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Assess Effect of Deficit Irrigation and Super Absorbent Ploymer on Crop Production and Growth Indices of Corn under Dry and Warm Climate Condition

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ABSTRACT

BACKGROUND: Polyacrylamide is the main synthetic polymer used, and it absorbs water through the formation of hydrogen bonds. Super Absorbent Polymer (SAP) can absorb water up to 200-400 times its weight and increase its size by up to 100 times.

OBJECTIVES: Evaluate effect of different irrigation regime and super absorbent polymer on agrophysiological traits of maize.

METHODS: This study was done via split plot experiment based on randomized complete blocks design during 2016 with three replications. The main factor included irrigation regimes (M_1: Conventional irrigation or control, M_2: Alternate furrow irrigation from 4 leaves stage until silk emergence and after conventional, M_3: Normal irrigation until silk emergence and after alternate furrow irrigation). Three level of super absorbent polymer (S_1: non use of SAP, S_2: 25 kg.ha^{-1}, S_3: 50 kg.ha^{-1} SAP) belonged to the sub factor.

RESULT: Result of analysis of variance indicated effect of different irrigation regime and SAP on seed yield, biologic yield and harvest index was significant at 1% probability level also interaction effect of treatments on measured traits (instead harvest index) was significant. Mean comparison result of different irrigation regime revealed the maximum amount of seed yield (5670 kg.ha^{-1}), biologic yield (1401 gr.m^{-2}), harvest index (40.47%), total dry weight (1800 gr.m^{-2}), leaf area index (4.95), crop growth rate (39 gr.m^{-2}.day^{-1}), net assimilation rate (8.5 gr.m^{-2}.day^{-1}) and relative growth rate (0.15 gr. gr^{-1}.day^{-1}) was obtained for M_1 and minimum of mentioned traits was for M_2 treatment. Compare different level of SAP showed that the maximum amount of seed yield, biologic yield, harvest index and growth indices belonged to S_3 treatment also the lowest amount of measured traits were for S_1 treatment. Assessment mean comparison result of interaction effect of treatments indicated maximum seed yield (6300 kg.ha^{-1}) and biologic yield (1456 gr.m^{-2}) was noted for M_1S_3 and lowest amount of measured traits belonged to M_2S_1 treatment.

CONCLUSION: Generally between different deficient irrigation treatments M_3 treatment had highest amount in total dry matter, leaf area index, crop growth rate, net assimilation rate, relative growth rate, biologic yield, seed yield and harvest index, so in water stress situation M_3 treatment with use 50 kg.ha^{-1} SAP it can be advice to farmers.

