ISSN: 2643-671X

Research Article

Journal of Agriculture and Horticulture Research

Influence of Hydrogel Composites Soil Conditioner on Navel Orange Growth and Productivity

Abobatta WF[1]* and Khalifa SM[2]

[1]*Citrus Department, Horticulture Research Institute, Agriculture Research Center, Giza, Egypt*

[2]*Horticulture Departments, Faculty of Agriculture, Al Azhar University, Cairo, Egypt*

[*]Corresponding author
Waleed Fouad Abobatta, Citrus Department, Horticulture Research Institute, Agriculture Research Center, Giza, Egypt, E-mail: wabobatta@yahoo.com

Submitted: 20 June 2019; **Accepted**: 08 July 2019; **Published**: 20 July 2019

Abstract

This investigation was carried out at a private orchard, in Nubaria district, Behera Governorate, on "Washington Navel orange" trees [Citrus sinensis L.(Osbeck)] during the grown seasons of 2016 and 2017. The experimental site represents newly reclaimed sandy soil irrigated through drip irrigation system. This work aims to study the impact of hydrogel composite as substance holding water in the soil on improvement total yield, and fruit characters of W Navel orange tree. The treatments were applied as soil application at zero, 500, 1000 and 1500 g hydrogel composite/tree.

The obtained results cleared that medium or high dose of hydrogel composite (1000 or 1500g/tree) enhanced the most studied parameters, it increased total yield, fruit weight, and enhancement fruit quality, different treatments of hydrogel composite increased fruit content of total soluble solids and total sugars. However, 1500g/tree treatment was the best treatment and recorded highest total yield. This may be due to the vital role of hydrogel composite in increasing water availability and nutrients for the tree for a longtime as well as increasing the fruit retained.

Moreover, with respect to tree growth, it was found that there was a significant increase in the vegetative growth parameters (shoot length, leaf area, and tree canopy) in all the treatments where hydrogel composite used as compared to untreated tree.

Keywords: Navel Orange Tree, Hydrogel Composite, Fruit Properties, Vegetative Growth

Introduction

Citrus considers being one of the most important fruit crops in the world, which occupied the third position between fruit crops after grapes and apples, also, rank first in international fruit trade in terms of value, more than seven million hectares are planted with citrus throughout the world [1].

Moreover, citrus is the largest horticultural industry in Egypt as its acreage, production and exportation potentialities are concerned, harvested area increased rapidly from year to another (541723 fed.) in 2017 from the total fruit crops area, which estimated to be (1609189 fed.), the fruiting acreage of citrus occupies about (439024 fed.) and produced about (4098590 tons) with the average of (10.336 tons/fed.) [2].

Navel oranges considered the main citrus variety in Egypt, it is representing 60 percent of all cultivated citrus area and 60 percent of the total orange production in Egypt [3].

The optimization of the use of water resources is strategic for the long-term competitiveness of the agricultural industry; the ever-expanding global demand for water, combined with the impacts of climate change is already making water scarcity a reality in many parts of the world.

The hydrogel composite is a soil conditioner able to retain water and plant nutrients, composite releases water and nutrient to the plants when surrounding soil near the root zone of plants starts to dry up. These materials cause more efficient water consumption, reduction in irrigation costs and intervals by 50%, increase soil's water holding capacity up to 2 to 4 times and soil porosity, providing plants with eventual moisture and nutrients as well as improving plant viability and ventilation and root development [4].

Previous research suggests that soil application with super absorbent polymers, increase the water volumetric content of the soil and as the soil dries, the stored water is released back slowly to the roots.

Hydrogels performance depends on their chemical properties like molecular weight, formation condition, along with the chemical composition of soil's solution or irrigation water [4]. There are three forms of hydrophilic polymers containing natural (polysaccharide derivatives), semi-synthetic (cellulosic primitive derivatives) and synthetic [5]. Synthetic polymers had higher stability under different conditions more than natural ones against environmental degradable, for that it is used widely in different fields [6].

