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Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2018 15(4):4229-4236. **OPEN ACCESS**

Long term effect of hydrogel on yield and yield components of double purpose (forage + seeds) mungbean grown in sandy soil

Mohamed Farouk Elkaramany[1], Ahmed Ibrahim Waly[2], Ahmed Mahmoud Shaban[3], Bakry Ahmed Bakry[1], and Abd El-Samad Mahmoud Younis[1].

[1]Field Crops Research Dept. National Research Centre, 33 El-Behouth Street, and P.O: 12622 Dokki Giza, **Egypt.** [2]Textile Div. [3]Water Pollution Dept. National Research Centre, 33 El-Behouth Street, and P.O: 12622 Dokki Giza, **Egypt.**

***Correspondence:** karamanynrc@yahoo.com **Accepted:** 05 Dec.2018 **Published online:**31 Dec. 2018

Effect of hydrogel in three rates (0.2%, 0.5%, 1%) weight to weight in soil and control (without) on yield and yield components of mungbean (Vigna radiata L.Wilczeck) as seventh season after hydrogel addition. The six bellow crops arranged in sequent's as summer season followed by winter seasons rice – barley – sunflower - wheat – mungbean forage – Egyptian berseem) in the same pot aims to study the effect of hydrogel on soil and yield components of mungbean for long time (seventh season) under newly reclaimed sandy soil. Greenhouse experiment was conducted during summer season of 2017 in research and production station of National Research Centre, Al Emam Malek village, Al Nubaria district, Al Behaira Governorate, Egypt. Results clear that increasing hydrogel from 0.2% to 0.5% and 1% reducing pH, Ca Co_3% and Ec ds/m. Macro and micro elements N, P, K, Cu, I, Mn, Z and available water (A.W) were increased with increasing rate of hydrogel in soil. The highest forage yield 6.85 ton/feddan at 50 days after sowing (DAS) ; the tallest plants 90.0 cm. the highest straw yield 1.82 ton/fed.; the highest biological yield 2.93 ton/fed. And the highest total carbohydrates in seeds 61.5%. were recorded by treatment of 1% hydrogel but 0.5% hydrogel produced the tallest pods 10.83 cm; highest no. of seeds/pod 13.25; highest no. of pods/plant 34.5 cm; seeds weight/plant 38.0 g; seed yield 1.26 ton/fed. And highest protein in seeds 24.35%.

Keywords: Long term, hydrogel, mungbean

INTRODUCTION

Decreasing irrigation quantity is one of the important objectives in countries of reduced water availability. Hydrogels have high absorbents of water which may be one gram dry weight absorb up to 1500 gram water respectively (Johnson 1984; Bowman and Evans 1999). Chemical properties of the hydrogel, soil and irrigation water type were determined the efficiency of hydrogel (Mikkelsen 1994). The non-cross-linked polyacrylamide PAM form was effective tool in reducing soil erosion and earthen canal bed stabilization (Woodhouse and Johnson 1991).

The useful effect of hydrogel in promoted growth and seedling under arid zone was reported by Callaghan et al., (1988 and 1989) also, (Viero et al., (000) reported the same trend with irrigation. Application of hydrogel especially in sandy soil reflect in plant water potential and water retention (Huttermann et al., 1999, Abedi-kaoupai and Sohrab 2004). Jahangir et al., 2008 revealed reduction in required irrigation. Many effectiveness of hydrogels in transplants and tree seedlings reported (Specht and Harvey-Jones 2000; Save et al., 1995; Callaghan et al., 1988, 1989).

Mungbean (*Vigna radiata* L. Wilczek) is a summer pulse crop with short duration (70 – 90 days) Elkaramany et al., 2001 , 2003 and double use (forage and seed) Elkaramany et al., 2005 and Elkaramany 2006 and high nutritive value. Forage contains 12 – 18% protein but seeds contain 22 – 28% protein, 60 -65% carbohydrates, 1 – 1.5% fats, 3.5 – 4.5% ash (El karamany, 2006). Mungbean is common used in cooking using green and mature pods, sprouts are rich in vitamins and amino acids also, in broilers diets as un-traditional feeding stuff Elkhimsawy et al., 1999 or its husks as crop by-products for feeding rabbits and decrease cost of feeding without loss in nutrition value Omer et al., 2017.

The arable land around the world suffers from low water availability which causes reductions in yield of many crops. (Bruce et al., 2002 and Ober 2001). Increasing water use efficiency by roots of plant in sandy soil one of the main objectives aim to tolerate drought stress. Hydrogel may be effective tool to insure soil moisture profile in the root zone which in turn in reducing amount of irrigation under sandy soil condition also, reducing fertilizers leaching from soil. Excellent benefits of hydrogel by many crops were reported by many researchers under Egyptian conditions Waly et al., 2015a on rice and barley; Waly et al., 2015b on sunflower and wheat ; Elkaramany et al., 2015 on sugar beet ; Waly et al., 2016 on botato and Elkaramany et al., 2016 on sunflower.

Thus the aim of this work was to examine effect of three rates of hydrogel on yield and yield components of mungbean as seventh crop in summer and winter seasons after addition of hydrogel as treatments before the first crop only with reducing irrigation to 75% from recommended.