KEYWORDS: *Alternate furrow irrigation, Maize, Polyacrylamide, Stress, Yield.*

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1. BACKGROUND

Maize is one of the valuable and important grains in temperate and subtropical areas in the world (Modhej *et al*., 2014). In the sub-tropics, water and nitrogen are the most important factors that limit the grain yield of maize. Maize produces higher yields under sufficient water and soil fertility; however, this crop has the least tolerance to unfavorable conditions (Muchow, 1989). Previous studies have reported that water deficit limits the growth of plant (Hung *et al*., 2005), by reducing the leaf area, height, dry weight, stomatal closure, photosynthesis and chlorophyll contents, enzymes degradation, and accumulation of amino acids (Hassani and Omide Beigi, 2001). Drought has more severe effects on plant at the beginning of vegetative growth stage (Ahmed Amal *et al*., 2005), and Post-flowering drought stress causes accelerate of leaf senescence and decrease the current photosynthetic activities (Efeoğlu *et al*., 2009). After pollination, the most significant sinks are grains (Bonnett and Incoll, 1992), therefore, the rate of sink demand is the most important component in determining mobilization rate of stem reserved assimilates. If transport of assimilates to grains decreases because of drought stress and poor soil fertility, the source limitation will increase. Studies previously have suggested that the deleterious effects of drought could be mediated by application of nutrients, which may enhance plant ability to tolerate the drought stress (Aslam *et al*., 2013). Alternate furrow irrigation (AFI) is a method whereby water is applied to every other furrow rather than to every furrow. Therefore, less water is usually applied with alternate furrow irrigation methods. Since a reduced amount of water applied (gross water application) does not consistently reduce yields, water use efficiency may be increased (Graterol *et al*., 1993). Alternate furrow irrigation was proposed as a method to increase water use efficiency and decrease chemical leaching compared with every-furrow irrigation and with small yield losses for different crops compared with fixed furrow irrigation system (Mailholl *et al*., 2001). Alternate furrow irrigation has been widely applied worldwide to improve irrigation efficiency with good results in corn, sorghum, potato, cotton and peppermint (Kang *et al*., 2000a). Irrigating plants at alternate furrows allows water to be applied to bigger areas than irrigating every furrow from a given water source for a given period than irrigating them at every furrows (Yonts *et al*., 2007). Nasri *et al*. (2010) reported increase frequent irrigation intervals alleviate water stress effect on yield and its components. In addition, alternate furrow irrigation methods may supply water in a manner that greatly reduces the amount of surface wetted, leading to less evapotranspiration and less deep percolation (Graterol *et al*., 1993). Generally, alternate furrow irrigation regime has been found to be a trade-off; “a lower yield for a higher water use efficiency”, in which water has been saved mainly by reduced evaporation from the soil surface (Kang *et al*., 2000a). Sepaskhah and Khajehabdollahi (2005) reported that decrease in corn yield due to water stress in AFI was mainly due to the decrease in the number of kernels per cob and to a lesser extent to the decrease in 1000-kernel weight. Water stress on maize has been shown to reduce plant height, diameter of shank, leaf area index and root growth (Wilson *et al*., 2006). Graterol *et al*. (1993) reported that approximately same yield levels were obtained under both practices in soybeans, with significantly less water (46%) applied under every other furrow irrigation. Yonts *et al*. (2007) reported that water application can be reduced by 20 to 30% through every other row irrigation while corn yield was not much reduced. Baker *et al*. (1997) reported that the use of alternate furrow irrigation reduced sugar cane yield when the same irrigation frequency was applied as every furrow irrigation. The water requirements of corn on a fine textured soil (with deep and shallow water table) were not met by alternate furrow irrigation even at 4-day irrigation intervals (Sepaskhah and Khajehabdollahi, 2005). Alternative furrow irrigation is commonly applied as part of a deficit irrigation program because it does not require the application of more than 50-70% of the water used in a fully irrigated program (Marshal *et al*., 2008). Alternate furrow irrigation was proposed as a method to increase water use efficiency and decrease chemical leaching compared to every-furrow irrigation and with small yield losses for different crops compared to a fixed furrow irrigation system (Abedi and Pakniyat, 2010). Tagheian-Aghdam *et al*. (2014) reported the alternative and fixed furrow irrigation treatments presented as the best solution for water saving in arid and semi-arid fields with 50% and 60% saving amount 6.9% and 14.22% reduction in corn biological yields. Relative growth rate (RGR) measures the increase in dry matter with a given amount of assimilatory material at given point of time (Rajput *et al*., 2017). Sharifi *et al*. (2014) reported that during plant growth stages RGR values are interrelated to dry matter accumulation and crop growth rate. The amount of growth and photosynthetic translocation is related to nutrients availability (Munir *et al*., 2012). Dwyer and Tewart (1986) reported that leaf area index is major factor determining photosynthesis and dry matter accumulation. Crop growth rate is related to leaf area index, for this reason that crop growth rate changes is depended to two parameters: namely leaf area index and net assimilation rate. Leaf area index is the component of crop growth analysis that accounts for the ability of the crop to capture light energy and is critical to understanding the function of many crop management practices. Leaf area index can have importance in many areas of agronomy and crop production through its influence on: light interception, crop growth weed control, crop-weed competition, crop water use, and soil erosion. To measure LAI, scientists generally have cut a number of plants at the soil surface, separated leaves from the other plant parts, and measured the area of individual leaves to obtain the average leaf area per plant. The product of leaf area per plant and the plant population gives the LAI. Alternatively, LAI could be measured none destructively with this procedure if area of the individual leaves was determined by some combination of the leaf length and width measurements (Shirkhani and Nasrolahzadeh, 2016). The variability of the harvest index in the plants depends on the difference in the production of the assimilates during the seed filling and re-transplantation of the assimilates before the pollination of each genotype and the strength of the reservoir (Nour mohammadi *et al*., 2001). In the agriculture science, polyacrylamide is the main synthetic polymer used, and it absorbs water through the formation of hydrogen bonds (Ahmed, 2015). SAP can absorb water up to 200-400 times its weight and increase its size by up to 100 times. The end products of SAP degradation in soil are carbon dioxide, water, and ammonia (Wallace, 1986). Polymers absorb and store water and nutrients in a gel form and undergo cycles of hydrating and dehydrating according to moisture demand, increasing both water and nutrient use efficiency in the crop plants (Islam *et al*., 2011, a). A superabsorbent polymer can hold 400 to 1500 times as much water as its dry hydrogel (Fazeli Rostampour *et al*., 2013). Fallahi *et al*. (2015) by investigate the effect of water deficit, irrigation after 120 (control), 155 (moderate water stress) and 190 mm (sever water stress) pan evaporation and super absorbent polymer rates (SAP) (0, 30, 60 and 90 $kg.ha^{-1}$) on growth, yield and water use efficiency of cotton reported that moderate water stress (irrigation intervals of aprox. 15 days) along with 60 $kg.ha^{-1}$ SAP application was the best treatment in terms of growth and yield indices of cotton, also water deficit and SAP application improved water use efficiency (WUE) of cotton, amount of WUE in moderate water stress treatment along with consumption of 60 or 90 $kg.ha^{-1}$ SAP was 26% higher than for control.