The hydrogels were claimed to reduce fertilizer (NPK) leaching. Increasing irrigation water level is causing a significant decrease in the available amount of N, P and K in the studied soil, due to increase leachability [7]. The hydrogel polymer compound seems to be extremely effective to be used as a soil conditioner in agricultural sector, to boost crop tolerance and growth in a sandy or light–weight gravel substrate. Hydrogel polymer has been established as a soil conditioner to reduce soil water loss and increase crop yield [8].

The main objective of this study is to determine the effect of Hydrogel composite as soil conditioner applied under drip irrigation system on the growth and total yield of Navel orange trees cultivated on newly reclaimed sandy soil at the North West desert of Egypt.

Materials and Methods

The present experiment was conducted during the two successive seasons of 2016 and 2017 on fifteen year's old Washington navel orange trees [***Citrus sinensis*** **L.(Osbeck)**] grown in sandy soil in a private orchard at Housh Eissa, El- Behera Governorate, Egypt. Washington navel orange trees budded on sour orange rootstock (***Citrus aurantium*** **L.**). The trees are planted 4 × 4 meters apart. All trees are irrigated using drip irrigation system with 8 adjustable discharge emitters/trees through 2 irrigation lines and all trees received equally irrigation water quantity. The experimentation was done on three trees (3 replicates each has tree) for each treatment nearly similar in vigor and subjected to the same cultural practices that followed in the farm. The soil conditioner was added in the soil under irrigation lines at 20 cm depth in both sides of trees in mid of January from each season for one time only. Soil conditioner (Hydrogel composites) samples were obtained from the Directory General of Protected Cultivation-Agriculture Research Center (ARC). Some chemical features of the composites are shown in Table 1. These composites are mixtures of polyacrylic of super absorption polymer (SAPs) and clay deposits (Bentonite) at ratio 1:5 (size/size) according to Ahmed, 1992. [9]. Also, the trees received the recommended fertilization program applied to all trees on equal bases according to the extension of the Ministry of Agriculture-Egypt.

Table 1: Some characteristics of the studied polymer

Characteristics of the studied polymer	
pH	7.12
Bulk density, g /cm^{-3}	0.67
Real density, g /cm^{-3}	1.72
Total porosity, %	61.0
Water Holding Capacity (WHC), cm^{3}/g^{-1}	60.0

Treatments

The experiment contained four treatments of Hydrogel composite as follow:
T1 0g/ tree "Control"
T2 500 g hydrogel composite / tree
T3 1000 g hydrogel composite / tree
T4 1500 g hydrogel composite / tree.

Measurements

Vegetative Growth

Average Shoots Length (cm)

Twenty shoots/tree replicated 3 times (3 trees) were devoted to measure the shoot length (cm) at the end of spring cycles.

Leaf Area (cm^2)

Twenty mature leaves replicated three times were abscised in December, then leaf area (cm^2) was calculated according to the following equation of Ahmed and Morsy (1999) [10].
Leaf area = 0.49 (Length x Width) + 19.09 = ---------- cm^2

Tree Canopy Volume (m^3)

Tree size, expressed as canopy volume, was calculated by the formula: 0.5238 x tree height x diameter square, according to Turrell, 1946 [11].

The Fruiting Characters

Number of Flowers, Number and Percentages of Fruit Set and Retention

Four branches (two years old) similar in growth were chosen, one branch in each original direction and twelve shoots per each main branch were tagged at balloon stage of the flower. At blooming, all opened flowers/shoot was counted. After the end of fruit set, the number of fruit set was recorded and fruit set percentage was calculated according to the following equation:

$$\textbf{Initial fruit set \%} = \frac{\text{Total No. of set fruits/shoot}}{\text{Total No. opened flowers/ shoot}} \times 100$$

$$\textbf{Final fruit set \%} = \frac{\text{Total No. of fruits at end of June/shoot}}{\text{Total No. flowers/shoot}} \text{ x } 100$$