MATERIALS AND METHODS

Green house experiment was carried out during summer of 2017 in Researches and Production Station of National Research Centre (NRC), Al-Nubaria District, Al Behaira Governorate, Egypt. The experimental soil before add hydrogel treatments was analyzed according to Chapman & Pratt 1978. Soil texture was sandy and its characteristics are shown in Table (1)

Location and climate of experimental site:

This experimental farm (latitude 30˚30'1.4"N, and longitude 30˚19'10.9"E, and mean altitude 21 m above sea level). The data of temperature and relative humidity were obtained from "Local Weather Station inside Researches and Production Station of National Research Centre (NRC). Summer is hot, with no rain, and mean air temperature in June, July, August and September was 25.50, 25.46, 26.06 and 24.71^{o} C, with mean relative humidity of 66.93, 75.47, 76.30 and 73.23, respectively.

Sandy soil from wild zone in NRC station was used in the 1st season. The crops arranged in sequent's as summer season followed by winter seasons rice – barley – sunflower - wheat – mungbean forage – Egyptian berseem). Earthenware pots 40 cm diameter and 30 cm in depth each one filled with 10 kg sandy soil then, treatment was done mixed with soil and covered by thin layer of sandy soil in each pot.

Treatments were:

A- Control without (hydrogel).
B- B- (hydrogel 0.2%) weight /weight.
C-(hydrogel 0.5%) weight /weight.
D- (hydrogel 1%) weight /weight in each pot.

Hydrogel prepared method was used as follow, in duple jacketed of a capacity 60 litter equipped with condenser, variable speed motor temperature controller adjusted at 30 °C was reactor charged with 4 kg starch slurred in 40 litter water followed by addition of 2 g emulsifier after 10 minutes acrylonitrile (AN) 4 kg added during 20 minutes with continues stirring for three hours. The obtained product was saponified in isopropanol (40 litters) with continues stirring with the addition of 0.65 equivalent sodium hydroxyl tell the color of the product changed from deep brown to yellowish color. The obtained hydrogel was filtered, dried and milled. Materials used commercial product without purification: Acrylonitrile (AN), Corn starch, Sodium hydroxyl, emulsifier

Table (1): Mechanical and chemical analysis of experimental soil before 1st season.

Sand %	Silt %	Clay %	pH	O M %	CaCO3 %	E.C. dS/m	Soluble N, ppm	Av.P, ppm	Ex. K, ppm
91.2	3.7	5.1	8.3	0.2	4.8	4.3	8.1	0.22	10.2

OM = Organic matter - AV = Available - EX = Exchangeable

At 50 DAS (days after sowing) whole canopy of each pot was cut 10 cm above surface of soil and weighted as forage yield, then attributed to per feddan. At harvest date 100 DAS the following characters were measured 1- Plant height (cm) 2- Pod length(cm) 3- Number of seeds/pod 4- Number of pods/plant 5- Seeds weight/plant (g) 6- Seed yield (ton/fed.) 7- Straw yield (ton/fed.) 8- Biological yield (ton/fed.) 9- Harvest index (seed yield/biological yield %) 10- Total carbohydrates in seed (%) 11- Protein in seeds (%). Characters measured per feddan by weight per pot (10 kg soil) then convert to per feddan (theoretical 106 kg soil) by multiply yield per pot x 10^6.

The experimental design was complete randomize block design in eight replicates. At harvest the obtained data were statistically analyzed according to SAS 9.4 program and treatments means were compared using least significant differences LSD at probability level of 5 %.

The simple correlation coefficient among all studied characters were computed according to Steel and Torrie 1980.

Total carbohydrates were determined (as glucose) after acid hydrolysis and spectro photometrically measured using phenol sulfuric acid reagent according to Dubbois et al., (1956).

Protein in seeds measured by Near Infra Red Grain Analyzer Produced by FOSS Analytical A/S Denmark www.foss.dk.

RESULTS AND DISCUSSION

Data presented at table 2 show mechanical and chemical analysis of experimental soil after harvest of mungbean crop as seventh season after addition of hydrogel treatments. It is clear that percentage of sand; pH; $CaCo_3$ and E.C were decreased but percentage of silt; clay and organic matter were slightly increased, these result may be due to effect of hydrogel by absorb water by many hundreds of its weight combined with nutrients added as fertilizers through seven seasons and effect of hydrogel in reducing leaching nutrients and organic matter from root growth zone, Johnson 1984; Bowman and Evans 1999 clear that hydrogels are super absorbents that absorb and store water hundreds of times their own weight, i.e. 400-1500 g water per dry gram of hydrogel.

It can be discussed from data in table 3 that the effect of increasing hydrogel from 0.2 to 0.5 to 1% in experimental soil resulted increasing available water and macro and micro nutrients N; P; K; Cu; I; Mn; and Z in ascending order meaning that 1% hydrogel had superiority in absorb all measured nutrients and decrease nutrients leaching from soil after seven seasons.

