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Influence of hydrophilic polymer on different crop growth parameters and yield in tomato

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A field experiment was conducted during *Rabi* 2008-09 at Main Research Station College of Agriculture, University of Agricultural Sciences, Dharwad to study the Impact of hydrophilic polymer on irrigation requirement and biophysical parameters in tomato. The treatments consisted of different concentrations of hydrophilic (0.50 to1.75 g/plant) and another was control. These treatments were imposed at the time of transplanting of seedlings. The results of the investigation revealed that among the treatments the application of liquasorb (1.75 g/plant) into the soil increased different crop growth parameters such as total dry matter(TDM) production (147.3 g /plant), leaf area(LA) /plant (78.23 dm^2 $plant^{-1}$), leaf area index (LAI)(1.419), absolute growth rate (AGR)(1.84 g $plant^{-1}$ day^{-1}), crop growth rate (CGR) (3.22 g m^{-2} day^{-1}), relative growth rate (RGR), (6.30 g g^{-1} day^{-1} x 10^{-3}) net assimilation rate (NAR) 0.0552 g $m-^{2}$ $day-^{1}$, leaf area duration (LAD) 26.97 days, biomass duration (BMD) 2579 g $days^{-1}$, and yield (36.6 t/ha) as compared to all other treatments. While lowest value of these parameters observed in control (without hydrophilic polymer). The results of this study have shown that the crop yield could be improved by adding hydrophilic polymer to the soil as the polymer in soil can store extra water and enable to the plants to utilize that water over an extended period of time.

Key words : Hydrophilic polymer, Total dry matter, Leaf area, Relative growth rate, Net assimilation rate, Biomass duration and leaf area duration

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INTRODUCTION

Tomato [*Lycopersicon esculentum* (L.) Mill.] is one of the most important vegetable crops grown widely all over the world. It is a self-pollinated crop and is a member of Solanaceous family with 2n = 24 chromosomes. Peru Equador region is considered to be the center of origin (Rick, 1969).Tomato is one of the most popular and widely growing vegetables around the world either outdoors or indoors. Among the main fruits and vegetables, tomato ranks 16th as source of vitamins. Tomatoes are important source of lycopene, minerals, vitamin-A, B and also excellent source of vitamin-C. Ripe tomato fruit is consumed fresh as salad and utilized in the preparation of range of processed products such as powder, ketchup, soup, canned fruit. It is also rich in medicinal value. The pulp and juice are digestible and blood purifier. It is reported to have antiseptic properties against intestinal infections. Indian contribution to the world's production was 10.26 million tones of annual production with an area of 5.72 lakh ha. In Karnataka, tomato occupies an area of 0.47 Lakh ha with the annual production of 12.85 Lakh tones (Anonymous, 2008).

An effective and planned utilization of available water or rainfall has therefore, become of one most essential factors, in Indian agriculture specific to vegetables such as tomato. Nowadays hydrophilic polymer have been tried to improve growth and ultimately yield. The use of hydrophilic polymers, particular under green house condition has shown that they have great potential to hold water and release slowly for crop growth and development of polymeric soil conditioners were known since the 1950s (Hedrick and Mowry, 1952). However, their wide commercial application failed even though the scientific basis for their use was quite well established. These polymers were developed to improve the physical properties of soil in view of increasing their water-holding capacity, increasing water use efficiency, enhancing soil permeability and infiltration rates, reducing irrigation frequency, reducing compaction tendency, stopping erosion and water run-off, increasing plant performance (especially in structure less soils in areas subject to drought). When these hydrophilic polymers (hydro gel) used in correctly and in ideal situations will have at least 95% of their stored water available for plant absorption (Johnson and Veltkamp, 1985). These substances can hold 400-1500 g of water per dry gram of hydro gel and degradation in soil was found to be approximately 10% per year (Tolstikh *et al.,* 1992).

