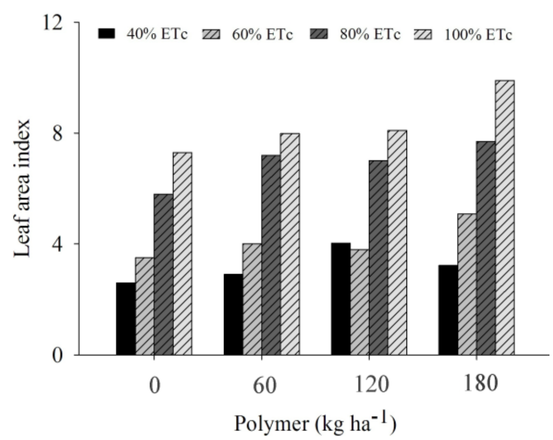

Figure 2. Effect of water stress and polymer (A200) on leaf area index.

Table 5. The Pearson correlation coefficients related to dry mater yield and other characteristics in forage sorghum.

characteristics	1	2	3	4	5
1- Dry matter	1				
2- Leaf area index	0.90 **	1			
3- Leaf area duration	0.48 **	0.47 **	1		
4- Relative water content	0.81 **	0.87 **	0.82 **	1	
5- chlorophyll index	0.84 **	0.91**	0.91 **	0.81 **	1

*** Significant at the 1% level*

Chlorophyll index

The irrigation regime and SAP levels had a significant effect on CI at 1% probability level and also the interaction effect of the two factors was significant (Table 3). The results showed that the highest amount of CI was achieved form high amounts of polymer (180 kg ha^{-1}) and also under the condition 100% ETc, but the lowest amount of CI was related to the treatment of 40% ETc without using polymer (Figure 3). The water stress resulted in significant decreases in chlorophyll content (18,33). SPAD value in the leaves significantly increased with the application of SAP [18,33]. CI was significantly correlated (Table 4) with RWC (0.81) and LAI (0.91).

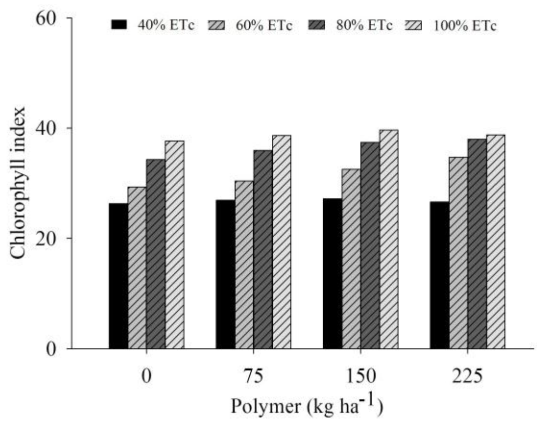

Figure 3. Effect of water stress and polymer (A200) on chlorophyll index.

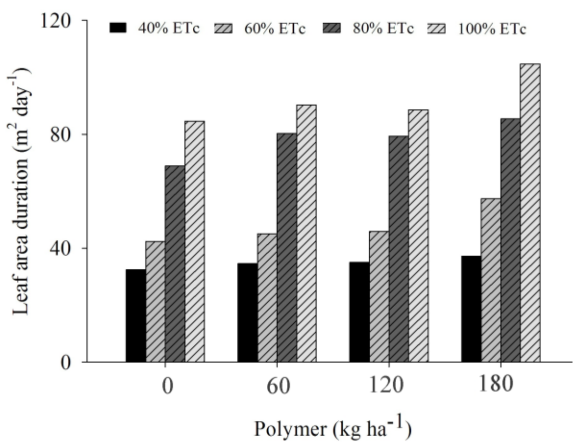

Figure 4. Effect of water stress and polymer (A200) on leaf area duration.

