Effects of Super absorbent polymer on tomato's yield under water stress conditions and its role in the maintenance and release of nitrate

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Abstract: Iran is located in an arid and semi-arid region and therefore water is the first and foremost limiting factor in agricultural productions. Scattered rainfall pattern and limited water resources have led to hardiness in plant establishments. Proper managements and applying advanced techniques to conserve soil moisture storage are two of the most effective measures to ensure a better use of these limited water resources. One way to use scattered precipitations and other water resources for storage and conserving water is to apply additives to soil such as super absorbent polymer. To do so a, completely randomized block design experiment was conducted. Main plot wasthree levels of irrigation (50, 75 and 100 percent of water demand) and three levels of A-200 super absorbent polymer, 12.5 and 25 gram per plant (or 0.45 and 0.9 ton per Hectare respectively) was applied as the subplot. The goal was to observe and study the effects of treatments on Tomato's yield under field conditions in city of Karaj. The results showed that among all of the treatments, application of 25 grams of super absorbent had the most effects on the Tomato's yield under all of the irrigation conditions. The highest yield obtained was from the treatment of 0.45 super absorbent per hectare and full irrigation with a yield increase of 56 percent in comparison with the treatment of same amount of irrigation with no super absorbent. The treatment of 0.9 ton per hectare Hydrogel and full irrigation had a yield improvement of 20 percent compared to thecontroltreatment.Also the presence of the super absorbent in the root zone in 0.9 and 0.45 ton per hectare treatments led to 31and 20 percent decrease in nitrate's deep percolation respectively. Thisenhances fertilizer use efficiency and reduces the environmental problems caused by nitrate transport to ground waters.

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1. Introductions

Iran is located among the arid and semiarid regions in the world. According to an increasing population there is a significant demand of food production and becoming self-sufficient on this subject is an important goal. Among the many effort that are made to achieve the goal, water issues and proper use of water resources is of great importance, since the first and foremost limiting factor in improving agricultural production is water. Using super absorbent is a proper management, if an optimal use of water resources is intended. These polymers have a high absorption capability and are considered as modifiers for soil. They have been named as materials that can hold large amount of nitrate, so they can prevent nitrate from percolating to lower layers of soil and as a result there is a less need for nitrate removal (Rajuet al 2002).materials such as hydrogels, in sand soils, usually reduced hydraulic conductivity (HC), but in heavy clay soil porosity will increased. The final swelling hydrogels in soil is less than the free state (Habibollahi and Hooshmand 2012). Tomato is a dicot flowering plant from the family of *solanaceae* and the order is *lycopercicum* genus. It is a rich source for vitamins, minerals and anti oxidant. Tomato is considered one of the most important horticultural crops in aspect of human health and food (Doris et al 2001) and accounts for 25 percent of world's total vegetable productions (Uysal, 2006). There is a growing interest for deficit irrigation in improving water use efficiency approaches. Deficit irrigation is a method that the amount of water used is less than the full irrigation and the crop experiences a mild water stress that has a minimal impact on production. When there is drought or low available water conditions, "deficit irrigation” technique can increase the economical benefit of production instead of producing the maximum yield per drop of irrigation water. The main purpose of deficit irrigation is to improve water use efficiency by increasing irrigation sufficiency (English, 1990). Henderson et al(1985) combined 0, 2 and 4 grams of Hydrogel per cubic meter of siliceous sand. Next they added Ammonium nitrate solution to saturated sand (dried sand which was saturated by distilled water). Then after each wash of sand with distilled water they measured the amount of removed nitrate and ammonium. They came to conclusion that remained amounts of ammonium in the soil with hydrogel were more than the remained amounts in the soil without hydrogel, especially in unsaturated cases but, nitrate was removed by a high amount in all of the soils. Adding superabsorbent to soil can have many benefits which can be named as: improving soil capacity and length of retaining water and nutrients, a steady use of water by plant, improved root growth, lesser removal and percolation of water and nutrients, a maximized crop production potential, a faster and healthier growth of plants especially in hot and dry areas and optimal use of water and fertilizers. This research was conducted to study the effects of superabsorbent on: water-holding capacities of soil; water productivity; performance, quality and quantity of produced tomato under water stress conditions and finally nitrate’s retention and removal from soil.

