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Effect of Polymer on Seedling Survival and Growth of Transplanted Tomato Under Water-Stress

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In this study, effect of water-retentive copolymer, poly(N-vinyl-2-pyrrolidone-crotonic acid) on seedling survival and growth of transplanted tomato has been investigated. 600 Tomato (*Lycopersicon esculaentum* Mill., cv. 191) seeds were germinated in laboratory and 400 seedlings were used for experiment. Seedlings were transplanted to: (1) soil (2) soil with polymer (3) sand and (4) sand with polymer. This copolymer can retain at least 155 times its weight of water and slowly releases it in 6 d. Hydrogel using significantly effected seedlings survival and growth rate of plants after transplantation. On average, 46, 77, 14 and 38 % of transplanted seedlings survived respectively in soil, soil with hydrogel, sand and sand with hydrogel. Growth rate has been significantly affected by hydrogel using in all growth mediums. The polymer is useful especially in sand medium under water stress and effected seedlings survival more than two-folds.

Key Words: Polymer, Seedling survive, Plant growth, Tomato.

INTRODUCTION

Polymers are huge molecules consisting of discrete units linked together to form long chains. Three classis of polymers commonly used today can be generally classified as natural polymers, semi-synthetic, or synthetic polymers[1,2]. The distinguishing features of a polymer are determined by the chemical properties of the monomeric units. The use of synthetic hydrophilic polymers in agriculture and afforestation has attracted considerable interest to investigate these products all around the world. In the early 1980's water-absorbing polymers or hydrogels were introduced for agricultural use[3]. Hydrophilic polymers work by absorbing and storing water and nutrients in a gel form and these are used specially in horticulture. These hydrogels have been used for many years and hundreds of types of hydrogels exist[4,5]. These hydrophilic polymers vary in effectiveness depending on the situation they are used in and their chemical makeup.

The need for improving the physical properties of soils to increase productivity in the agricultural sector led to development of water-soluble polymeric soil conditioners. Many synthetic polymers are water super absorbers with the capability of absorbing 400 to 1500 g water per dry gram of polymer[6,7] and some of them become gels in contact with water. When mixed with the soil, they form amorphous gelatinous mass on hydration and are capable of cyclical absorption and desorption over long periods of time, hence acting as slow-release source of water in the soil[8]. Hydrogels were developed to improve the physical properties of soil in view of increasing water-holding capacity, increasing water use efficiency, enhancing soil permeability and aeration, reducing irrigation frequency, stopping erosion, increasing plant performance and plant growth[3]. The usual goal of adding hydrogels to the soil matrix is to add water-holding capacity (especially in sandy soils) and when they used correctly and in ideal situations will have at least 95 % of their stored water available for plant absorption, improve the physical properties of soil and can reduce nutrients losses from soils[9,10]. Hydrogels can absorb hundreds or thousand of times their weight in water and increase retention of large quantities of water in soil that becomes available for plants. Thus, plant growth rates could be increased[11]. Root water uptake is driven by the difference between the potential of the soil water and the root water.

Kinnersley *et al.*[12] suggested that dry weight of duckweed (*Lemna minor* L.) and corn (*Zea mays* L.) was more than doubled when plants were grown in media containing polymers.

Hydrophilic polymers can, in some situations, be used as fertilizer release agents in the soil matrix[1]. They have the ability to enhance plant growth when nutrients are incorporated into the hydrogel matrix and then released to the plant as needed. The addition of phosphorus to the hydrogel caused an increase in seedlings growth of Chili peppers[13]. Lentz and Sojka[14] found that the addition of polymers into the irrigation water significantly reduced the runoff of phosphorus in sediment by 84 % and nitrogen by 83 % in soils. Previously study[15] showed that the combination of the polymer and controlled-released fertilizers (N, P, K) notably increased tomato yield from17.5 to 27.9 %. El Sayed *et al.*[16] suggested that polymer incorporation encouraged growth of tomato under saline conditions. Previous studies[17-19] in tomato, seedling survival, dry weight were unaffected by hydrogel incorporation in the soil.

It can be concluded that the effects of hydrophilic polymers are probably depend on application rates, plants species, soil conditions, irrigation or rainfed conditions. The objective of this study was to investigate the effect of polymer on survival and growth of tomato seedlings after transplantation under water stress.