Retained Fruits Percentage

Final fruit set was calculated per each treatment, and total fruit number per each treatment were counted at harvest time, and retained fruits percentage was calculated as following equation:

$$\textbf{Retained fruits percentage} = \frac{\text{Total fruit number/treatment}}{\text{Final fruit set number/treatment}} \text{x100}$$

Tree Yield and Yield Efficiency

Harvesting was achieved during the regular commercial harvesting time on December 15th for each season, yield (Kg/tree) was recorded. Fruit yield increment or reduction percentage was compared with the control was calculated by the following equation:

Fruit yield increment or reduction (%) =

$$\frac{\text{Fruit yield (kg)/treatment - Fruit yield (kg)/ control}}{\text{Fruit yield (kg)/ control}} \times 100$$

Physical and Biochemical Fruit Characteristics at Harvest

Samples of ten fruits at harvesting time for each replicate for treatment were picked, then transferred to the postharvest lab in Department of Horticulture, Faculty of Agriculture, Al-Azhar University, Cairo, to determination the fruit characteristics were: Fruit weight (g), fruit volume (cm^3) fruit peel weight (g) and fruit pulp weight (g).

Physical Fruit Characteristics

Fruit weight (g), fruit volume (cm^3) and flesh firmness (lb / $inch^2$) using a pressure tester (Digital force - Gouge Model IGV-O.SA to FGV-100A. Shimpo instruments) were determined.

Biochemical Fruit Characteristics

Were determined according to AOAC for fruit juice TSS% using handy refractometer, fruit juice total acidity as citric acid by titration against Na OH (0.1N), TSS/Acid ratio were determined as the method described by Smith, et al., 1956 and fruit juice Vitamin C (ascorbic acid mg/100ml juice) by titration with 2-6 dichlorophenol indophenol pigment [12-13].

Statistical Analysis

All data obtained during both seasons were subjected to analysis of variance and significant differences among means were determined according to Duncan's multiple test range [14].

Results and Discussion

Effect of Different Levels of Hydrogel Composite on Vegetative Growth of Navel Orange

Shoot Length (cm) and Leaf Area (cm^2)

Tabulated results in Tables (2) revealed that leaf area and average shoot growth of Washington Navel orange tree were significantly affected by applied levels of hydrogel composite in both seasons. Since 1500 g / tree treatment (T4) recorded the highest significant leaf area and average shoot growth compared with control treatment (T1) in both seasons of the study.

In this concern tabulated date reveled that, T4 of hydrogel composite recorded the highest significant increased average shoot growth (20.5 & 24.69 cm) when compared to 1000g/tree (T3), 500g/tree (T2) and control treatments in both seasons of the study, followed by T3 (18.02& 22.03 cm) and T2 (16.48 & 18.86 cm), whereas, control treatment had the lowest average shoot growth values (13.05&14.68 cm) respectively, in this experiment.

Regarding leaf area, T4 was statistically increased leaf area (19.29 &20.48 cm^2) when compared to other treatments in both seasons. Also, T3 treatments were significantly increased leaf area (16.80 cm^2) in compare to T2 and T1 in the first season, wherever, T1 recorded list significant values (12.48 and 13.26 cm^2) in both seasons. These findings may be due to trees that grown in soil mixed with hydrogel composite had more available water in soil, so improving growth and produced large canopy volume comparing with those grown without hydrogel [15-16].

Tree Canopy Volume (m^3)

In this concern data in Table (2) reveled that, hydrogel composite treatment was statistically increased tree canopy volume when compared to control treatment respectively, Moreover, T4 recorded the highest tree canopy value (39.23 and 44.04 m^3) in both seasons when compared to other treatments in this study. Whereas, T3 was significantly increased (27.71 and 31.73 m^3) in compared to T2 (22.49 and 25.55 m^3) and T1 (19.33 and 22.29 m^3) respectively, during the experimental seasons (2017-018).

The previous results may be due to the positive effect of hydrogel composite to improve moisture retention by coarse soils [17].