2. OBJECTIVES

Current research was conducted to evaluate effect of different irrigation regime and super absorbent ploymer on seed yield and growth curves of maize.

3. MATERIALS AND METHODS

3.1. Field and Treatments Information

This study was done according split plot experiment based on randomized complete blocks design during 2016 with three replications. The main factor included irrigation regimes (M_1: Conventional irrigation or control, M_2: Alternate furrow irrigation from 4 leaves stage until silk emergence and after conventional, M_3: Normal irrigation until silk emergence and after alternate furrow irrigation). Three level of super absorbent polymer (S_1: non use of SAP or control, S_2: 25 $kg.ha^{-1}$, S_3: 50 $kg.ha^{-1}$ SAP) belonged to the sub factor. The place of current study was located in Ahvaz city at longitude 48°40'E and latitude 31°20'N in Khuzestan province. Also the average annual rainfall, temperature, and evaporation in region were 242 mm, 24 C and 3000 mm, respectively. The physical and chemical properties of studied soil mentioned in table 1. The size of each plot was 6×5 m^2 and each block includes nine treatments. The distance between rows was 75 cm with six rows per treatment. The spacing between the main plots consisted of two nonplanting lines, and distance between the subplots was one line. Selection of mentioned amounts of super absorbent polymer (SAP) is due to the fact that in various studies between 100 and 200 $kg.ha^{-1}$ SAP was used, but in current research the lowest amount of SAP was studied to maximize the economic efficiency can be achieved.

Table 1. Physical and chemical properties of studied field

Soil depth (cm)	0-30	EC ($ds.m^{-1}$)	4.29
pH	7.75	O.C (%)	0.58
P (ppm)	8.74	K (ppm)	179
Fe (ppm)	9.95	Clay (%)	32
Silt (%)	35	Sand (%)	33
Soil texture	Clay	ρ_b ($g.cm^{-3}$)	1.37

3.2. Farm Management

Nitrogen was applied in amount 250 $kg.ha^{-1}$ from urea source in two step, half with planting and the remaining half at the 8 leaf stage. Also 150 $kg.ha^{-1}$ phosphorus (triple super phosphate source) and 150 $kg.ha^{-1}$ potassium (sulphate potassium source) was used before planting. For control weeds by herbicide, before planting field was sprayed by Atrazine (1 $kg.ha^{-1}$) and Laso (4 $L.ha^{-1}$) mix and after it the farm was discarded with the tractor. Also during the growth period, all plots were weeded manually. No serious incidence of insect or disease was observed, so no pesticide or fungicide was applied.

3.3. Measured Traits

In order to determine the yield two planting lines from each plot harvested and after the removal of marginal effect were carried to the laboratory and were placed in the oven at 75°C for 48 hours and after ensuring that the samples were completely dry, they were weighed and finally the total yield was measured. Harvest index (HI) was calculated according to formula of Gardner *et al.* (1985) as follows:

Equ.1. HI= (Seed yield/Biologic yield) × 100.

By measuring 3 factors including leaf area, leaf dry weight and total dry weight, the physiological parameters of growth including LAI, NAR, CGR and RGR were obtained using the following equations. To determine the leaf area of the linear relationship S= K. L.W was used in which S, L and W were the leaf area, L and W respectively, the maximum length and width of each leaf and K= 0.75 correction coefficient. The leaf area index was calculated from leaf area ratio to ground level. Crop growth rate, net assimilation rate and relative growth rate were measured according fallowing formula (Buttery, 1970; Enyi, 1962):

Equ.1. CGR ($gr.m^{-2}.day^{-1}$) = TDM_2-TDM_1/T_2-T_1

TDM_1= Primary dry weight (gr),

TDM_2= Secondary dry weight (gr)

T_1= initial sampling time,

T_2= Secondary sampling time

Equ.2. NAR ($gr.m^{-2}.day^{-1}$) = CGR* $LnLA_2$-$LnLA_1$/LA_2-LA_1

LA_1= Initial leaf area, LA_2= Secondary leaf area

Equ.3. RGR ($gr.gr^{-1}.day^{-1}$) = [Ln (TDM_2) - Ln (TDM_1)]/T_2-T_1

3.4. Statistical Analysis

Analysis of variance and mean comparisons were done by MSTAT-C software and Duncan multiple range test at 5% probability level.