Research Methodology

The experiment was carried out in E-block; plot No.125 belonging to Department of Crop Physiology, Main Research Station College of Agriculture, University of Agricultural Sciences, Dharwad. Tomato seedlings of variety Shakatiman were obtained from KLE nursery Pvt. Ltd., Belgaum and transplanted on 31th October, 2008. The experiment was laid out in Randomized Block Design with three replications. The treatments involving different concentrations of hydrophilic polymer (Luquasorb) were imposed in soil at the time of transplanting of tomato. The details of all the treatments are furnished below: T_1 = Soil application of hydrophilic polymer @ 0.50 g/plant, T_2 = Soil application of hydrophilic polymer @ 0.75 g/plant, T_3 = Soil application of hydrophilic polymer @ 1.00 g/plant, T_4 = Soil application of hydrophilic polymer @ 1.25 g/plant, T_5 = Soil application of hydrophilic polymer @ 1.50 g/plant, T_6 = Soil application of hydrophilic polymer @ 1.75 g/plant and T_7 = Control.

For analyzing the growth patterns of the crop, five plants were selected randomly from each plot and were tagged for recording observations for total dry matter production, leaf area, leaf are index, crop growth rate ,absolute growth rate, net assimilation rate, relative growth rate, leaf area duration and biomass duration.

Total dry matter production per plant (g):

Three plants from each treatment were selected randomly, separated into leaf and stem, and then they were chopped into small pieces to enable drying and were oven dried at 80^0C to a constant weight. The oven dry weight of stem along with leaf was used to work out dry matter production (g) per plant.

Leaf area ($dm^2 plant^{-1}$):

The leaves from three selected plants from each treatment were used for the estimation of leaf area. Leaf area was computed by using disc method and expressed as cm^2 $plant^{-1}$ at 20, 40, 60, 80 DAT and at harvest. The procedure of Stickler *et al.*, (1971) was adopted.

Leaf area index:

The leaf area index was calculated at 20, 40, 60, 80 DAT and at harvest by dividing the leaf area per plant by the land area occupied by the plant (Sestak *et al.*, 1971)

$$LAI = \frac{\text{Leaf area } (dm^2)}{\text{Land area } (dm^2)}$$

Crop growth rate (CGR, g m^{-2} day^{-1}):

Crop growth rate is the dry matter produced per unit ground area per unit time (Watson, 1956). It was calculated by using the following formula and expressed as g m^{-2} day^{-1}

$$CGR = \frac{(W_2 - W_1)}{(t_2 - t_1)} x \frac{1}{A}$$

where,

W_1 = dry weight of the plant (g) at time t_1

W_2 = dry weight of the plant (g) at time t_2

t_1 and t_2 = time intervals (days)

A = unit land area (cm²)

Absolute growth rate (AGR, g $plant^{-1}$ day^{-1}):

It is the dry matter produced per unit time (g day^{-1}) and was calculated by using the following formula of (Radford, 1967) as follows:

$$AGR = \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

where,

W_1 = Dry weight of the plant (g) at time t_1

W_2 = Dry weight of the plant (g) at time t_2

t_1 and t_2 = Time intervals (days)

Net assimilation rate (NAR, g m^{-2} day^{-1}):

It is the rate of dry weight increases per unit leaf area per unit time (Radford, 1967). It is expressed as g cm^{-2} per day and calculated as follows:

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} x \frac{(\log e A_2 - \log e A_1)}{(A_2 - A_1)}$$

where,

A_1 and W_1 = leaf area (cm^2) and dry weight of the plant (g), respectively at time t_1

A_2 and W_2 = leaf area (cm^2) and dry weight of the plant (g), respectively at time t_2

t_1 and t_2 = time interval in days

Relative growth rate (RGR, g g^{-1} $plant^{-1}$):

