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CASE STUDY

Growth of olive saplings in different media containing artificial and natural super absorbents at two irrigation intervals

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ABSTRACT: A factorial experiment was conducted to evaluate the impact of super absorbents and organic wastes of rice, olive marc, vermicompost and farmyard manure on the soil water holding capacity and the growth of plant based on randomized complete block design with 13 treatments at two irrigation intervals 5 and 10 days. The olive saplings with same heights and better appearances were planted in an open space roofed with a plastic cover with a height of 3 m to avoid the effects of rainfall and snowfall on the results. Stockosorb superabsorbent and weighted zeolite and the rest of bulk materials were mixed. Results showed that the substrate containing 10 g per kg soil of zeolite and the substrate including 20% vermicompost + 15% rice wastes + 15% manure + 50% soil had the best yield and can modify the effect of 10 day irrigation interval compared to the 5 day.

KEYWORDS: *Olive; Organic wastes; Vermicompost; Water holding capacity; Zeolite.*

INTRODUCTION

Olive is one of the most important horticultural products, especially in Guilan Province of Iran, with an under-cultivation area over 8229 hectares which the yellow variety forms more than 70% of the olive groves. In order to produce good and economical products, considering the climatic and soil conditions, the total annual amount of water required for olive, 500 to 7500 cubic meters per hectare per year has been estimated. The precipitation rate must be subtracted from this value which equals 500 to 750 millimeter (mm) of water and the rest must be compensated by irrigation (however, irrigation is better to be done in dry and rain-free seasons of the year). It should not be assumed that additional water and excessive irrigation helps the olive tree, but we should know that additional water, in addition to saturating the soil, also suffocates the roots (Mohammad *et al*, 2004). The food production is under threat due to the climate change, soil erosion, soil degradation and the recurrent droughts (Singh *et al*., 2016). The key issue to achieve a sustainable development is based on the sustainable management of soils (Akhter *et al*., 2004). It is necessary then, to find the right sustainable management. The possibility using organic agricultural wastes or artificial superabsorbent, in addition to having positive effects on physical properties of the soils, can also be a major step in preventing the probable environmental effects of agricultural wastes. The soil is a key part of the earth system that control the biological, erosional, hydrological and geochemical cycles and supply the humankind with goods, resources and services (Keesstra *et al*., 2016). Millions tones of agricultural, animal and urban wastes are annually produced in the country that can have a role in providing the soil organic matter, but unfortunately its major portion is either burnt or abandoned in a corner and causes

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environmental pollution (Mohammad *et al*, 2004). Camberato *et al*. (2006) used the organic wastes of paper industry to improve the physical properties and fertility of the soil and concluded that using this material would increase the soil organic matter, soil aggregate production, water holding capacity of the soil and Cation exchange capacity (CEC). Effects of hydrogel on water storage in sandy soil and sandy loam soil and its impact on growth of barely, wheat and peas was studied by Akhter *et al*. (2004) in Pakistan. The results showed that water-holding capacity of the soil was linearly increased (R=0.988) by adding 0.1, 0.2 and 0.3% of hydrogel to the soil. Adding hydrogel to the soil caused a four to five day delay in wilting of the sapling in both two types of the used soils. Sivapalan *et al*., (2001) tested the effects of a moisture absorbent polymer called aquasorb on performance and efficiency of using soy bean water in sandy soil during a greenhouse experiment. The results showed that the amount of water stored in soil at a pressure of 0.01 Millipascal (Mpa) was increased up to 23 and 93% for application of 0.03 and 0.07% by weight of polymer. Use efficiency of soybean water had a 12-fold increase in 0.03% and a 19-fold increase in 0.07% compared with the control. Olive orchard show many environmental concerns due to the soil erosion, lack of organic matter and a general degradation of the soils (Fernández-Romero *et al*., 2016). Water resources are relevant for the crop yield and there is a need to research on them (Muluneh *et al*., 2016). Roudbar County, as an olive plantation pole of Iran, is located in mountain physiography and it has soil slopes in steep lands and mountains. A major problem of the soils under olive plantation in these areas is the coarse and rocky texture of the fields which is the reason for low water retention in the soil. For the same reason, number of irrigation intervals in these fields is high and they are done every 3-4 days. To solve the problem, it is necessary to increase the number of irrigation intervals. This research has studied the effects of some organic wastes and moisture superabsorbent on growth of olive saplings in two different intervals of irrigation in a soil collected from steep slopes of Roudbar, under climatic conditions of the area. The current study aims at: 1) Applying the super absorbents and organic wastes of rice, olive marc, vermicompost and farmyard manure to increase the water holding capacity of the soil.2) Determination of the best application rate of super absorbents and mixture of organic materials in a substrate under drought stress condition. 3) Evaluation of abilities of the mentioned substrates in additional irrigation interval to maintain growth of the plant. This study has been carried out in Roudbar County in Guilan Province of Iran in 2013.