4. RESULT AND DISCUSSION

4.1. Total dry weight (TDW)

Compare different irrigation regime revealed maximum amount of TDW (1800 gr.m^{-2}) belonged to M_1 treatment and lowest one was for M_2 (1430 gr.m^{-2}), also between dificiet irrigation treatments M_3 had higher TDW (Fig. 1).

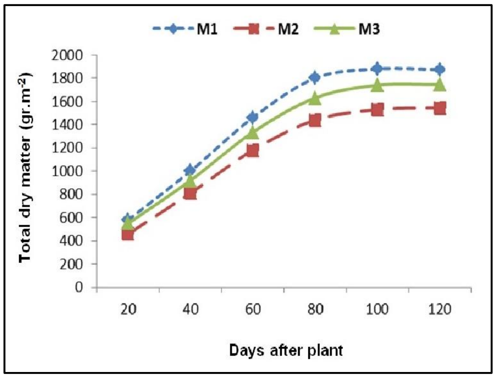

Fig. 1. Effect of different level of irrigation regime on total dry matter

The trend of variation of total dry weight is initially low and ascending trend continues up to 80 days after planting and from this point onwards, it will grow to the end of the growing period. The amount of TDW accumulation in different irrigation treatments in the early stages of growth was not significantly different, due to the low green cover and nutrition demand and the lack of competition between bushes at this time. But with the onset of stem elongation and the extension of the plant green area, the difference among the treatments will be significant. So that the plant in conventional irrigation (M_1) treatment with better ability to spread the green area and plant height could be able use available moisture, nutrient and light to produce higher TDW than other treatments (Fig. 1). It seems by decreasing the irrigation, stomatal conduction and pure photosynthesis led to reduce TDW in M_2 treatment. These results were consistent with the findings of Saberali *et al*. (2007). Moghimi *et al*. (2014) reported that low irrigation in early vegetative growth reduced the dry matter content of maize plants, but at the reproductive stage it decreased more severely. Among different SAP treatments S_3 by consume 50 kg.ha^{-1} had higher amount of TDW (1780 gr.m^{-2}) and control had lowest level of TDW (1400 gr.m^{-2}) (Fig. 2). Allah Dadi *et al*. (2005) reported use SAP led to keep soil moisture content, reduce evaporation and and improve TDW.

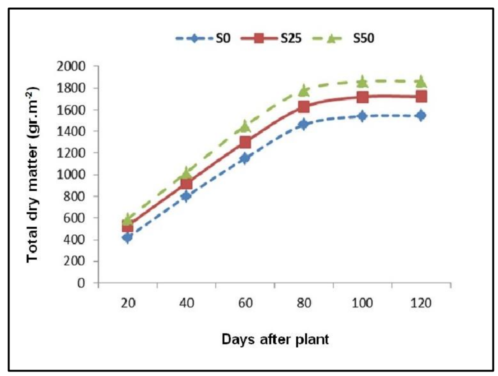

Fig. 2. Effect of different level of super absorbent polymer on total dry matter

4.2. Leaf area index (LAI)

Compare different irrigation regime indicated maximum amount of LAI was for M_1 treatment (4.95) and the lowest one belonged to M_2 (3.94), and between dificiet irrigation treatments M_3 had higher LAI (Fig. 3). Conventional irrigation had higher LAI because of more deveople leaf area and continuity it, led to have sufficient physiological source to recive more light and produce dry matter.

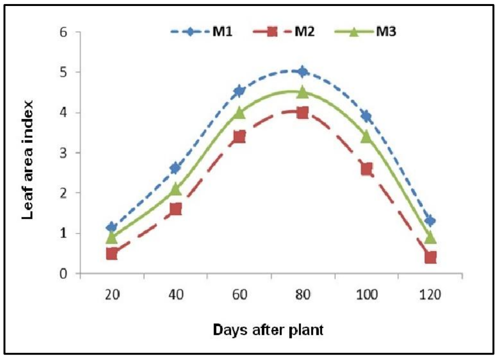

Fig. 3. Effect of different level of irrigation regime on leaf area index

Osborne (2002) report similar result. The reason of decreasing leaf area index after flowering stage can be related to increasing shading of leaves on each other, the yellow and aging of leaves of the plant community and decreasing the penetration of light into the lower parts of the plant community. During the vegetative stage, water stress decreases the growth of stem and leaf cells, so it led to reduce leaf area index in I_2 treatment, wich consisted with result of Lauer (2003). Boudjabi *et al*. (2015) reported that drought stress significantly affected leaf area index and with increasing drought stress, leaf area index decreased significantly. Reducing leaf area index with increasing water deficit stress can be attributed to the decrease in leaf size due to the lack of suitable moisture for maintaining turgor stress for growth of leaf cells along vegetative growth (Tarumingkeng and Coto, 2003). At early stages of growth, all superabsorbent treatment had similar trend, but 80 days after planting, 50 kg.ha^{-1} super absorbent (S_3) had the highest LAI (4.83) (Fig. 4). It seems this effect is mainly due to the absorption of significant amounts of water by SAP around the crop root, resulting in the plant producing more leaf area. Increasing leaf area, led to increase amount of light absorption and eventually increasing the CGR.