It is the rate of increase in the dry weight per unit dry weight already present and expressed as gg^{-1} day^{-1} (Radford, 1967). It was calculated by using the following formula:

$$RGR = \frac{(\log_e W_2 - \log_e W_1)}{(t_2 - t_1)}$$

where,

W_1 = Dry weight of the plant at time t_1

W_2 = Dry weight of the plant at time t_2

t_1 and t_2 = Time interval in days

Leaf area duration (days):

Leaf area duration (LAD) is the relation of potential green leaf area for a particular period and was worked out by the formula as suggested by Power *et al*. (1967).

$$LAD\ (days) = \frac{L_1 + L_2}{2} \times (t_2 - t_1)$$

where,

L_1 = LAI at time t_1

L_2 = LAI at time t_2

Biomass duration (g days)

The biomass duration (BMD) was calculated by using the following formula of Se stak *et al*. (1971).

$$BMD\ (g\ days) = \frac{TDM_1 + TDM_2}{2} \times (t_2 - t_1)$$

where,

TDM_1 = total dry matter (g) at t_1

TDM_2 = total dry matter (g) at t_2

RESULTS AND ANALYSIS

The results of the present study as well as relevant discussion have been discussed under following heads:

Total dry matter production (g/plant):

The data on total dry matter production presented in Table 1 indicated significant differences between the treatments at all stages except at 20 DAT. The total dry matter content increased continuously from 20 DAT to harvest. At 40, 60, 80 DAT, T_6 recorded maximum dry matter (44.30, 75.10, 110.7 g per plant, respectively) and differed significantly with other treatments. Lomont and Connel (1984) also reported the beneficial effect of three commercial Hydrogel (super absorbent-hydrophilic polymer) on the final shoot dry weight or shelf-life of petunias or marigolds in several potting media.

Leaf area (dm^2 $plant^{-1}$) and Leaf area index (LAI):

Leaf area and leaf area index increased continuously from 20 to 80 DAT and then declined at harvest (Table2).The maximum leaf area and leaf area index at 80 DAT and at harvest with T_6 recording significantly higher leaf area (78.23, 70.43 dm^2 $plant^{-1}$, 0.754, 1.278, respectively) over all other treatments and differed significantly from rest of treatments.

Absolute growth rate (AGR, g $plant^{-1}$ day^{-1}) and Crop growth rate (CGR, g m^{-2} day^{-1}):

The data pertaining to effect of hydrophilic polymer on AGR and CGR presented in (Table 3) indicated significant differences between the treatments and it increased from 20 - 40 DAT to harvest. At 40 - 60 DAT, it was found to be higher in T_6 (1.54g $plant^{-1}day^{-1}$, 2.80 g m^{-2} day^{-1}), respectively and differed significantly with rest of treatments. A similar trend was noticed at 60 - 80 DAT and harvest.

Relative growth rate (RGR, g g^{-1} day^{-1} x 10^{-3}) and Net assimilation rate (NAR, g m^{-2} day^{-1}):

The data on RGR and NAR (Table 4) indicated that RGR increased from 20 - 40 to 40 - 60 DAT then declined thereafter and at 40 - 60 DAT, T_6 recorded significantly higher RGR (11.93 g g^{-1} day^{-1} x 10^{-3}) followed by T_5 (11.90 g g^{-1} day^{-1} x 10^{-3}). While NAR increased continuously from 20 to 60 DAT in all the treatments and there was a marginal decrease in NAR from 60 DAT onwards.

Leaf area duration (LAD, days):

Leaf area duration (LAD) and biomass duration (BMD) as influenced by hydrophilic polymer (liquasorb) indicated significant difference between the treatments at all stages (Table 5). In general, LAD values increased from 20 to 80 DAT and then declined at harvest. At 20 - 40 DAT control recorded significantly lower LAD (2.58 days) as compared to other treatments,. At 40 - 60 DAT, T_6 recorded significantly higher LAD (9.76 days), while

Table 1: Influence of hydrophilic polymer (Luquasorb) on total dry matter production (g/plant) at different stages in tomato