MATERIALS AND METHODS

The study area geographic coordinates with 36º 32’ to 37º 7’ from the equator and 49º 11’ to 50 º 5’ eastern longitudes from the prime meridian, with a height of 250 meters from the sea level (Fig. 1). According to meteorology divisions, this area is hot and dry Mediterranean. The soil texture is of silt loam and some physical and chemical properties of the soil have been presented in Table 1. Municipal solid waste compost was provided by compost factory of Rasht

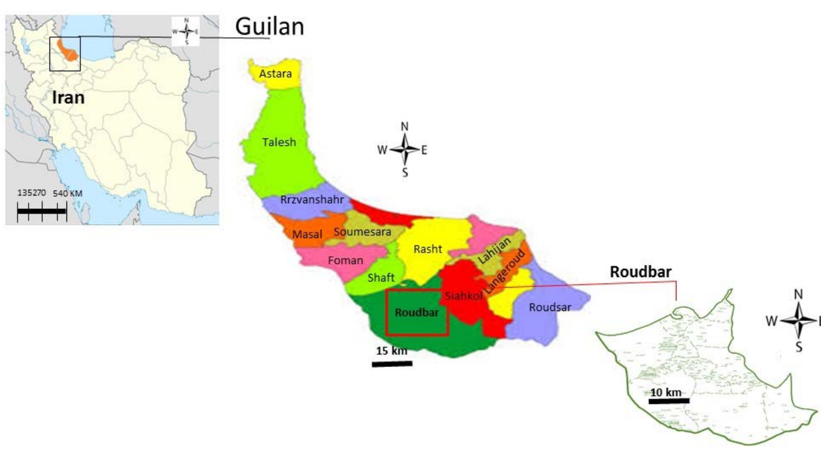

Fig 1: The study area of geographical location

and the olive marc was taken from oil extraction factory of Roudbar. Guilan Province has 230000 hectare (ha). of rice fields from which 1.4 thousand tons of straw and 210 thousand tons of bran are obtained and only a small part of the straw is used as animal feed and its major part is burned by the farmers on the farms. Burning straw on the farms, in addition to destroying organic materials of the soil surface, has also caused severe air pollutions. so that, problem of burning straw and the smoke made by that in rice harvest season is one of the main problems of people and authorities which has caused severe respiratory problems for the citizens. Even according to the local authorities, 11 of residents of Rasht were taken to hospital due to inhalation of the toxic gas made by burning straw on September 2011.

A factorial experiment carried out based on *randomized complete block design* with 26 treatments, 3 replications and 78 plots (Table 2). On May 2013, after providing the olive saplings from Golha tree nursery located in Astaneh Ashrafieh, the samples with same heights and better appearances were selected as plant samples and were planted in pots number 7 and they were placed in an open space roofed with a plastic cover with a height of 3 meters to avoid the effects of rainfall and snowfall on the results. Stockosorb super absorbent and weighted zeolite and the rest of bulk materials were mixed. The plants were irrigated by agricultural water with an Electrical conductivity (EC) equal 1.2 Deci Siements per metre (d/Sm), using sprinkler 1.5 litr (L). for each pot in 5 and 10 day irrigation intervals. At the end of experiment, fresh and dry weight of the roots, leaves and stems, number of lateral branches, length of stem and root, stem diameter, chlorophyll content of the leaves and nitrogen and phosphorous concentrations of the leaves were measured. The substrates were extracted according to method of Soltanpour (1985), using Diethylenetriaminepentaacetic Acid (DTPA) bicarbonate ammonium solution (BA-DTPA) and phosphorous of the resulted extract was measured by Spectrophotometry method. Total nitrogen in the substrates was measured using the *Kjeldahl method (Goos, 1995)*.

Data analysis was done using MSTATC software, mean comparison of the data was carried out through LSD method and the diagrams were drawn using the Excel software.

RESULTS AND DISCUSSION

Data Variance Analysis

Data variance analysis (Table 3) shows that different amounts of natural and artificial superabsorbent in the

Table 1: Some physical and chemical properties of the soil

Depth (m)	Clay (%)	Sand (%)	Silt (%)	Electrical conductivity (dS/m)	Total N (%)	P (mg/kg)	K (mg/kg)	Soil acidity
0-30	14.4	36.8	48.8	0.40	0.08	8	241	7.95
30-60	8.4	34.0	57.8	0.38	0.01	6	137	8.00

Table 2: Characteristics of the soil factors

Factor	Treatment	Characteristics
first factor (Substrates)	$Soil_{100}$	100% soil (control)
	$S_{5g/kg}$	5 g/kg soil
	$S_{10g/kg}$	10 g superabsorbent/kg soil
	$S_{5g/kg}$ Moisturized	5 g moisturized superabsorbent/ kg soil
	$S_{10g/kg}$ Moisturized	10 g moisturized superabsorbent/kg soil
	$Zeolite_{5g/kg}$	5 g zeolite/kg soil
	$Zeolite_{10g/kg}$	10 g zeolite/ kg soil
	$Soil_{70}R_{10}O_{20}M_{10}$	70% soil + 10% waste rice + 10% Olive wastes +10% Manure compost
	$Soil_{50}R_{15}O_{20}M_{15}$	50% soil + 15% waste rice + 20% Olive wastes + 15% Manure compost
	$Soil_{70}R_{10}V_{10}M_{10}$	70% soil + 10% waste rice + 10% vermicompost + 10% Manure compost
	$Soil_{50}R_{15}V_{20}M_{15}$	50% soil + 15% waste rice + 20% vermicompost + 15% Manure compost
	$Soil_{70}R_{15}C_{15}$	70% soil + 15% waste rice + 15% municipal solid waste compost
	$Soil_{50}R_{25}O_{25}$	50% soil + 25% waste rice + 25% municipal solid waste compost
Second factor (interval irrigation)	First interval irrigation	irrigation every 5 days
	Second interval irrigation	irrigation every 10 days

soil have had significant effects in 1% level on plant growth indices including height of the main stem, length of the root, chlorophyll, number of lateral branches, stem diameter, fresh and dry weight of the stem, root and leaves and nitrogen and phosphorous of the leaves.