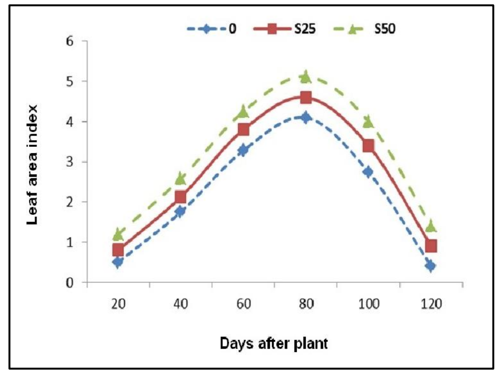

Fig. 4. Effect of different level of super absorbent polymer on leaf area index

Some researcher reported similar result about positive effect of SAP on increase leaf area index under water stress (Hassanzadeh *et al*., 2016; Moazenghamsari *et al*., 2009). Fazelirostampour *et al*. (2012) reported that application of 75 kg.ha^{-1} SAP increased growth indices such as leaf area index significantly compared to control, which was consistent with the results of this study.

4.3. Crop growth rate (*CGR*)

The crop growth rate was low in all treatments in the early stages due to the incomplete vegetation cover and low leaf area index. Over time, the CGR increased rapidly because of the leaf area and light absorption increased. Compare different irrigation regime indicated maximum amount of CGR was for M_1 treatment (39 gr.m^{-2}.day^{-1}) and the lowest one belonged to M_2 (28 gr.m^{-2}.day^{-1}), also between dificiet irrigation treatments M_3 had higher CGR (Fig. 5).

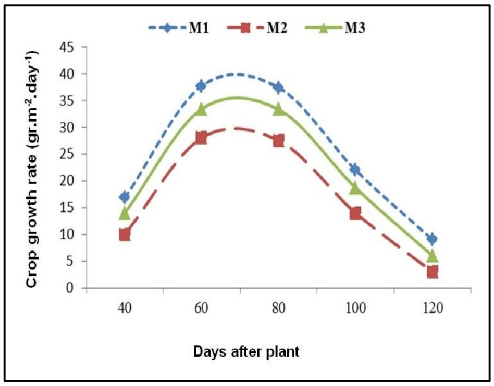

Fig. 5. Effect of different level of irrigation regime on crop growth rate

It seems that increasing drought stress during plant growth causes competition for water absorption between aerial and ground sections will be increase, due to that competition, the plant allocates more of the assimilates to the root than to aerial part, and reduces the CGR, but when full moisture was available (in control treatment), the CGR was at its highest. Bomesa and Wayne (2008) reported that water stress by decrease leaf area, reduce photosynthesis area and the production of dry matter, and so amount of crop growth rate of dificet irrigation were lower than conventional irrigation during plant growth, mentioned result which confirmed the findings of current study. Maximum crop growth rate was obtained in treatment of 50 kg.ha^{-1} SAP or S_3 (37 gr.m^{-2}.day^{-1}) treatment, this is due to the faster coverage canopy or, in other words, to the higher LAI of this treatment and the lowest amount of CGR in the control treatment (25 gr.m^{-2}.day^{-1}) was related to the lower LAI (Fig. 6). Joshanirad *et al.* (2013) reported that with the increase in the amount of SAP in the sorghum, the CGR increased, so that the levels of 40 and 80 kg.ha^{-1} SAP led to increase CGR 7% and 11%, than to control.

4.4. Net assimilation rate (NAR)

It seems that at the beginning of growth, due to the small number of leaves, the low competition and shading leaves on each other, NAR has a maximum value, but NAR has decreasing trend with the development of plant leaves, shading and reduce photosynthetic efficiency. Due to shadowing of young leaves on old leaves, it reduces the amount of photosynthetic produce.