Treatments	Days after transplanting				At harvest
	20	40	60	80	
T_1 (HP@ 0.50 g/plant)	25.30	41.23	69.83	103.23	137.43
T_2 (HP@ 0.75 g/plant)	25.47	41.73	70.07	103.80	138.60
T_3 (HP@ 1.00 g/plant)	25.60	41.80	71.20	105.57	140.67
T_4 (HP@ 1.25 g/plant)	25.90	42.23	72.23	107.17	142.90
T_5 (HP @ 1.50 g/plant)	26.37	430.3	73.57	108.57	144.83
T_6 (HP@ 1.75 g/plant)	27.43	44.30	75.10	110.70	147.37
T_7 (Control)	25.10	39.97	67.90	100.7	134.63
Mean	25.74	42.04	71.43	105.61	140.92
S.E. (±)	0.81	0.31	0.32	0.28	0.36
C.D. (P=0.05)	NS	0.93	0.97	0.86	1.08

NS = Non significant

Table 2: Influence of hydrophilic polymer (Luquasorb) on leaf area (dm²/plant) and leaf area index at different stages in tomato

Treatments	20 DAT		40DAT		60DAT		80DAT		At harvest	
	LA	LAI	LA	LAI	LA	LAI	LA	LAI	LA	LAI
T_1 (HP@ 0.50 g/plant)	5.01	0.091	10.20	0.185	32.63	0.592	69.33	1.258	61.53	1.116
T_2 (HP@ 0.75 g/plant)	5.43	0.098	10.50	0.190	34.43	0.625	71.13	1.291	63.33	1.149
T_3 (HP@ 1.00 g/plant)	5.94	0.106	11.27	0.204	36.20	0.657	72.90	1.323	65.10	1.181
T_4 (HP@ 1.25 g/plant)	6.31	0.114	11.70	0.212	37.40	0.679	74.10	1.344	66.30	1.203
T_5 (HP @ 1.50 g/plant)	7.25	0.131	12.27	0.223	39.20	0.711	75.90	1.377	68.10	1.235
T_6 (HP@ 1.75 g/plant)	7.90	0.143	12.87	0.233	41.53	0.754	78.23	1.419	70.43	1.278
T_7 (Control)	4.62	0.083	9.63	0.175	31.30	0.568	68.00	1.324	60.50	1.092
Mean	6.03	0.109	11.20	0.203	36.10	0.655	72.80	1.321	65.04	1.179
S.E. (±)	0.98	0.013	0.11	0.002	0.18	0.004	0.19	0.003	0.24	0.003
C.D. (P=0.05)	NS	NS	0.34	0.006	0.56	0.011	0.59	0.009	0.72	0.010

NS =Non significant
DAT = Days after transplanting

Table 3: Influence of hydrophilic polymer (Luquasorb) on absolute growth rate (g/day) and crop growth rate (g /m² /day) at different stages in tomato

Treatments	20-40 DAT		40-60 DAT		60-80 DAT		80 DAT-harvest	
	AGR	CGR	AGR	CGR	AGR	CGR	AGR	CGR
T_1 (HP@ 0.50 g/plant)	0.80	1.45	1.43	2.60	1.67	3.04	1.71	3.11
T_2 (HP@ 0.75 g/plant)	0.81	1.48	1.44	2.62	1.68	3.05	1.74	3.16
T_3 (HP@ 1.00 g/plant)	0.81	1.47	1.47	2.67	1.70	3.10	1.77	3.22
T_4 (HP @ 1.25 g/plant)	0.82	1.48	1.51	2.74	1.74	3.16	1.79	3.25
T_5 (HP @ 1.50 g/plant)	0.83	1.52	1.53	2.78	1.75	3.18	1.81	3.30
T_6 (HP @ 1.75 g/plant)	0.84	1.53	1.54	2.80	1.77	3.22	1.84	3.35
T_7 (Control)	0.79	1.44	1.40	2.54	1.64	2.98	1.70	3.08
Mean	0.82	1.48	1.47	2.68	1.71	3.10	1.77	3.21
S.E. (±)	0.02	0.03	0.01	0.019	0.03	0.011	0.04	0.013
C.D. (P=0.05)	NS	0.10	0.03	0.057	0.08	0.032	0.11	0.040

DAT = Days after transplanting
NS =Non significant

T_1 and T_2 were at par with each other. A similar trend was observed at 60 - 80 DAT with T_6 recorded higher LAD (26.97 days), but it was at par with T_5.