Effects of Media Substrates on Growth Indices

Table 4 shows the effects of different substrates on plant growth indices. The results showed that the lowest growth was observed in control treatment. The minimum stem height, root length, weight of root and stem and leaves and number of lateral branches in control treatment was significantly less than treatments of superabsorbent and organic wastes. The maximum height of main olive stem in a substrate of 50% soil, 15% rice wastes, 20% vermicompost and 15% manure (100.8 centimetre) was obtained which had a significant increase compared to treatment of 100% soil (control) with a main stem height of 66.83 centimetre. The humic acid found in vermicompost causes an increase in growth and height of the plant through increasing the ion exchange capacity of the soil and growth hormones, also increasing the activity of micro-organisms (Luic and Pank, 2005). Increase in water holding capacity of the soil, permeability, porosity and decrease of soil bulk density is due to adding vermicompost to the soil. Use of vermicompost has positive effects on dry matter and nutrients uptake of the plant. Desirable effect of vermicompost is probably due to relatively high amounts of nutrients and hence, the increased availability of macro and micro elements (Jat and Ahlawat, 2008). Paradelo *et al*, (2009) studied the effects of compost and grape

Table 3: Variance analysis of the data

Variations sources	Degrees of freedom	Mean square					
		Stem height	Root length	Chlorophyll	Number lateral branches	Stem diameter	Stem fresh weight
Substrates	12	**427.3	**398.3	**130.5	**160.7	**0.050	**551.9
Irrigation interval	1	**334.6	**374.8	**252.3	**130.7	**0.007	**373.5
Irrigation× Substrates	12	**75.2	17.3 ^{ns}	4.8 ^{ns}	1 ^{ns}. 5	^{ns} 0.001	10.05 ^{ns}
MSE	50	16.4	14.5	4.5	3.6	0.001	5.6
C.V(%)		4.5	12.6	3.0	13.4	5.3	5.5

Variations sources	Degrees of freedom	Mean square						
		Stem dry weight	Root fresh weight	Root dry weight	Leaf fresh weight	Leaf dry weight	Leaf nitrogen	Leaf phosphorous
Substrates	12	224.7**	**459.2	**54.3	**204.0	**55.9	**0.14	**0.101
Irrigation interval	1	**201.2	**126.6	**124.0	**180.3	**51.4	**0.024	**0.002
Irrigation× substrates	12	2.07 ^{ns}	^{ns} 7.93	**1.28	^{ns} 3.37	**1.38	**0.001	0.002 ^{ns}
MSE	50	1.08	4.29	1.30	3.29	3.54	0.002	0.001
C.V(%)		4.37	10.61	11.58	9.30	24.13	4.13	3.23

Table 4: Effect of treatment on plant growth indices

Treatments	Stem height (cm)	Root length (cm)	Lateral branch Number	Stem diameter (mm)	Stem fresh weight (g)	Stem dry weight (g)	Root fresh weight (g)	Root dry weight (g)	Leaf Fresh weight (g)	Leaf dry weight (g)
$Soil_{100}$* (control)	66.83 f	16.83 g	2.50 h	0.39 g	24.68 g	12.17 i	7.00 h	5.55 g	7.73 g	3.233 h
$S_{5g/kg}$	96.00 b	31.83 d	7.33 g	0.52 f	26.93 g	17.63 h	11.47 g	5.28 g	12.70 ef	6.69 efg
$S_{10g/kg}$	94.83 b	37.33 bc	13.67 e	0.66 c	48.17 bc	28.72 c	32.12 a	14.74 a	20.83 bcd	9.37 cd
$S_{5g/kg}$ Moisturized	92.50 bc	24.17 ef	10.50 f	0.55 ef	34.70 f	19.28 g	14.05 ef	8.76 de	13.67 ef	8.06 de
$S_{10g/kg}$ Moisturized	94.83 b	42.33 a	18.17 b	0.72 a	60.58 a	36.20 a	16.60 d	13.19 b	19.32 d	8.21 cde
$Zeolite_{5g/kg}$	82.33 e	32.83 d	15.00 cde	0.59 d	46.10 cd	22.32 f	12.33 fg	8.93 de	12.80 ef	4.92 gh
$Zeolite_{10g/kg}$	94.00 b	38.67 ab	20.83 a	0.69 bc	47.00 c	31.90 b	33.20 a	12.50 b	21.58 bc	12.31 ab
$Soil_{70}R_{10}O_{20}M_{10}$	86.83 de	20.17 fg	14.50 de	0.57 de	43.88 de	22.72 f	13.28 fg	9.18 d	14.18 e	6.17 efg
$Soil_{50}R_{15}O_{20}M_{15}$	85.83 de	33.33 cd	15.50 cde	0.57 de	41.88 e	25.78 d	31.88 a	12.20 bc	22.72 b	10.35 bc
$Soil_{70}R_{10}V_{10}M_{10}$	88.50 cd	26.00 e	13.67 a	0.66 bc	36.98 f	22.47 f	17.63 d	7.68 ef	14.40 e	5.45 fg
$Soil_{50}R_{15}V_{20}M_{15}$	100.8 a	36.00 bcd	21.17 bcd	0.70 ab	50.22 b	24.55 de	26.17 b	12.16 bc	29.47 a	13.88 a
$Soil_{70}R_{15}C_{15}$	92.67 bc	18.67 g	16.17bc	0.66 c	41.78 e	21.95 f	15.83 de	6.98 f	12.02 f	5.123 gh
$Soil_{50}R_{25}O_{25}$	88.00 cd	26.67 e	17.17 cd	0.67 bc	43.50 de	24.02 e	22.33 c	10.93 c	19.52 cd	7.582 def