EXPERIMENTAL

600 Tomato (*Lycopersicon esculaentum* Mill., cv. 191) seeds were used for germination. Before sowing, seeds were soaked for 0.5 h in water kept at 40°C followed by 15 min in a 10 % solution of sodium phosphate to eliminate microorganisms. Seeds were germinated in darkness at 28°C and 400 seedlings (average 5 cm) were selected for transplanting. The objective of the selection process was to reduce variability in subsequent growth of the plants caused by differences in the germination rate. Selected plants were transplanted to plastic pots. The seedlings themselves were watered before transplantation in order to minimize transplantation shock.

The pots (250 cm^3) were filled with soil or sand and only one seedling was transplanted to each pots. The experiment consisted of 4 treatments, *i.e.* soil for control, soil with polymer, sand for control and sand with polymer.

The pots were placed in plant growth chamber with 14:10 h light-dark photoperiod at 25ºC and 60 W/m^2 light flux. Plant height was measured from the surface of soil to the apical meristem, using an ordinary vertical ruler. Measurements were made on days 7, 14, 21 and 28 from transplantation. Seedling survival is defined as the number of seedling, which were alive at 7, 14, 21 and 28 d after transplantation.

Poly(N-vinyl-2-pyrrolidone-crotonic acid) copolymer (PCrA 0.18 Gel) was synthesized by reported method[20]. The P (VP/CrA) hydrogels Rectangular bar films (1.5 × 2 × 15 mm) were prepared and dried under a vacuum at 333 K for 48 h for the testing of its water holding capacity. This hydrogels can retain at least 155 times its weight of water and slowly release it in 6 d. These hydrogels can be used many times. Hydrogels were placed in pots so as to allow maximum contact with the roots of the seedlings. The pots were watered profusely after transplantation to allow the hydrogels to absorb water. For the water stress, seedlings were irrigated only one time in week.

The results of the all measurements were analyzed statistically and the effects of the hydrogel on seedling survival and growth of transplanted tomato under water stress.

RESULTS AND DISCUSSION

In first week, 48 % of the transplanted seedlings survived in soil and 45 % of these seedlings continued their liveliness until the end of the experiment (Table-1). There were only small differences between the weeks. 78 % Seedlings survived in soil with polymer and these rates *ca.* (77 %) continued in the other weeks (Table-1). There are considerable differences between control (soil) and polymer application (soil + polymer). More seedlings survived when hydrogel was used.

Only 15 % seedlings survived in sand and on average 38 % seedlings survived when hydrogel was used (Table-1). This results show that polymers affect the seedling survival rate under water stress. Especially in sand, hydrogels enhanced seedling survival rate more than 100 % (Table-1). In previous reports[21,22], hydrogels have been used to increase seedlings and transplants survival in the arid regions. The present results support these studies. The role of hydrogels in decreasing water stress and increasing plants growth or seedling survival has not been clearly demonstrated. Good results were obtained with Easter lily and chrysanthemum[19] and maize[23]. Similarly, increases in seedling survival were reported with maize and soybean[24] and cucumber[25]. However, the effects of hydrogels on seedling survival have been inconsistent. Many studies with different plants showed that the effects of hydrogels are dependent on crops species and on growing media[26-28].

TABLE-1
PER CENT SEEDLING SURVIVAL*

Medium	Times after transplantation (d)			
	7	14	21	28
Soil	48a	45a	45a	45a
Soil + polymer	78b	77b	77b	77b
Sand	15c	14c	14c	14c
Sand + polymer	39a	38a	38a	38a

*values with similar superscripts within a column are not significantly different at p = 0.05.

In tomato, seedling survival, growth and dry weight were unaffected by hydrogel incorporation in the soil[17-19]. But, Wallace and Wallace[29] obtained high tomato yields with hydrogels and Rughoo *et al.*[30,31] reported that hydrogels had no effect on seedling survival under irrigation but under rainfed conditions or water stress, more seedlings survived when hydrogels were used.

The present results showed that seedling survival was affected by hydrogel in both growing media under water stress. Hydrogels effected seedling survival more than 170 % in sand and 71 % in soil. The conservation of water by hydrogels increased seedling survival in both growing mediums.