Biomass duration (BMD) (g days^{-1}):

The data on biomass duration (BMD) presented in (Table 5) indicated significant differences between the treatments at all the stages. The BMD values increased

Table 4: Influence of hydrophilic polymer (Luquasorb) on relative growth rate (g/g/dayx10$^{?3}$) and net assimilation rate (g m^{-2} day^{-1}) at different stages in tomato

Treatments	20-40 DAT		40-60 DAT		60-80 DAT		80 DAT-harvest	
	RGR	NAR	RGR	NAR	RGR	NAR	RGR	NAR
T_1 (HP@ 0.50 g/plant)	10.61	0.0391	11.63	0.0286	8.44	0.0137	6.21	0.0109
T_2 (HP@ 0.75 g/plant)	10.62	0.0414	11.67	0.0296	8.45	0.0141	6.24	0.0111
T_3 (HP@ 1.00 g/plant)	10.64	0.0436	11.78	0.0299	8.49	0.0141	6.25	0.0112
T_4 (HP @ 1.25 g/plant)	10.65	0.0461	11.89	0.0311	8.49	0.0144	6.26	0.0113
T_5 (HP @ 1.50 g/plant)	10.73	0.0474	11.90	0.0322	8.53	0.0149	6.26	0.0114
T_6 (HP @ 1.75 g/plant)	11.04	0.0552	11.93	0.0330	8.56	0.0151	6.30	0.0115
T_7 (Control)	10.41	0.0375	11.42	0.0273	8.40	0.0133	5.23	0.0108
Mean	10.67	0.0443	11.53	0.0302	8.48	0.0142	5.82	0.0111
S.E. (±)	0.37	0.0002	0.18	0.0002	0.05	0.0001	0.14	0.0001
C.D. (P=0.05)	NS	0.0007	0.53	0.0007	0.15	0.0003	NS	0.0004

Table 5: Influence of hydrophilic polymer (Luquasorb) on leaf area duration (days) and biomass duration (g /days) at different stages in tomato

Treatments	20-40 DAT		40-60 DAT		60-80 DAT		80 DAT-harvest	
	LAD	BMD	LAD	BMD	LAD	BMD	LAD	BMD
T_1 (HP@ 0.50 g/plant)	2.76	665	8.10	1111	23.74	1731	17.08	2407
T_2 (HP@ 0.75 g/plant)	2.88	672	8.47	1123	24.40	1747	17.74	2431
T_3 (HP@ 1.00 g/plant)	3.11	674	8.83	1130	25.04	1765	18.38	2459
T_4 (HP @ 1.25 g/plant)	3.27	681	9.23	1146	25.47	1795	18.81	2501
T_5 (HP @ 1.50 g/plant)	3.53	694	9.76	1166	26.12	1821	19.74	2534
T_6 (HP @ 1.75 g/plant)	3.77	717	8.01	1194	26.97	1857	20.31	2579
T_7 (Control)	2.58	641	7.43	1079	23.26	1686	16.60	2353
Mean	3.13	678	8.55	1136	25.00	1772	18.34	2466
S.E. (±)	0.133	7.78	0.039	5.36	0.071	4.85	0.070	5.51
C.D. (P=0.05)	0.400	23.97	0.117	16.54	0.213	14.95	0.210	16.53

DAT = Days after transplanting

from 20 DAT to harvest. At 20 - 40 DAT, significant differences were obtained between the treatments with T_6 (717gdays^{-1}) recording higher BMD. A similar trend was also observed at 40 - 60 DAT and 60-80 DAT with T_6 (1194 and 1857 g days^{-1} , respectively) recorded significantly higher BMD.