Soil*: 100% Soil، S: Superabsorbent, R: Rice waste, O: Olive waste, M: Compost manure, V: Vermicompost, C: Municipal solid waste compost marc vermicompost on physical properties of the soil in quantities of 4, 8 and 16% of dry soil weight during an incubation experiment. They concluded that the mentioned materials significantly increase the soil strength, water holding capacity of the soil and size of the soil aggregates. Adding superabsorbent in both dry and moisturized states also increased height of the plant. Application of 10 gramme (g) of moisturized superabsorbent led to a significant increase in length and dry weight of the root compared to control and other treatments. Sheikh Moradi *et al*., (2010) proved that use of superabsorbent, practically led in water retention in the soil and reduction of irrigation frequency that caused an increase in root penetration and depth and its development in the soil and consequently increase of root length. Researchers conducted by Panayiotis *et al*., (2004) confirmed the effects of superabsorbent polymers in density and growth of the root.

Considering that the superabsorbent has no direct nutritional roles, increase in yield of the plant is due to improvement in physical condition of the soil. This growth increase is caused by indirect role of amendment materials in uptake increase of Nitrogen, Phosphorus and Kalium by the plant and growth, appropriate aeration and available water. By increasing the water holding capacity of the soil, superabsorbent polymers can be effective in delaying the moisture stress in plants and providing a buffering state against yield loss overtime, between two irrigations**.** Mohammad *et al*, (2004) reported the positive effect of igita amendment material (moisture absorbent material) on increase in holding capacity of the moisture and water available in soil and also, increase in yield of soybean per unit area. Results of the research showed that application of amendment materials can cause to increase yield of soybean under drought stress and dehydration conditions. This effect is due to absorbing significant amounts of water in structure of superabsorbent and subsequently, releasing the absorbed water in the soil around the root of the plant during the drought. Most of the measured criteria in this research were increased by adding superabsorbent to the soil that was consistent with the results obtained Martinez *et al*., (2001) in different plants. In addition to treatment of 10 g of dampened superabsorbent, treatments of 10 g zeolite and treatment $Soil_{50}R_{15}V_{20}M_{15}$ (50% soil, 15% rice wastes, 20% vermicompost and 15% farmyard manure) had more favorable and better impacts on growth of the plant compared to other treatments. However, using 10 g superabsorbent was much better than 5g and also, in zeolite, using 10 g has more impacts compared to 5 g. In mixing the soil with organic wastes, mixture of 50% organic wastes with 50% soil has more effects on the growth of the plant compared to the mixture of 30% organic wastes with 70% soil. This increase may be due to increase in organic materials and availability of proper amounts of nutrients in the soil, on the other hand, improvement of water holding capacity and physical properties of the soil. Also, considering production and supply of moisture absorbent materials as the soil amendments, these materials can cause moisture absorption due to low precipitation in arid areas, better absorption of irrigation water and its storage in the soil and so, prevent the moisture stresses and failure of irrigation programs in these types of regions. The organic materials decrease evaporation and transpiration, increase water storage especially in light textured soils, reduce the gaps and cracks in soil surface especially in fine textured soils, improve and modify the aggregate production and prevent compressibility of the soils. Moldes et al., (2007) reported that municipal solid waste compost can provide the whole macronutrients necessary for growth of the plant and improves yield of the plant. Emerson (1995) reported to increase FC moisture by the increase of organic materials in meadows. He expressed that regardless of amount of clay, by increase of organic carbon amount, the moisture holding capacity is increased due to formation of the gels resulting from decomposition of organic residues and the microbial discharges. During a long-term experiment (28 years), Morlat and Chaussod, (2008) studied the effects of different organic amendments on chemical, physical and biological properties of a sandy soil. Effects of annual application of pruned and chopped branches of vineyard (2 tons per hectare of fresh weight), cattle manure (10 and 20 tons per hectare of fresh weight) and mashed mushroom compost (8 and 16 tons per hectare of fresh weight) compared to the control were studied. The results showed that water holding capacity was increased and bulk density was decreased. Organic materials improve the chemical, physical and biological properties of the soil like porosity, stability of the aggregates and bulk density of the soil (Yongjie and Yangsheng, 2005). The treatments containing vermicompost had totally more effects on growth of the plants compared to treatments containing only farmyard manure compost. In their study, Ostos, *et al*., (2008) also reported an increase in height of bushes by using compost. These researches believe the reason to be high amount of nutrients especially nitrogen and phosphorous in municipal solid waste compost. On the other hand, the reason for relative advantage of vermicompost over municipal solid waste compost in increase of plant growth can be production of humic materials and other growth stimulant materials like plant growth hormones during production process of vermicompost by the micro-organisms and as a result, increase of biomass, microbial activity and biodiversity and soil fertility improvement.