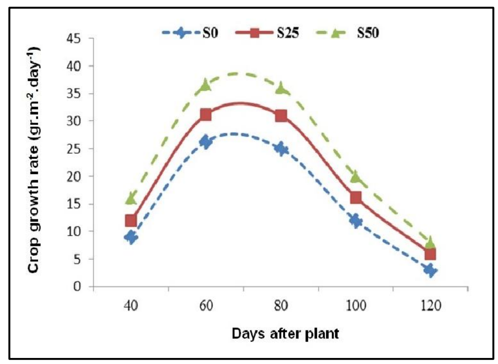

Fig. 6. Effect of different level of super absorbent polymer on crop growth rate

This means that the amount of absorption per leaf area unit is reduced, and by increasing the number of leaves and increasing leaf area in the plant community, in general, led to increase dry matter and accumulation. Among different irrigation regime conventional irrigation (M_1) had highest NAR (8.5 gr.m^{-2}.day^{-1}) and and the lowest one belonged to M_2 (6.5 gr.m^{-2}.day^{-1}), also between dificiet irrigation treatments M_3 had higher NAR (Fig. 7).

The three irrigation treatments initially had a high net absorption rate but due to lower rate of photosynthetic organ to respiratory organs NAR decreased significantly.

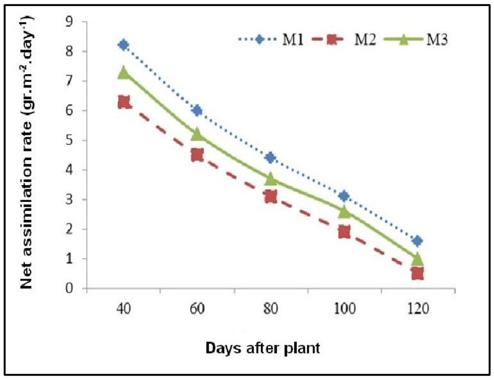

Fig. 7. Effect of different level of irrigation regime on net assimilation rate

Conventional irrigation treatment (control) has a higher net absorption rate than other treatments due to the spread of proper leaf area and the more production of assimilates. Among different SAP treatments S_3 by consume 50 kg.ha^{-1} had higher amount of NAR (8.8 gr.m^{-2}.day^{-1}) and control (6.9 gr.m^{-2}.day^{-1}) had lowest level of NAR (Fig. 8). Khodadadi Dehkordi *et al*. (2013) by evaluate the effects of water stress and superabsorbent on corn growth factors stated that stress had a negative effect on LAI, CGR and NAR, is due to lower leaf area cover, reduced absorption of sunlight and unnecessary changes in the process of absorbing and accumulate assimilates. Also by uing the superabsorbent in current study, the effect of water deficit on the corn crop was reduced and led to achieve higher LAI, CGR and NAR than to the control treatment.

4.5. Relative growth rate (*RGR*)

Among different irrigation regime conventional irrigation (M_1) had highest amount of RGR (0.15 gr. gr^{-1}.day^{-1}) and and the lowest one belonged to M_2 (0.12 gr. gr^{-1}.day^{-1}), also between dificiet irrigation treatments M_3 had higher RGR (Fig. 9). Between irrigation treatments, conventional irrigation has been shown to be superior in RGR due to higher photosynthetic efficiency and dry matter production compared to other treatments. Among different SAP treatments S_3 by consume 50 kg.ha^{-1} had higher amount of RGR (0.14 gr. gr^{-1}.day^{-1}) and control had lowest level of RGR (0.11 gr. gr^{-1}.day^{-1}) (Fig. 10).

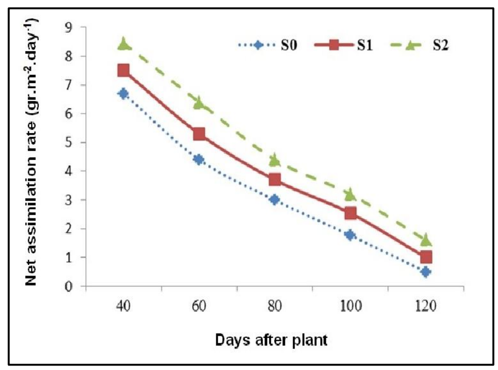

Fig. 8. Effect of different level of super absorbent polymer on net assimilation rate

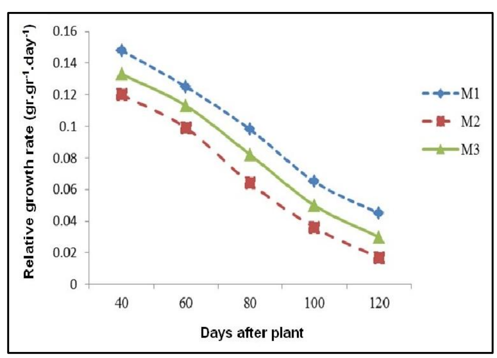

Fig. 9. Effect of different level of irrigation regime on relative growth rate

Yazdani *et al*. (2007) by evaluate effect of different levels of superabsorbent on growth indices reported the highest amount of dry matter accumulation, leaf area index and relative growth rate was achieved in 225 kg.ha^{-1} superabsorbent treatment that was consistent with the results of this research.