Total dry matter (TDM) is the integral of crop growth rate over the entire growing period and is related to yield, harvest index, assimilatory surface area (leaf area) and other growth attributes (Yoshida, 1972). In the present study, the total dry matter (TDM) increased from 20 DAT to harvest, due to soil application of hydrophilic polymer (HP) at all the stages. This increase in TDM might be attributed to an increase in leaf area, LAI, LAD, accumulation of carbohydrates, proteins, total amino acids and other biochemical and physiological parameters especially in presence of hydrogel polymer (El-Sayed *et al.*, 1995). Similarly, a significant increase in TDM due to hydrogel polymer was also reported by Silberbush *et al.* (1993) in corn, Volkamar and Chang (1995) in canola, Akhter *et al.* (2004) in barley and wheat and Yazdani *et al.* (2007) in soybean.

Assimilatory surface area (leaf area) indicates a good idea of the photosynthetic capacity of the plant and decreased leaf area is an early response to water deficit. The results of the present investigation showed that with an increase in hydrophilic polymer (HP) concentration there was a significant increase in leaf area, leaf area index (LAI) and leaf area duration (LAD) at all stages. Hydrophilic polymer (HP) increases the turgor pressure inside the cells by providing or maintaining sufficient amount of water as per requirement of plant and thus causing increase in leaf area and other related growth parameters (Al-Harbi *et al.*, 1999 and Yazdani *et al.*, 2007).

Leaf area duration (LAD) is a useful concept not only depicting the efficiency of photosysnthetic system, but also showing a linear relationship with dry matter accumulation (Chetti and Sirohi, 1995). In the present study, it was noticed that LAD was significantly higher in hydrophilic polymer treated plots. The use of HP was found to be more effective in increasing LAD particularly at later stages, which subsequently resulted in higher yield. Similar results were also obtained by Ouchi *et al*. (1990.)

Absolute growth rate (AGR) refers to dry weight increase per unit time. In the present study AGR increased from 20 DAT to at harvest and polymer treatments recorded higher AGR values at all the stages which clearly indicate that the efficiency of plant in terms of dry matter production enhanced with the application of hydrophilic polymers.Crop growth rate (CGR) is influenced by LAI, photosynthetic rate and leaf angle. Net assimilation rate (NAR) increased as growth advanced and later on decreased due to leaf shading and senescence. A significant increase in CGR was observed in the treatments. These results are in accordance with Yazdani *et al*. (2007) in soybean.

Biomass duration (BMD) indicates the maintenance of dry matter over a period of time and is essential for prolonged supply of photosynthates to the developing sinks. Significantly higher BMD values were recorded in polymer treated plots at all the stages. This suggests that hydrophilic polymer (HP) resulted in increased TDM, LAI, LAD, AGR, CGR, and NAR and finally resulted in increased BMD. Similar results were also reported by Al-Harbi *et al*. (1999) in tomato.

Conclusion:

Since irrigation water is a limiting factor in the country; it is important to improve the water use efficiency of the plants. The use of water retaining polymers has potential for horticultural and other crops. The results of this study have shown that the crop growth parameters increased and these having positive correlation with yield that's why yield could be improved by adding hydrophilic polymer to the soil as the polymer in soil can store extra water and enable to the plants to utilize that water over an extended period of time.

LITERATURE CITED

Akhter, J., Mahmood, K., Malik, K. A., Mardan, A., Ahmad, M. and Iqbal, M. M. (2004). Effects of hydrogel amendment on water storage of sandy loam and loam soils and seedling growth of barley, wheat and chickpea. *Plant Soil Environment*, **50**(10): 463-469.