Jat and Ahlawat, (2008) believe that using vermicompost has positive effects on dry material, yield of the seed, protein level and uptake of nutrients by the plant. Favorable effect of vermicompost is probably as a result of relatively higher amounts of nutrients and thus, the increased abundance of macro and micro nutrients. According to the results, the soil used for olive growing has a lower potential that unfortunately in lots of cases, no enough natural and artificial superabsorbent is added to these soils.

Effects of irrigation intervals on growth indices

According to the results from Table 5, all measured indices of plant growth in 10 day irrigation interval were significantly decreased compared to the 5 day irrigation interval. The decrease in growth by increase of irrigation intervals is due to drought conditions in the substrates between two irrigations and moisture stress. Stomatal closure in response to stress is a mechanism to reduce the water loss in the plant textures, but if it continues for a long time, the photosynthesis rate is extremely decreased due to reduction in carbon dioxide fixation (Tarddieo, 2005). Reduction of photosynthesis results in decrease of plant growth. Stress reduces the elongation and this is directly related to water potential. Growth only happens under condition of availability of water and water potential maintenance. Under moisture stress condition, number and area of the leaf are reduced and in order to maintain its moisture condition, the plant has to do osmoregulation. Thus, it uses its metabolic energy to produce intermediate materials or mineral accumulation that may cause toxicity in the plant.

By decrease in water potential of the soil and consequently, relative water content of the leaf (RWC), the stomatal conductance is reduced, the carbon dioxide available for plant is limited and finally the photosynthesis is decreased (Martinez, 2007). The leaf area index is reduced under water deficit stress (Chandra Babu, *et al*., 2004) and decrease in leaf area results in photosynthesis reduction in the plant. On the other hand, water deficiency causes decrease of chlorophyll content, Leaf senescence and consequently reduction of leaf area duration and increase in transfer of nitrogen from leaves. These factors all together cause photosynthesis reduction.

Interaction of media substrates and irrigation intervals on growth indices

Tables 6 and 7 shows the interaction of substrates and irrigation intervals with plant growth indices. What's prominent in the results is the significant increase in growth of the plants in different treatments of natural and artificial superabsorbent in the 10 day irrigation interval compared to the control in 5 day irrigation interval. In other words, by increasing the irrigation intervals to 10 days, growth of the plant has been still more than the control in mentioned treatment, even with the 5 day interval. The superabsorbent (stockosorb), provides a better condition for growth of the plant, specifically under drought stress condition by increasing the water retention and thus, increasing the water available for the plant, improving the soil aggregation and structure, increasing stability of the aggregates, reducing bulk density of the soil and improving deep growth of the root. By reducing the evaporation and increasing the water holding capacity,

Table 5: Effect of irrigation intervals on plant growth indices

Irrigation interval	Stem height (cm)	Root length (cm)	Lateral branch Number	Stem diameter (mm)	Stem fresh weight (g)	Stem dry weight (g)	Root fresh weight (g)	Root dry weight (g)	leaf Fresh weight (g)	leaf dry weight (g)
5 days	96.08 a	31.76 a	15.61 a	0.62 a	44.22 a	25.40 a	20.80 a	11.11 a	18.51 a	8.61 a
10 days	83.00 b	27.41 b	13.02 b	0.60 b	39.84 b	22.19 b	18.25 b	8.95 b	15.47 b	6.99 b

Table 6: Interaction of treatment and irrigation interval on plant growth indices
(Stem length, height, diameter, weight fresh and lateral branch number)

Treatments	Irrigation interval (day)	Stem height (cm)	Root length (cm)	Lateral branch number	Stem diameter (mm)	Treatments	Irrigation interval (day)	Stem Height (cm)	Root Length (cm)	Lateral branch Number	Stem diameter (mm)
Soil$_{100}$* (control)	5	69.7 i	17.33	3.00	0.40	Soil$_{70}$R$_{10}$O$_{20}$M$_{10}$	5	89.7 fghi	22.33	16.00	0.56
	10	64.0 i	16.33	2.00	0.38		10	84.0 ijk	18.00	13.00	0.55
S$_{5g/kg}$	5	102.0 abc	34.00	8.00	0.53	Soil$_{50}$R$_{15}$O$_{20}$M$_{15}$	5	91.3 defgh	34.33	17.33	0.60
	10	90.0 efghi	29.67	6.67	0.51		10	80.3 k	32.33	13.67	0.55
S$_{10g/kg}$	5	102.3 abc	39.00	15.67	0.68	Soil$_{70}$R$_{10}$V$_{10}$M$_{10}$	5	94.3 def	28.00	14.67	0.63
	10	87.3 ghij	35.67	11.67	0.64		10	82.7 jk	24.00	12.67	0.68
S$_{5g/kg}$ moisturized	5	104.0 a	26.33	11.67	0.55	Soil$_{50}$R$_{15}$V$_{20}$M$_{15}$	5	106.3 a	41.33	22.67	0.72
	10	81.0 jk	22.00	9.33	0.54		10	95.3 def	30.67	19.67	0.68
S$_{10g/kg}$ moisturized	5	a 107.7	46.67	19.67	0.74	Soil$_{70}$R$_{15}$C$_{15}$	5	103.0 ab	20.00	15.00	0.67
	10	82.0 jk	38.00	16.67	0.71		10	52.3 jk	17.33	17.33	0.65
Zeolite$_{5g/kg}$	5	85.0 hijk	32.67	17.00	0.61	Soil$_{50}$R$_{25}$O$_{25}$	5	97.3 bcd	31.67	19.67	0.69
	10	79.67 k	33.00	13.00	0.55		10	78.7 k	21.67	14.67	0.65
Zeolite$_{10g/kg}$	5	96.3 cde	39.67	22.67	0.68						
	10	96.7 defg	37.67	19.00	0.67						