In this experiment the comparison of control treatment (T1) with highest levels of hydrogel treatment (T4) showed implementation of shoot length, from (13.05 & 14.68 cm) and canopy volume (19.33&22.29 m^3) under normal condition to (20.50 & 24.69 cm as shoot length) and (39.23 &44.04 m^3) under hydrogel application.

These results show that super absorbent polymers helps to increase the capacity of soil cationic exchange and better absorption of water and nutrition materials, our results in the same line with who reported that these super absorbent polymer prevent water and nutrition materials washing and therefore increase canola yield, also, Huttermann et al 1999 indicated that super absorbent polymer increase the capacity of water storage in sandy soil and improve stability and growth of *Pinus halepensis* seedling [18-20].

Table 2: Effect of Levels of Hydrogel composite on Leaf area (cm^2), shoot length (cm) and canopy volume (m^3) Washington navel orange cultivar in 2016 and 2017 seasons

Treatment	Leaf area (cm2)		Average shoot length growth in Spring cycle (cm)		Canopy Volume(m^3)	
	2016	2017	2016	2017	2016	2017
Control	12.48	13.26	13.05	14.68	19.33	22.29
500 g/ tree	13.60	14.85	16.48	18.86	22.49	25.55
1000 g /tree	16.80	17.81	18.02	22.03	27.71	31.73
1500 g / tree	19.29	20.48	20.5	24.69	39.23	44.04
L.S.D. at 5%	2.60	1.19	0.80	2.28	4.25	4.61

Effect of Different Levels of Hydrogel Composite on Fruiting Flowering and Fruit Set

With respect of the effect of hydrogel composite application on flowering behavior of W. Navel orange trees, data in Table (3) cleared that hydrogel composite applications were positively effect on flowering parameters (Flower number /shoot, fruit number / shoot, percentages of initial fruit set / shoot, final fruit set / shoot and Retained fruits) of W Navel orange trees.

Data in Table (3) illustrated that hydrogel composite treatments significantly increased flowers number /shoot in compared to control treatment in the first season, whereas, 1500g/tree treatment was the highest significant values (133.9) in the first season, and control was the lowest (120.67 and 125.78) during experiment seasons. However hydrogel composite treatments improved flowers number/ shoot in the second season without significant differences between all treatments.

Concerning fruit number/ shoot date in Table (3) showed significant increase with increasing hydrogel concentrations, however T4 recorded highest significant values (41.42 and 42.45) in both seasons compare with other treatments, the increases were calculated in final fruit set ratio to be 2.36 and 2.49 for the aforementioned treatment, moreover, data indicate that there is a beneficial effect of hydrogel composite on the retained fruits ratio of w. navel orange tree.

The obtained results indicated that the highest value of number of flowers /shoot, fruit set percentage, and yield were associated with highest rate of hydrogel composite compared to untreated trees in both seasons, in the meantime, T3 treatment had a similar trend on this respect.

The results revealed that increasing concentration of hydrogel composite up to 1500gm / tree gave maximum values of the studied characters respectively. The superiority of the highest level of the hydrogel composite might be referred to regulates nutrients absorb by plant, availability enough water for longtime than control. Such results are in harmony with on *Citrus limon* and on Grandnain Banana Plants, who found that, increasing the amount of hydrogel increased flower number per shoot, fruit setting and yield (Kg /tree) [21-22].

Table 3: Effect of Levels of Hydrogel composite on flowering, percentages of fruit set and fruit retention of Washington navel orange tree in 2016 and 2017 seasons

Treatment	Number of flowers/ shoot		Number of fruit / shoot		Initial fruit set %/ shoot		Final fruit set %/ shoot		Retained fruits %	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Control	120.67	125.78	24.49	29.40	20.31	20.47	1.61	1.72	6.81	7.45
500 g/ tree	123.73	127.23	32.77	34.49	25.13	26.33	1.99	2.22	8.43	9.58
1000 g/tree	128.20	129.14	39.53	38.59	28.79	29.14	2.28	2.45	9.65	10.60
1500 g/ tree	133.90	135.47	41.42	42.45	29.89	29.55	2.36	2.49	10.02	10.75
L.S.D. at 5%	8.67	10.73	5.75	8.15	3.21	1.85	0.25	0.16	1.07	0.67