Al-Harbi, A. R., Al- Omran, A. A. Shalaby and Choudhary, M. I. (1999). Effeficacy of a hydrophilic polymer declines with time in greenhouse experiments.*Hort. Sci*., **34**:223-224.

Anonymous (2008). www.indiastat.com (National Horticulture Board)

Chetti, M.B. and Sirohi, G.S. (1995). Effect of water stress on leaf charaterictcs and recovery in mungbean (*vigna radiata l.wilezek*) cultivars. *J. Maharasthra Univ.*, **20**:85-87.

El-Sayed, H., Kirkwood, R.C. and Graham, H.R. (1995). Studies on the effects of salinity and hydro gel polymer treatments on the growth, yield production, solute accumulation in cotton and maize. *J. King Saudi Univ. Agric. Sci.,* **7**(2): 209-227.

Hedrick, R.M. and Mowry, D.T. (1952). Effect of synthetic polelectrolyte on aggration ,aeration and water relationship of soil. *Soil Sci.,* **73**:427-441.

Johnsen, M.S. and Veltkamp, C.J. (1985). Structure and functioning of water storage agriculture polyacryamides. *J. Sci. Food & Agric.,* **36**: 789-799.

Lomont, G.P. and Connell, M.A. (1984). Can water absorption gels improving shelf life of polt plants. *Australia Hort*., **9:**9-12.

Ouchi, S.A., Nishikawa and Kamada, E. (1990). Soil improving effects of a super- water absorbent polymer(part-2). Evaporation, leaching of salts and growth of vegetables. *J. Soil Sci. Plant Nut.,* **61**:606-613.

Power, J.F., Willis, W.O., Gunes, D.L. and Peichman, G.A. (1967). Effect of soil temperature, phosphorus and plant age on growth analysis of barley. *Agronomy J.,* **59**: 231-234.

Radford, P. J. (1967). Growth analysis formulae – their use and abuse,*Crop Science,***7**:171-175.

Rick, C. M. (1969). Origin of cultivated tomato, current status of the problems. Abstract XI *International Botanical Congress*, pp. 180.

Stickler, F.C., Wearden, S. and Pauli, A.W. (1961). Leaf area determination in grain sorghum. *Agron. J.,* **53:**187-188.

Sendur Kumaran, S., Natrajan, S., Muthvel, I. and Sathiayamurthy,b V. A. (2001). Standardization of hydrophilic polymers on growth and yield of tomato. *J. Madras Agric*., **88**(1-3): 103-105.

Sestak, Z., Catsky, J. and Jarvis, P.G. (1971). Plant photosynthetic production, *Manual of Methods,* Ed. Junk, W.N.V. Publications, The Hungus, pp. 343-381.

Silberbush, M., Adar, E. and De-Malach, Y. (1993). Use of hydrophilic polymer to improve water storage and availability to crops grown in sand dunes II. Tomato irrigated sprinkling with different water salinities. *Agricultural Water Management*, **23**: 303-313.

Tolstikh, L. I., Akimov, N.I , Golubeva, I.A. and Shvetsov, I.A. (1992). Degradation and stabilization of polyacrylamidein polymer flooding conditions. *Internat. J. Polymer Matter,* **17**:177-193.

Volkamar, K.M. and Chang, C. (1995). Influence of hydrophilic gel polymers on water relations, growth and yield of barley and canola. *Canadian J. Plant Sci.,* **75**: 605-611.

Watson, D.J. (1956). *Leaf growth in relation to crop yield.* Ed. F.L. Milthorpe, Butterworths Scientific Publications London pp. 178-191.

Yazdani, F., Allahadadi, I. and Akbari, G. A. (2007). Impact of hydrophilic polymer on yield and growth analysis of soybean (*Glycine max* L.) under drought stress condition. *Pakistan J. Biol. Sci.,* **10**(23): 4190-4196.

Yoshida, S. (1972). Physiological aspects of grain yield. *Ann. Rev. Plant Physiol*., **23**:437-464.

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