Table 7: Interaction of treatment and irrigation interval on plant growth indices
(Root fresh and dry weight, stem dry weight and leaf fresh and dry weight)

Treatment	Irrigation interval (day)	Stem dry weight (g)	Root fresh weight (g)	Root dry weight (g)	leaf dry weight (g)	Treatment	Irrigation interval (day)	Stem dry weight (g)	Root fresh weight (g)	Root dry weight (g)	leaf dry weight (g)
Soil$_{100}$* (control)	5	12.86	7.90	6.813 ijkl	3.59 kl	Soil$_{70}$R$_{10}$O$_{20}$M$_{10}$	5	23.87	14.96	10.24 efg	7.08fghij
	10	11.47	6.10	4.290 m	2.87l		10	21.56	11.60	8.13hij	5.26hijkl
S$_{5g/kg}$	5	19.60	11.43	5.360 klm	7.58 fghi	Soil$_{50}$R$_{15}$O$_{20}$M$_{15}$	5	27.20	33.83	13.65bc	11.58bcd
	10	15.66	11.50	5.207 lm	5.80 hijkl		10	23.76	29.93	10.75ef	9.17defg
S$_{10g/kg}$	5	31.26	33.20	16.62 a	10.70 bcde	Soil$_{70}$R$_{10}$V$_{10}$M$_{10}$	5	23.16	17.63	8.63ghi	5.35hijkl
	10	26.16	31.03	12.8 bcd	8.05 efgh		10	21.66	17.63	6.73jkl	5.55hijkl
S$_{5g/kg}$ moisturized	5	21.36	15.40	10.44 efg	9.23 defg	Soil$_{50}$R$_{15}$V$_{20}$M$_{15}$	5	26.26	28.00	13.23bc	14.72a
	10	17.20	12.70	7.087 ijk	6.90 fghij		10	22.83	24.33	11.09def	13.04ab
S$_{10g/kg}$ moisturized	5	38.56	18.86	14.53 b	9.93 cdef	Soil$_{70}$R$_{15}$C$_{15}$	5	23.10	16.87	8.14hij	5.74hijkl
	10	33.83	14.33	11.84 cde	6.50 ghikj		10	20.80	14.80	5.82klm	4.50ijkl
Zeolite$_{5g/kg}$	5	23.50	12.73	10.77 ef	5.70 hijkl	Soil$_{50}$R$_{25}$O$_{25}$	5	25.56	26.43	12.10cde	7.98efgh
	10	21.13	11.93	7.10 ijk	4.27 jkl		10	22.46	18.23	9.76fjh	7.18fghij
Zeolite$_{10g/kg}$	5	33.90	33.20	14.00 b	12.78 abc						
	10	29.90	33.20	11.00 def	11.83 abcd						

the organic wastes increase the amount of available water; so, they delay reaching the wilting point. This is consistent with ideas of Moradi Kor *et al*., (2013). If mixed with substrates, the superabsorbent can improve physical texture of the substrate and increase water holding capacity (Martyn and Szor, 2001), easy access of the plant root to water and nutrients (El-Hadi, Wanas, 2006) and decrease of drought stress (Arbona, *et al*., 2005). Increase in percentage of available water due to using superabsorbents is also consistent with ideas of Akhter *et al*. (2004). The effects of hydrogel (superabsorbent) on water storage in sandy soils and sandy loam and its impact on growth of barely, wheat and pea was reported by Akhter *et al*., (2004) in Pakistan. The results showed that by adding 0.1, 0.2 and 0.3% of hydrogel to the soil, the water holding capacity is linearly increased (R= 0.988).

It was found that treatments of 10 g moisturized superabsorbent, 10 g of zeolite and Soil$_{50}$RW$_{15}$V$_{20}$CM$_{1}$ (50% soil, 15% rice wastes, 20% vermicompost and 15% farmyard manure) had better effects on plant growth in compared to other treatments. Table 8 shows the yield reduction percentage in different growth indices in 10 day irrigation interval in compared to 5 day irrigation interval in 3 mentioned treatments.

According to Table 8, in treatment 10 g zeolite, length of root in 10 day irrigation interval is even more than 5 day irrigation interval and fresh weight of the root is not different with the 5 day irrigation interval and this shows ability of zeolite in developing the root which can help growth of the plant especially during drought periods by increasing the water absorption efficiency. In a research conducted on Trigonella Foenum-graecum plant, Moradi Kor *et al*., (2013) described that using zeolite had increased fresh weight of the root. In a research conducted on *Narcissus tazetta* plant, Farahmand *et al*. (2007) expressed that using zeolite mixed with soil increased fresh weight of the root and fresh and dry weight of the leaf. Natural zeolite causes increase in plant growth and decrease in costs of required nutrients by keeping some cations in their structure and then releasing them in substrate. It also causes uptake, maintenance and balance of moisture inside the environment. In treatment of 10 g zeolite, no significant difference is observed in height of the plant, stem diameter, weight of the leaf and nitrogen concentration in the leaf among 10 day and 5 day irrigation intervals. By evaluating the results, maybe we can introduce $Soil_{50}RW_{15}V_{20}CM_{15}$ treatment (50% soil, 15% rice wastes, 20% vermicompost and 15% manure) as a better treatment, after treatment of 10 g of zeolite in 10 day irrigation interval that has resulted in less decrease in number of lateral branches, dry weight of the root and fresh weight of the leaf in the 10 day irrigation interval compared to the 5 day irrigation interval. Uma and Malata (2009) believe the relative reason for superiority of vermicompost in increase of plant growth and dry weight of leaf to be production of humic materials and other growth stimulating materials like plant growth stimulating hormones during vermiompost production process done by micro-organisms and consequently, increase of mass, microbial activity and biodiversity and improvement of soil fertility.