2. Materials and Methods

This research was conducted on 2012 at the research field adjacent to the weather station of the Agriculture and Natural Resources campus of University of Tehran in Karaj with latitude of 35° and 55°longitude of 50° and 54′ and the altitude of 1312.5 m. Average annual precipitation in this region is 260mm. Mean annual temperature is 14.1 °C with maximum and minimum of 42 and -20 °C respectively. The average relative humidity is 53 percent and annual evaporation is 2184 mm. This region is considered a semi-arid climate with relatively cold winters and temperate summers. A dominant wind of North West to South East with daily average wind speed of 2.2 m/s and the total annual sunshine is calculated to be 2899 hours. About 43, 28, 28 and 1 percent of annual rain falls in winter, autumn, spring and summer respectively. March and April are rainiest months while, August and September are the least rainiest. July is the hottest-driest month and January is the wettest-coldest month of the year. The average of longest periods of droughts is reported to be 77 days and the dry period begins at late April and lasts to late October. Completely randomized block with three replications and five plants in each plot was the design of the experiment to examine different levels of super absorbent and irrigation. The three levels of super absorbent were 0, 12.5 and 25 grams per plant and irrigation levels were 50, 75 and 100 percent of crop water demand. Koral varieties of tomato seed were used. The seeds were planted in small plastic plots in greenhouse with a soil combination of equal proportions of sand, clay and Leaf composts.The seedlings were readied to be moved to field after 35 days from the planting date. The seedling were moved and planted in a loamy soil field with 41.2, 14.8 and44 percent of sand, clay and silt respectively. The average bulk density was 1.55 gram per cubic centimeters withContentmoisture at field capacity of 28 percent and permanent wilting point of 11 percent.The chemical properties of soil are presented in Table 1.

Table 1.The chemical properties of soil

Mn (mg/Kg)	Zn (mg/Kg)	Fe (mg/Kg)	Na (ppm)	Mg (ppm)	Ca (ppm)	K (mg/Kg)	P (mg/Kg)	N (%)	O.C (%)	SAR	EC (dS/m)	pH
8.5	2.64	5.81	61	17	160	574	31.4	0.105	0.87	1.23	1.01	8.2

Since at the early stages of the planting, plants had a shallow root, then all the treatments were irrigated equally (0.7 ds/m), so the irrigation level treatments started two weeks after the seedling transplanting to the study field. The amount of irrigation water was calculated based on soil moisture deficiency, according to soil moisture content at field capacity and measured moisture by the Profile Probe device.

3. Results

Among the irrigation treatments for the soils with Hydrogel, there were significance differences in number, weight and diameter of the fruit per plant, fresh and dry matter of brushwood and stem length at 1 percent level(Table2). There was a significance difference in dry matter percentage at 1 percent level among irrigation treatments and interactions between them. In addition, direct relationship between Vitamin C and amount of water in the plant was observed. These results indicate that by lowering the amount of water, processes involved in producing vitamin C reduces dramatically. Among the irrigation and Hyrdolgel added soil treatments and the interaction between them, there was a significance difference in yield at 1 percent level (table2).

Table 2. Variance analysis for the effects of irrigation and Hydrogel levels on measured characteristics and water and fertilizer use efficiency

							Mean-square			
Plant fresh	stem diameter	stem lenght	Plant dry matter	Vit C	fruit stiffness	percentage of	fruit diameter	fruit weight	Df	resource variation
weight -gr	Cm	Cm	Percentage	mg.100gF W	kg/cm²	dry fruit %	cm	gr		
31803.7^{ns}	0.037 ^{ns}	1.59^{ns}	4.9^{ns}	0.173^{ns}	0.012 ^{ns}	0.0217^{ns}	0.275^{ns}	9.55^{ns}	2	block
693425.93	0.069 ^{ns}	319.37 **	35.5 **	217.9 **	20.5 **	36**	20.35 **	773.35**	2	irrigation
654503.7*	0.067 ^{ns}	335.81 **	2.11 ^{ns}	51.8 **	1.84 **	0.237 **	11.43 **	321.46**	2	Hydrogel
275470.37*	0.078 ^{ns}	0.14 ^{ns}	2.45 ^{ns}	4.27 **	0.645 **	0.737 **	0.339 **	91.74 **	4	Hydrogel*irrigation
76357.87	0.0439	16.84	4.91	0.378	0.0125	0.0149	0.122	2.46	16	error

fertilizer use efficiency					Mean-square				
g/unit of added nutrients			water use	crop yield	%nitrate removed of	Root dry matter	Plant dry	Df	resource variation
p	K	NO3	efficiency-(g/lit)	kg/plant	combined layer with hydrogel	percentage	weight-gr		
1776^{ns}	308.33 ^{ns}	444^{ns}	12.33^{ns}	1.32^{ns}	0.3951^{ns}	0.108^{ns}	675.24^{ns}	2	block
56752**	9852.77 **	14188**	394.11 **	7.28 **	694.11 **	117.46 **	20604.06 **	2	irrigation
275344**	47802.77 **	68836**	1912.11 **	7.55 **	1800.7 **	14.42 **	13945.08 **	2	Hydrogel
1592**	276.38 **	398**	11.055 **	0.417 *	43.55 **	1.756 **	7447.059 **	4	Hydrogel*irrigation
30	52.08	75	33.33	0.58	0.758	0.29	1407.42	16	error

ns,* and Indicate that there is no significant difference, significant difference at 5 and 1 percent level, respectively.**