Table 4: Effect of Levels of Hydrogel composite on yield and yield efficiency of Washington navel orange tree in 2016 and 2017 seasons

Treatment	yield(Kg/ tree)		Increase % in yield than control	
	2016	2017	2016	2017
Control	76.00	78.33	0.00	0.00
500 g/ tree	91.67	95.00	20.77	21.28
1000 g/tree	107.00	111.00	40.88	41.75
1500 g/ tree	113.67	118.33	49.67	51.09
L.S.D. at 5%	3.73	2.43	8.96	4.39

Among all the treatments, T4 was found to be the best with respect to yield (113.67 and 118.33 kg/tree) which was significantly higher than other treatments; while T2 recorded lower yield (91.67 and 59 kg/tree) comparing other hydrogel treatment in both seasons, but still higher than control treatment which recorded the lesser values (76.00 and 78.33 kg/tree) in both experiment seasons , this may be due to increasing water availability and the soil was wet for a longer time, so, increasing the availability of nutrients, and also helps in reducing the fruit drop due to water stress, this agrees with the study by for the increased yield of *citrus reticulata* by the application of hydrogel [21].

Moreover, with respect to increasing yield ratio, data in figure (1) cleared that, there is appreciable improvement in the increase yield ratio in all the treatments as compared to control, T4 has the highest increasing yield ratio (49.67 and 51.09) compared to all other treatments in both seasons, followed by T3 which record (40.88 and 41.75), wherever T2 recorded less increasing yield ratio (20.77 and 21.28) in both experimental seasons.

Effect of Different Levels of Hydrogel composite on somefruit physical and biochemical characters.

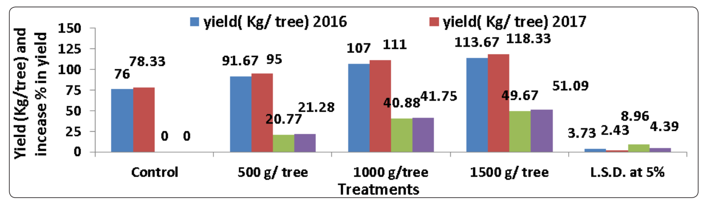

Figure 1: Effect of Levels of Hydrogel composite on total yield (kg/ tree), and increase % in yield of Washington navel orange tree in 2016 and 2017 seasons

Some Fruit Physicals Characters

With this respect, data in Table (5) indicated that hydrogel composite treatments had a positive effect on fruit physical characters of W navel orange under this experimental condition during both seasons.

Concerning fruit weight, T4 increased fruit weight significantly (404.13 and 416.10 g) when compared to other treatments, also, results in Table (5) cleared that control treatment was the lowest values (249.92 and 277.27 g) in both seasons.

Data in Table (5) illustrated that T4 was significantly improved fruit volume significantly (447.44 and 460.64 ml) when compared to other treatments, followed by T3 (369.54 and 396.25 ml), Whereas, T2 was significantly increased fruit volume (310.56 and 320.24 ml) when compared to control treatment, however, control treatment was the lowest values (264.68 and 292.33 ml) in both seasons.

Concerning fruit firmness, results in table (5) cleared that hydrogel composite applications were increased fruit firmness with insignificant effect for the 1st season, whereas, T3 recorded the highest values (13.16 and 14.16 lb/inch^2) compared to other treatments in both seasons, followed by T4 (12.82 and 13.04 lb/ inch^2), this may be due to the accumulation effect of hydrogel composite application in compared to the 1st season of this study. Whereas, T2 was increased fruit firmness (11.63 and 11.89 lb/ inch^2) when compared to control treatment in both seasons.

Generally, hydrogel composite applications improved fruit physio-chemical parameters as compared with control treatment in both seasons.