Transplants are used in vegetable production for two main reasons. Earlier production from a plant that is partially grown can result in higher prices for early vegetables and establishing market contacts sooner. But the ability of the transplants to survive is the main problem in arid regions. Tomato is very important food resource for all people and is efficient in water absorption and rapid formation of new roots under irrigation. But, under water stress, seedling survival is main problem and this hydrogel can solves this problem. This polymer can preserve its own shape and can be used for many times.

The results indicate significant differences between soil and sand media, but there is a general trend of increasing with polymer in soil and in sand. It is concluded that hydrogel helps maintain consistent moisture in the root zone, thus reducing hydric stress. When the sand was used alone, only 14 % seedlings survived, but with polymer 38 % seedlings survived. The polymer can increases survival by up to 170 %. Similar results have been found for soil (71 %). Such an increasing rate of seedling survival with polymer has not been shown in the literature, this may be due to characteristics of polymer that release water about in 6 d and reduces water stress. Rughoo *et al.*[30] suggested that under irrigation, the hydrogels had no effect on seedling survival or yield of tomato, but under rainfed conditions, significantly more seedlings survived in plots where the hydrogels were used. Similarly, the other researchers suggested that plants grown in hydrogels needed irrigation less frequently[32], roots actually penetrated the hydrogels aggregate to get to the available water[33]. Previous studies and the present results indicate that the effects of polymers are related with water stress.

Growth rate of plants

The average height of plants grown in soil and sand mediums is shown in Table-2 and Fig. 1. The results indicated a significance difference between growth mediums and used polymer. Apparent correlation was found between the use of polymer and height of plant growth in both growing media. A grand mean height of 34.2 cm was achieved in soil with polymer (Table-2). The average growth rates of plants were higher in growth medium where the polymer was used. These correlations indicated that plant height was mostly affected by using of polymer. The growing media showed considerable differences at the assessment of the main parameter of plant growth (Fig. 1). Polymer increased the growth of tomato up to 36 % in both growing media. Lee and Kim[34] found similar results with tomato. They noted that polymer influenced negligibly the growth of tomato up to 35 % in soil. The present results indicated that addition of hydrogel to growing media increased plant growth (*ca.* 36 %).

TABLE-2
GROWTH RATES (HEIGHT OF PLANTS IN cm)*

Mediums	Measurements times after transplantation (d)			
	7	14	21	28
Soil	4.9a	9.1c	19.9d	25.1e
Soil + polymer	5.3a	12.2c	26.4e	34.2f
Sand	3.1b	3.3b	4.1a	5.1a
Sand + polymer	4.2a	5.4a	10.8c	18.0d

*values with similar superscripts within a column are not significantly different at $p = 0.05$.

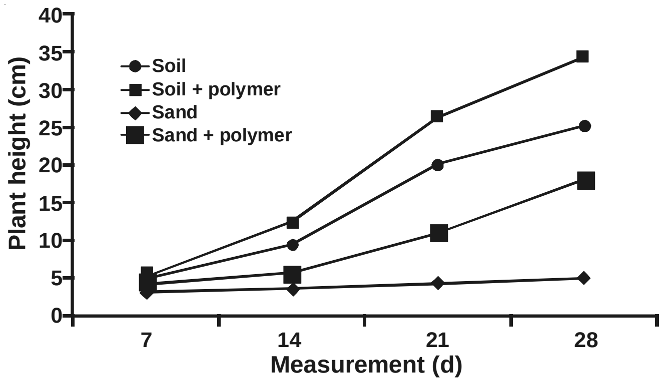

Fig. 1. Growth rates

The results of the present work indicate that this polymer has a good water-retention capacity and it can be used in agriculture, especially in drought-prone areas where water can be scarce. When polymer is applied to the root zone, it retains the moisture and slowly releases it to the growing plants and it can be used for production of tomato in arid regions. Raju *et al.*[35] proposed the same suggestions that the hydrogels can solve water problem in arid regions.

It can also help to save water, time, money and energy which otherwise spent on high frequency irrigations. These findings also have potential beneficial implication to general horticulture. The beneficial of the polymers may be due to their inherent capacity to conserve and release water, but it may also be due to a growing media and plant species.

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