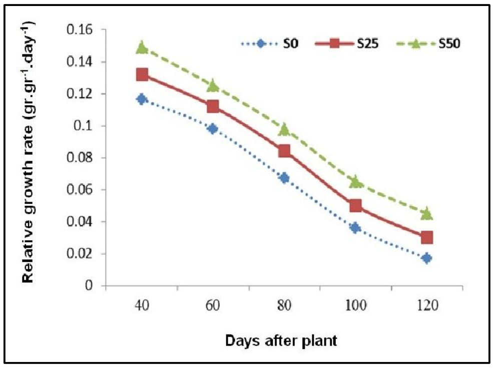

Fig. 10. Effect of different level of super absorbent polymer on relative growth rate

4.6. Seed yield

Evaluation result of analysis of variance revealed effect of different irrigation regime, SAP and interaction effect of treatments on seed yield was significant at 1% probability level (Table 2). Mean comparison result of different irrigation regime indicated the maximum seed yield (5670 kg.ha^{-1}) was obtained for M_1 and minimum of that (4210 kg.ha^{-1}) was for M_2 treatment (Table 3). Performing deficit irrigation and limiting access to water at the reproductive stage will result in the reduction seed yield, which is due to the high sensitivity of the reproductive organ to drought stress. Drought stress by drcreasing the transfer of assimilate from leaves and other parts of the plant to the seeds led to reduce seed yield in cereals. These results were consistent with the findings of Valifar *et al*. (2013). Compare different level of SAP showed that the maximum and the minimum amount of seed yield belonged to S_3 (5550 kg.ha^{-1}) and S_1 (4310 kg.ha^{-1}) treatment (Table 3). Assessment mean comparison result of interaction effect of treatments indicated maximum seed yield (6300 kg.ha^{-1}) was noted for M_1S_3 and lowest one (3870 kg.ha^{-1}) belonged to M_2S_1 treatment (Table 4). Kang *et al*. (2000b) by compare conventional irrigation and variable furrow irrigation in corn planting, concluded alternate furrow irrigation, while increasing seed yield, saved 50% of water consumption, and introduced an effective way to reduce the amount of water consumed in dry areas. It seems that the cause of increasing seed yield in 50 kg.ha^{-1} SAP treatment is due to it able to increase the supply water, nutrient and pigments for crop and improve the growth and corn seed yield. Rafie *et al*. (2013) reported that superabsorbent significantly increased seed yield, 1000 seed weight, number of seed per ear, which was consistent with the results of this research. Kohestani *et al*. (2009) reported that under without drought stress, superabsorbent increased seed yield by reducing the leaching of nutrients in the soil and increasing root growth. Islam *et al*. (2011b) evaluate the effectiveness of different rates of SAP (low, 10; medium, 20; high, 30 and very high, 40 kg.ha^{-1}) for winter wheat production under drought-affected field and reported the optimum application rate of SAP would be 30 kg.ha^{-1} as it increases both wheat yield and soil fertility.

Table 2. ANOVA result of measured traits

S.O.V	df	Seed yield	Biologic yield	Harvest index
Replication	2	4666^{ns}	785^{ns}	34.55^{ns}
Irrigation regime (M)	2	59896^{**}	77117^{**}	109.57^{**}
Error I	4	641	3534	6.84
Super absorbent polymer (S)	2	12764^{**}	32518^{**}	67.7^{**}
I × S	4	6278^{**}	22337^{**}	0.56^{ns}
Error II	12	432.2	1827.2	4.78
CV (%)	-	4.21	3.26	5.86

^{ns}, * and ** are non-significant and significant at 5 and 1% probability levels, respectively.

Lower rates (10 and 20 $kg.ha^{-1}$) are not sufficient and higher rate (40 $kg.ha^{-1}$) is not economic. They suggested that the application of SAP at 30 $kg.ha^{-1}$ could be an efficient soil management practice for winter wheat production in the drought-affected regions.

4.7. Biologic Yield

According result of analysis of variance effect of different irrigation regime, SAP and interaction effect of treatments on biologic yield was significant at 1% probability level (Table 2). Mean comparison result of different irrigation regime revealed the maximum biologic yield (1401 $gr.m^{-2}$) belonged to M_1 and minimum of that (1216 $gr.m^{-2}$) was for M_2 treatment (Table 3). Compare different level of SAP showed that the maximum and the minimum amount of biologic yield belonged to S_3 (1378 $gr.m^{-2}$) and S_1 (1239 $gr.m^{-2}$) treatments (Table 3). Assessment mean comparison result of interaction effect of treatments showed maximum biologic yield (1456 $gr.m^{-2}$) was noted for M_1S_3 and lowest one (1146 $gr.m^{-2}$) belonged to M_2S_1 treatment (Table 4). Increasing the biomass of crop under coventional irrigation conditions was due to great extension of leaves, which caused a strong physiological source to produce dry matter. Ghobadi and Shirkhani (2011) reported that the highest biological yield was obtained under coventional irrigation conditions and drought stress led to reduce the amount of dry matter under stress situation, which was similar to the results of this research. Pandy *et al.* (2000) reported that water stress lead to reduced leaf area and reduced growth and dry matter of the crop. They believe that dificet irrigation reduces the dry matter production at vegetative growth, but at reproductive stage, it dramatically reduces the dry matter. Vegetative growth stage, however, has less effect on final yield compared with water shortage during flowering and seed filling stages, but it has a significant effect on leaf and stem development and severely decreased of accumulation assimilates in these organs is important, these results confirmed the findings of this study.