Table 5: Effect of Levels of Hydrogel composite on some fruit physical characteristicsof Washington navel orange cultivarin 2016 and 2017 seasons

Treatment	Fruit weight (g)		Fruit Volume (cm³)		Firmness (lb/inch²)	
	2016	2017	2016	2017	2016	2017
Control	249.92	277.27	264.68	292.33	10.87	11.33
500 g/ tree	274.43	283.21	310.56	320.24	11.63	11.89
1000 g/tree	338.93	364.23	369.54	396.25	13.16	14.16
1500 g/ tree	404.13	416.10	447.44	460.64	12.82	13.04
L.S.D. at 5%	28.11	32.46	42.65	15.31	1.77	1.24

Some Fruit Chemicals Characters

The data in Table (6) indicated that the mean values of each studied character were high enough to be significant in both seasons. Regarding the effect of hydrogel composite application on fruit chemical characters the data in Table (6) indicated that the mean values of total soluble solids, TSS/acid ratio and vitamin C were high enough to be significant in both seasons. While, the control treatment was significantly increased W. navel orange fruit juice acidity (1.24 and 1.28) when compared to hydrogel treatments in both seasons of experiment.

Moreover, application of different amount of hydrogel composite induced significant differences in TSS% in both seasons in comparing with untreated trees, 1000g/ tree hydrogel composite treatment was recorded highest significant values of juice TSS content (12.20 and 12.48) when compared to all treatments, whereas, control treatment was the lowest value (10.79 and 11.16) in both seasons of this study.

Total Acidity Percentage

Present data in the Table (6) indicated that the control treatment was statistically increaseof total acidity percentage in Washington navel orange fruits when compared with the other treatments. Whereas, T4 and T3 recorded the lowest values in first and second seasons respectively compared to other treatments.

TSS/Acid Ratio

Hydrogel composite treatments significantly improved the (TSS/ acidity ratio) of fruits in both seasons, on the other hand, addition of hydrogel (1000g/tree) toW. Navel orange trees clearly significantly increased TSS/acidity ratio compared with the control treatment in both seasons.

Vitamin C (mg/100gm)

Concerning to the effect of hydrogel composite treatments, data in the Table (6) indicated that, soil addition of hydrogel with different amounts significantly affected Vit. C content when compared to the control treatment in both seasons.So, T4 was recorded the highest values of Vit. C, followed by T3 treatment, while the control treatment recorded the lowest values in both studied seasons.

Table 6: Effect of Levels of Hydrogel composite on some fruit chemicals characteristicsof Washington navel orange cultivarin 2016 and 2017 seasons

Treatment	T S S %		Total acidity %		T S S/ acid ratio		VC ml g/100 ml of juice	
	2016	2017	2016	2017	2016	2017	2016	2017
Control	10.98	11.16	1.24	1.28	9.10	8.70	47.11	48.44
500 g/ tree	11.79	11.93	1.14	1.18	10.66	10.11	52.38	53.71
1000 g/tree	12.20	12.48	0.99	0.99	12.54	12.57	58.10	59.43
1500 g/ tree	12.15	12.29	0.98	1.01	12.21	12.18	58.38	59.78
L.S.D. at 5%	00.28	0.14	0.18	0.033	2.10	0.42	3.09	3.1

Conclusion

The results of this studies cleared that the locally prepared hydrogel composite has practically high-water absorption capacity that was reserved in subsequent wetting and drying cycles. The addition of the hydrogel improved the vegetative growth (plant height, circumference, and the number of leaves/plant). Also, it increased total yield, fruit weight, and enhancement fruit quality, different treatments of hydrogel increased fruit content of total soluble solids and total sugars.

The favorable influences of hydrogel composite application on fruit set and yield could be related to increasing water availability, so, the soil was wet for a longer time and the vital role of hydrogel composite in increasing the availability of nutrient supply, improving the efficiency of macro-elements which in turn, should be reflected on production of high yield.

The use of hydrogel amendments as cultural practice will be useful for increased plant establishment under drought conditions, still, need furthermore studies for different crops.