Results of this research show that adding natural and artificial superabsorbent to the soil can result in saving water by delaying the wilting time of the plant and increasing the irrigation intervals.

Effects of treatments on chlorophyll, N and P concentrations of the leaf

Tables 9 and 10 show the effects of substrate, irrigation intervals and their interaction on chlorophyll, amount of nitrogen and phosphorous. According to table 8, using superabsorbent up to 10 g per kg of soil (dampened polymer) (a_5) caused the chlorophyll to become 77.45 the SPAD number but in control treatment, chlorophyll 63.45 became the SPAD number. Mafakheri, *et al*., (2010), in their research on broad bean plant proved that superabsorbent has a significant effect on chlorophyll and makes the plant green which is consistent with this experiment. During different irrigation intervals, using the 5 day irrigation interval caused the chlorophyll to become 71.87 SPAD (Service Platform Application Development) number. But in 10 day irrigation interval, chlorophyll was decreased to 68.272 SPAD number.

The researches have proved that drought stress reduces chlorophyll content of the plant (Nikolaeva, *et al*., 2010). Akhkha *et al*. (2011) showed that chlorophyll content of the leaf is decreased by increase of drought stress. Nikolaeva *et al*. (2010) also reported 13 to 15% decrease in chlorophyll content of the leaf compared to the control in the plants under stress. The photosynthesis amount is limited in response to drought stress due to stomatal factors (stomatal closure) and non-stomatal factors (defect in metabolic processes) and generally, the chlorophyll content is decreased (Mafakheri, *et al*., 2010). Moreover, recycling of the materials especially nitrogen is decreased under drought stress conditions and since the chloroplasts need nitrogen to produce chlorophyll, the chlorophyll production rate is decreased and it becomes slower (Moradi Kor, *et al*., 2013).

Using different substrates containing natural and artificial superabsorbent caused a significant increase

Table 8: The reduction percent of growth in treatments of $S_{10g/kg}$ moisturized, $zeolite_{10g/kg}$ and $soil_{50}R_{15}V_{20}M_{15}$ at 10 days irrigation interval in compared to 5 days interval

Treatment	Stem Height (cm)	Root length (cm)	Lateral branch Number	Stem diameter (mm)	Stem fresh weight (g)	Stem dry weight (g)	Root fresh weight (g)	Root Dry weight (g)	leaf Fresh weight (g)	leaf dry weight (g)
$S_{10g/kg}$ Moisturized	23.86	18.55	15.25	4.95	11.15	12.26	24.02	18.51	27.77	34.54
$Zeolite_{10g/kg}$	6.27	- 1.04	23.53	4.94	13.86	11.77	0	21.42	17.35	7143
$Soil_{50}R_{15}V_{20}M_{15}$	10.32	25.81	13.24	5.55	15.82	13.06	13.10	16.17	11.12	11.41

Table 9: Effect of treatment and irrigation interval on the chlorophyll, nitrogen and phosphorous of leaf

Treatment	Chlorophyll (SPAD)	N (%)	P (%)
$Soil_{100}$*(control)	63.45h	0.683e	0.78e
$S_{5g/kg}$	68.38f	1.10d	1.14d
$S_{10g/kg}$	74.73bc	1.24b	1.25ab
$S_{5g/kg}$ Moistured	72.70cde	1.16c	1.17cd
$S_{10g/kg}$ Moistured	77.45a	1.60ab	1.26ab
$Zeolite_{5g/kg}$	73.72bcd	1.17c	1.17cd
$Zeolite_{10g/kg}$	75.33ab	1.25ab	1.25ab
$Soil_{70}R_{10}O_{20}M_{10}$	67.25fg	1.15cd	1.17cd
$Soil_{50}R_{15}O_{20}M_{15}$	65.45gh	1.25ab	1.23b
$Soil_{70}R_{10}V_{10}M_{10}$	71.02e	1.15cd	1.15cd
$Soil_{50}R_{15}V_{20}M_{15}$	71.92de	1.28ab	1.28a
$Soil_{70}R_{15}C_{15}$	64.35h	1.17c	1.18c
$Soil_{50}R_{25}O_{25}$	65.17gh	1.29a	1.28a
Irrigation Interval			
5 days	71.87a	1.19a	1.20a
1 day	68.27a	1.15a	1.16a

Table 10: Interaction of treatment and irrigation interval on the chlorophyll, nitrogen and phosphorous of the leaf