Leaf area duration

According to the results of analysis of variance, irrigation regime and SAP levels significantly affected LAD at 1% statistical level, but the interaction effect of the two factors was not significant (Table 3). The results showed that the highest amount of LAD was achieved form high amounts of polymer (180 kg ha^{-1}) and also under the condition 100% ETc, but the lowest amount of LAD was related to the treatment of 40% ETc without using polymer (Figure

4). Brevedan and Egli, (2003) suggested that drought stress reduces the LAD [22,34]. In drought conditions the nutrients transfers from leaves increases, accelerating the leaf senescence [22,35,36]. On the other hand, Islam_et al. (2011) showed that SAP could be an effective way to increase both water and nutrient use efficiency in crops and an increase in LAD. LAD was significantly correlated (Table 4) with RWC (0.82), LAI (0.47) and CI (0.91).

Dry matter

The irrigation regime and SAP levels had a significant effect on DM at 1% probability level. But the interaction effect of the two factors was significant (Table 3). The results showed that the highest amount of DM was achieved form high amounts of polymer (180 kg ha^{-1}) and also under the condition 100% ETc, but the lowest amount of DM was related to the treatment of 40% ETc without using polymer (Figure 3). The interaction effect of irrigation regime and SAP levels on dry matter indicated that using 60 kg ha^{-1} SAP in 80% ETc treatment could increase dry matter similar to treatment of 100% ETc (Table 5). Many researchers have reported that when the irrigation decline the dry matter decreased (Aishah et al., 2011; Berengner and Faci, 2001; Done et al., 1984; Howell et al., 2008). Islam et al. (2011) showed that the DM increased with increasing rate of superabsorbent polymer and the value increased by only 10.4% with low application of SAP, while it increased significantly by 20.5 and 32.9% with medium and high application, respectively. DM was significantly correlated (Table 4) with LAD (0.48), RWC (0.81), LAI (0.9) and CI (0.84).

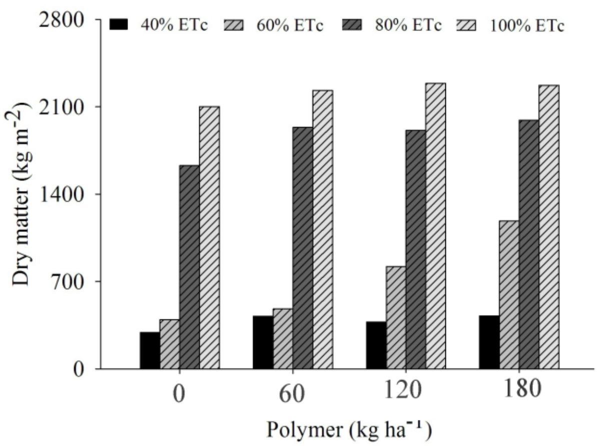

Figure 5. Effect of water stress and polymer (A200) on dry matter.

Table 5. The interaction of Irrigation regime and polymer (A200) on dry matter in forage sorghum during 2013 season

Irrigation levels	Superab A200 levels	Dry matter (g.m2)
I1	S4	2272a
	S3	2288a
	S2	2230.7a
	S1	2334.7a
I2	S4	2193.3a
	S3	2144a
	S2	2168a
	S1	1529.3b
I3	S4	952c
	S3	752c
	S2	425.3d
	S1	393.3d
I4	S4	380d
	S3	374.7d
	S2	356d
	S1	292d

Means followed by a similar letter are not significantly different at P<0.05 according to duncan's multiple range test.

CONCLUTION

Water stress decreased relative water content, chlorophyll index, leaf area index, leaf area duration and dry matter. Our results have shown that the applied SAP had an important effect on forage sorghum and increased relative water content, chlorophyll index, leaf area index, leaf area duration and dry matter. Water stress directly affects leaf chlorophyll content, LAD and finally dry matter. Reduction in the leaf area in response to water stress occurs either through a decline in the leaf expansion or accelerated leaf senescence and therefore, a decrease in photosynthesis. Probably the application of SAP could be an effective management practice in soils characterized by low water holding capacity where irrigation water and fertilizer often leach below the root zone within a short period of time, leading to poor water and fertilizer use efficiency by crops. Therefore, SAP increases leaf area index, leaf area duration and consequently dry matter through increasing both water and nutrient use efficiency in crop. The results showed that 80% ETc and 60 kg ha^{-1} SAP produced desirable dry matter and consequently, 20% water saved.

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