Acknowledgment

The authors are grateful to the Directory General of Protected Cultivation, Agriculture Research Center for supplying the soil conditioner (Hydrogel composites) which was the basic material of the present research work. We also thanks to Mr. Abd El-Wahed Nasser Abd El-Wahed, Assistant Lecturer, Department of Horticulture, Faculty of Agriculture, Al-Azhar University, for providing the a private orchard where we conducted the research.

References

1. FAO (2016) Citrus fruit fresh and processed statistical bulletin. Food and Agriculture Organization of the United Nations.
2. Annual Reports of Statistical Institute and Agricultural Economic Research in Egypt (2017).
3. Abobatta WF (2018) Improving Navel orange (Citrus sinensis L) productivity in Delta Region, Egypt. Adv Agr Environ Sci 1: 36-38.
4. Abedi Koupai J, Mesforoush M (2009) Evaluation of superabsorbent polymer application on yield, water and fertilizer use efficiency in cucumber (Cucumis sativus). J Irrigation and Drainage 2: 100-111.
5. Mikkelsen RL (1999) Using hydrophilic polymers to control

nutrient release. Nutr Cycl Agroechosys 38: 53-59.
6. Peterson D (2002) Hydrophilic polymers and uses in landscape. Horticul Sci 75: 10-16.
7. Ekebafe LO, Ogbeifun DE, Okieimen FE (2011) Polymer applications in agriculture. Biokemistri 23: 81-89.
8. Abobatta WF (2018) Impact of hydrogel polymer in agricultural sector. Adv Agr Environ Sci 1: 59-64.
9. Ahmed TM (1992) Effect of water on retentivity of some water holding substances and their effects on the water retentivity of a sandy soil.Report.
10. Ahmed FF, Morsy MH (1999) A new method for measuring leaf area in different fruit species. Minia J of Agric Res & Develop 19: 97-105.
11. Turell FM (1946) Tables of surfaces and volumes of spheres and of prolate and oblate spheroids, and spheroidal coefficients. Univ Calif Press Barkeley.
12. AOAC (2005) Association of Official Analytical Chemist. Official Methods of Analysis 18th Edition Washington DC USA.
13. Smith F, Cilles AM, Hamilton KJ, Gedes AP (1956) Colorimetric methods for determination of sugar and related substances. Anal Chem 28: 350-356.
14. Duncan DB (1955) Multiple range and multiple F test. Biometrics 11:1.
15. Max E, Austin L, Bondari K (1992) Hydrogelas a Field Medium Amendment for Blueberry Plants. Hort Science 27: 973-974.
16. Abdel Raouf, AM, Samira RM (2003) Improving Physical Properties and its Effect on Acacia tortilis Seedlings Growth Under Field Conditions. Asian Journal of Plant Sciences 2: 861-868.
17. McGuire E, Carrow RN, Troll J (1978) Chemical soil conditioner effects on sand soils and turfgrass growth. Agron J 70: 317-321.
18. Abraham J, Pillai VNR (1995) N'-methylene bisacrylamide-cross linked poly-acrylamide for controlled release urea fertilizer formulations. Communications in Soil Science and Plant Analysis 26: 3231-3241.
19. Tohidi Moghadam HR, Shirani Rad AH, Nour Mohammadi G, Habibi D, Modarres Sanavy SAM et all., (2009) Response of six oilgrain rape genotypes to water stress and hydrogel application. Agropec Trop Goiania 39: 243-250.
20. Huttermann A, Zommorodi M, Reise K (1999) Addition of hydrogels to soil for prolonging the survival of pinushalepensisgrainlings subjected to drought. Soil Till Res 50: 295-304.
21. Pattanaaik SK, Singh B, Wangchu L, Debnath P, Hazarika BN et al., (2015) Effect of Hydrogel on Water and Nutrient management of Citrus limon, International Journal of Agriculture Innovations and Research. 3: 1555- 1558.
22. Barakat MR, El Kosary S, Borham TI, Abd ElNafea MH (2015) Effect of hydrogel soil addition under different irrigation levels on Grand Nain banana plants. J Hort Sci and Ornamen Plants 7: 19-28.