Table 3. Mean comparison of seed yield, biologic yield and harvest index affected different irrigation regime and SAP

Treatments	Seed yield (kg.ha^{-1})	Biologic yield (gr.m^{-2})	Harvest index (%)
Irrigation regime			
M_1	5670^a	1401^a	40.47^a
M_2	4210^c	1216^c	34.68^c
M_3	4960^b	1306^b	38.01^b
Super absorbent polymer			
S_1	4310^c	1239^c	34.84^c
S_2	4960^b	1305^b	36.67^b
S_3	5550^a	1378^a	40.28^a

*Similar letters in each column show non-significant difference at 5% probability level via Duncan test.

I_1: Conventional irrigation or control, **I_2**: Alternate furrow irrigation from 4 leaves stage until silk emergence and after conventional, **I_3**: Normal irrigation until silk emergence and after alternate furrow irrigation.

S_1: non use of SAP or control, **S_2**: 25 kg.ha^{-1}, **S_3**: 50 kg.ha^{-1} SAP.

In this study it seems, the use of SAP by providing the amount of water required for growth and dry matter production can increase the biological yield with more growth and, as a result, more dry matter production. It seems that by adding SAP to the soil, the field capacity in the soil increases and the crop has access to water for a longer time. Also, the SAP absorbs the required nutrients of the plants and, in their turn, releases them to the plant and thus prevents the leaching of these elements. This set of conditions improves biological yield under drought stress conditions. Rafiei *et al*. (2013) reported apply SAP in 3 levels (control, 100 and 200 kg.ha^{-1}) on corn farm significantly increased seed and biological yield. Some researchers reported use SAP under water stress condition led to increase biologic yield in compare to control (Nazarli *et al*., 2010; Khalili Mahalleh *et al*., 2011; Moslemi *et al*., 2012). Khalili Mahalleh *et al*. (2011) reported SAP causes the stomatal to stay open for a long time for stabilization of carbon dioxide and improve crop dry weight.

4.8. Harvest index

Result of analysis of variance showed the effect of different irrigation regime and SAP on harvest index was significant at 1% probability level but interaction effect of treatments was not significant (Table 2). Compare different level of irrigation regime showed that the maximum and the minimum amount of harvest index belonged to M_1 (40.47%) and M_2 (34.68%) treatment (Table 3). Mean comparison result of different level of SAP revealed the maximum harvest index (40.28%) was obtained for S_3 and minimum of that

(34.84%) was for S_1 treatment (Table 3). The harvest index introduce the path in which the assimilates are distributes between vegetative parts of the plant and seeds, so seed yield has greate effect on calculate harvest index. Setter (2000) stated that water stress is a limiting factor for plant growth, in addition to reducing the dry matter production, it disrupts carbohydrate distribution and thus reduces the harvest index. Valifar *et al*. (2013) believed the reduction in harvest index at different levels of water stress was attribute to a greater reduction in seed yield than biological yield, and reported that, under stress conditions, the redistribution content to the seed reduced and led to decrease seed yield and drop harvest index, which similare to the findings of this research. Moslemi *et al*. (2012) reported the role of SAP in increasing of harvest index can be justified these materials can be able to storage water and nutrient and release at stress condition with decrease leaching to keep nutrient led to increase seed yield, biologic yield and harvest index. Sayyari *et al*. (2012) reported the highest seed yield and its components and harvest index was achieved to apply 45 $kg.ha^{-1}$ SAP. Reports of Robiul Islam *et al*. (2011), showed an increase in harvest index with application of 40 $kg.ha^{-1}$ SAP, which was consistent with the results of this study.

5. CONCLUSION

Generally result of current study revealed between different dificiet irrigation treatments M_3 treatment had highest amount in total dry matter, leaf area index, crop growth rate, net assimilation rate, relative growth rate, biologic yield, seed yield and harvest index, so in water stress situation M_3 treatment with consume 50 $kg.ha^{-1}$ SAP it can be advice to farmers.

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FOOTNOTES

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