Substrates	Irrigation interval (day)	Chlorophyll (SPAD)	N (%)	P (%)		Irrigation interval (day)	Chlorophyll (SPAD)	N (%)	P (%)
$Soil_{100}$* (control)	5	64.4	0.73	0.86	$Soil_{70}R_{10}O_{20}M_{10}$	5	69.5	1.16	1.18
	10	62.5	0.63	0.70		10	64.9	1.14	1.16
$S_{5g/kg}$	5	72.5	1.12	1.16	$Soil_{50}R_{15}O_{20}M_{15}$	5	66.8	1.26	1.24
	10	64.2	1.09	1.12		10	64.0	1.24	1.23
$S_{10g/kg}$	5	75.9	1.26	1.27	$Soil_{70}R_{10}V_{10}M_{10}$	5	72.5	1.16	1.16
	10	73.5	1.21	1.24		10	69.5	1.14	1.14
$S_{5g/kg}$ Moisturized	5	73.8	1.18	1.17	$Soil_{50}R_{15}V_{20}M_{15}$	5	74.4	1.30	1.30
	10	71.5	1.15	1.16		10	69.3	1.27	1.27
$S_{10g/kg}$ Moisturized	5	80.0	1.28	1.27	$Soil_{70}R_{15}C_{15}$	5	65.3	1.18	1.20
	10	74.8	1.23	1.24		10	63.3	1.15	1.17
$Zeolite_{5g/kg}$	5	75.3	1.18	1.18	$Soil_{50}R_{25}O_{25}$	5	66.4	1.32	1.29
	10	72.1	1.16	1.17		10	63.8	1.27	1.27
$Zeolite_{10g/kg}$	5	77.0	1.26	1.27					
	10	76.6	1.23	1.24					

in nitrogen compared to the control which the highest nitrogen amount was observed in the leaf in substrate of moisturized superabsorbent. In the 5 day irrigation interval, it caused nitrogen amount to become 1.19 %. But in 10 day irrigation interval, the nitrogen became 1.15%. The highest nitrogen content of the plant was observed in treatment 50% soil+ 25% rice wastes+ 25% municipal solid waste compost along with the 5 day irrigation interval up to 1.32%. Results of the experiment done by Hu and Barker, (2004) showed that waste compost cause uptake of high amounts of elements like nitrogen, calcium, potash and magnesium in leaves of tomato plant. During their study, Ostos *et al*. (2008) reported an increase in height of bush due to using municipal solid waste compost. These researchers believe the reason for this to be high amounts of nutrients especially nitrogen and phosphorus in municipal solid waste compost.

One reason for why there is no significant difference in nitrogen amount in low irrigation treatment compared to the 5 day irrigation treatment is the increase in density of the root due to imperfect irrigation treatment and its higher contact levels with soil in nutrients uptake from the soil (Hu, *et al*., 2009). Another research showed that applying imperfect irrigation treatment speeds mineralization of organic nitrogen in soil. Also, re-irrigation of a part of root which has been left dry for a while results in increase of nitrate production (Ostos *et al*., (2008). Under this condition, more nitrogen is available for the plant and a higher level of nitrogen uptake is provided in imperfect irrigation treatments of the root compared to low treatments of normal irrigations.

CONCLUSION

The results showed that using a superabsorbent substrate and irrigation has positive significant effects in 1% level, on indices like height of the plant, fresh and dry weight of the shoot, fresh and dry weight of the root, length of the root, chlorophyll, lateral branches, diameter of stem and nitrogen and phosphorus of the leaf. The results obtained from interaction of substrate and irrigation interval showed that the maximum height of the main stem of olive was related to the treatment 10 g per kg soil of superabsorbent (moisturized polymer) along with the 5 day irrigation interval up to 107.7 cm and the minimum main stem height was observed in 100% treatment of the soil, together with the 10 day irrigation interval up to 64 cm. Finally, according to the results it can be concluded that the substrate containing 10 g per kg soil of zeolite and also the substrate including 20% vermicompost+ 15% rice wastes+ 15% manure+ 50% soil has had the best yield and can modify the effect of 10 day irrigation interval compared to the 5 day one.

RECOMMENDATIONS

- To experiment corrective effects of natural and artificial superabsorbent in soils with different textures.
- The researches carried out on moisture absorbent materials so far, has been mostly about effects of these materials on physical properties of the soil and impacts of these materials on chemical and mechanical properties of the soil has not been discussed enough. Therefore, environmental effects of these materials on water and soil environment and their impacts on sustainable agriculture are the subjects which require more investigations and deliberations.
- To investigate the effects of different proportions of superabsorbent on quantitative and qualitative properties of various types of olive.
- To use other agricultural wastes such as peanut cocoon compost and Azolla compost to improve water holding capacity of the soil.
- To use the chips of the pruned branches of olive trees instead of olive marc.
- To investigate the effects of superabsorbent, irrigation intervals and salinity stress on growth factors of olive.
- To experiment corrective effects of natural and artificial superabsorbent in fertile olive groves.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

ABBREVIATIONS

BA-DTPA	Bicarbonate ammonium diethylen-etriaminepentaacetic acid
CEC	Cation exchange capacity
cm	Centimetre
CM	Compost manure
CV	Coefficient of variation
d/Sm	deci Siemens per metre
DTPA	Diethylenetriaminepentaacetic acid
EC	Electric conductivity
g	Gram
ha	Hectare
k	Kalium (Potassium)
km	Kilometre
L	Liter
m	metre
mg/kg	milligramme per kiloogramme
mm	millimetre
Mpa	Millipascal
M.S.E	Mean square error
MSWC	Municipal solid waste compost
N	Nitrogen

OW	Olive wastes
P	Phosphorus
RW	Rice wastes
RWC	Relactive water content
S	Superabsorbent
SPAD	Service platform application development
V	Vermicompost

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