For the deficit irrigation treatments, 75 and 50 percent of water demand irrigation had the most and the least water and fertilizer use efficiency respectively (Table3). The treatment with 25gram super absorbent per plant had the most water and fertilizer use efficiency while the one with no superabsorbent had the worst (table3). The least yield was observed for the treatment with 50percent deficit irrigation and there was no significance difference between the other two treatments. 50 percent deficit irrigation treatment had the most root dry matter and the least root dry matter was observed in full irrigation treatments (table3). The most fruit dry matter was for the 75 percent deficit irrigation treatment and the least was for full irrigation (table3). The full irrigation treatments had the most yield and vitamin C amount and the least stiffness, while the 50 percent deficit irrigation had the lowest yield and vitamin C and the most stiffness (table3).

Table 3.Comparing the effects of different irrigation treatments on measured characteristics, water and fertilizer use efficiency

Plant fresh	stem diameter	stem lenght	Plant dry matter	Vit C	fruit stiffness	percentage of	fruit diameter	fruit weight	irrigation treatments
weight -gr	Cm	cm	percentage	mg.100gF W	kg/cm²	dry fruit%	cm	gr	
1406.7a	1.68a	72.22a	17.87a	40.81 a	6.84c	5.16c	7.02a	67.77a	full irrigation
1423.3a	1.63a	64.78b	13.9b	32.48 b	8.57b	9.11a	6.57b	62.58b	low irrigation 75% water requeirement
934.4b	1.52a	60.44c	15.98ab	32.11 b	9.85a	6.72b	4.22c	49.76c	low irrigation 50% water requeirement

fertilizer use efficiencyg/unit of added nutrients			water use	crop yield	%nitrate removed of	Root dry matter	Plant dry	irrigation treatments
p	k	NO3	efficiency-(g/lit)	kg/plant	combined layer with hydrogel	percentage	weight -gr	
337.22b	809.33b	404.67b	67.44b	5.5a	41.79a	34.64c	244.86 a	full irrigation
372.77a	894.66a	447.33a	74.55a	5.28a	31.66b	36.97b	196.81 b	low irrigation 75% water requeirement
306.6c	736c	368c	61.33c	3.84c	24.30c	41.73a	149.17 c	low irrigation 50% water requeirement

Among the Hydrogel treatments, the one with 25gram super absorbent per plant had the most yield, water and fertilizer use efficiency, vitamin C, fresh and dry matter of the plant and number, weight and diameter of the fruit (table4). The most stiffness was for the none-Hydrogel treatment and no other significance difference was observed among other treatments.

Table 4. Comparing effects of different levels of Hydrogel on measured characteristics, water and fertilizer use efficiency.

Plant fresh	stem diameter	stem lenght	Plant dry matter	Vit C	fruit stiffness	percentage of dry fruit	fruit diameter	fruit weight	hydrogel levels
weight -gr	cm	cm	percentage	mg.100gFW	kg/cm²	%	Cm	gr	
1535.6a	1.65a	72.33a	15.53a	37.7a	8.939a	6.84c	7.0644a	63.85a	25ghyrdogel per plant
1231.1b	1.66a	64.88b	15.75a	34.75b	8.23b	7.16a	5.945b	63.126a	12.5ghyrdogel per plant
997.8b	1.51a	60.22c	16.46a	32.95c	8.098a	7.01b	4.81c	53.15b	without hydrogel

fertilizer use efficiencyg/unit of added nutrients			water use	crop yield	%nitrate removed of	Root dry matter	Plant dry	hydrogel levels
P	K	NO3	efficiency-(g/lit)	kg/plant	combined layer with hydrogel	percentage	weight-gr	
993.33a	413.889a	496.66a	82.77a	5.9a	20c	36.83b	237.73a	25ghyrdogel per plant
802.66b	334.44b	401.33b	66.88b	4.597b	29.86b	37.3b	193.94b	12.5ghyrdogel per plant
644c	268.33c	322c	53.66c	4.13c	47.89a	39.22a	159.18b	without hydrogel

4. Conclusion

Adding Hydrogel to soil can improve the soil capability to retain moisture, so as a result the plant can use more water during its growth. In this research the effects of Hydrogel on yield and growth parameters was studied. The soil's cation exchange is increased because nutrients are absorbed by polymers. These nutrients will be available to the plant during its growth and in time will increase the vegetative growth. If the irrigation is lowered, then the photosynthesis will decrease and these eventually will lead to drying and death of the plant. Deficit irrigation led to a decreased yield but the plant did not reach the permanent wilting point. According to the results from this research and the duration that polymer stays in soil, it can be concluded that using adequate amount of super absorbent polymer still increase the yield in both deficit and full irrigation conditions. This conclusion is consistent with the one which Syvertsenet all made. That was; soil with added hydrogel increases yield per used water and this, improve water and nutrients use efficiency by plant (Syvertsenet all 2004).

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