As shown in table 4 treatment of 1% hydrogel had superiority on other treatments in producing 6.85 ton/feddan forage as first purpose of mungbean sown as summer crop in the period of very shortage in legume green fodder with high nutritive value under Egyptian condition especially in sandy soil also, high irrigation requirement due to hot climate in Summer under Egyptian condition. Forage yield increase in ascending order 2.86 – 3.36 – 6.02 to 6.86 ton/feddan by increasing addition of hydrogel from without (control) to 0.2% to 0.5% to 1% hydrogel in soil. The tallest plants 90.0 cm produced by treatment of 1% hydrogel, the second 81.25 cm from 0.5%, the third 76.25 cm the control and the fourth was 0.2% hydrogel.

Treatment of 0.5% hydrogel recorded the best results in characters of pod length 10.83 cm; no. of seeds/pod 13.25; no. of pods/plant 34.5 and heaviest seeds weight/plant 38.0 g.

Results were in accordance with those obtained by Huttermann et al., 1999, Abedi-kaoupai and Sohrab 2004 who reported that hydrogel application in sandy soil promotes an increase in water retention capacity and plant water potential also, Callaghan et al., (1988,1989) found that hydrogel amendments in sandy soils promoted seedlings survival and growth under arid conditions, while Viero et al.,(2000) under similar conditions found only an increase in seedling growth when hydrogel was applied in combination with irrigation.

Data presented in table 5 and figure 1 clear that treatment of 0.5 % hydrogel produced the highest seed yield 1.26 ton/feddan, treatment of 1% came in the second order 1.11 ton/fed., treatment 0.2% came third 1.01 and the fourth was control 0.8 ton/feddan, the same trend was recorded in protein % in seeds 0.4 – 1% - 0.2% - control (without) and treatments arranged in descending order 24.35%, 23.52%, 21.94% and 21.75%.

Treatment of 1% hydrogel had superiority in straw, biological yields and carbohydrates in seeds, in straw yield it recorded 1.82 ton/fed. Followed by 0.5% (1.58 ton/fed.), 0.2% (1.23 ton) and control (1.04 ton). Due to biological yield 1% hydrogel was first by production of 2.93 ton/fed., second was 0.5% (2.84 ton), third was 0.2% hydrogel (2.23 ton) and the fourth was control (without hydrogel) (1.84 ton).

Table (2): Mechanical and chemical analysis of experimental soil after harvest of 7th season.

Characters / Treatments	Sand %	Silt %	Clay %	pH	OM %	$CaCo_3$ %	E.C. dS/m
Control without (hydrogel)	91.10	3.70	5.20	7.9	0.35	1.4	1.7
0.2% (hydrogel)weight/weight	90.66	3.94	5.50	7.9	0.40	1.3	1.6
0.5%(hydrogel)weight/weight	90.58	3.96	5.56	7.8	0.45	1.3	1.4
1% (hydrogel)weight/weight	90.48	3.98	5.64	7.5	0.50	1.3	1.2

OM% = Organic matter%

Table (3): Macro, micro nutrients and available water of experimental soil after harvest of 7th season.

Characters / Treatments	N ppm	AV. P ppm	EX. K, ppm	Cu ppm	I ppm	Mn ppm	Z ppm	A.W %
Control without (hydrogel)	52	12	36	0.36	2.12	0.29	1.93	10.2
0.2% (hydrogel)weight/weight	64	13	40	0.58	2.62	0.37	2.05	10.6
0.5%(hydrogel)weight/weight	68	14	52	0.60	2.88	0.42	2.64	12.0
1% (hydrogel)weight/weight	92	15	68	0.68	3.64	0.51	3.24	14.0

EX = Exchangeable - AW = Available Water

Table 4- Effect of hydrogel % in soil on yield and yield components of mungbean double purpose (forage + seed)

Characters / Treatments	Forage yield ton/fed. At 50 DAS	Plant height (cm)	Pod length (cm)	No. of Seeds /pod	No. of pods/ plant	Seeds weight /plant g
Control without (hydrogel)	2.86	76.25	7.50	7.50	18.00	25.25
0.2% (hydrogel)weight/weight	3.36	62.00	8.65	9.50	24.00	30.25
0.5%(hydrogel)weight/weight	6.02	81.25	10.83	13.25	34.50	38.00
1% (hydrogel)weight/weight	6.85	90.00	8.00	10.50	25.50	31.50
LSD at 0.05	0.65	1.70	1.64	1.65	7.23	10.03

Table 5- Effect of hydrogel % in soil on yield and yield components of mungbean.

Characters / Hydrogel % In soil	Seed yield/ (ton/fed.)	Straw yield ton/fed	Bio-yield/ ton/fed	Harvest index%	TC % in seeds	P % in seeds
Control without (hydrogel)	0.80	1.04	1.84	43.59	46.7	21.75
0.2% (hydrogel)weight/weight	1.01	1.23	2.23	45.18	60.4	21.94
0.5%(hydrogel)weight/weight	1.26	1.58	2.84	44.34	61.0	24.35
1% (hydrogel)weight/weight	1.11	1.82	2.93	38.67	61.5	23.52
LSD at 0.05	0.12	0.37	0.42	5.00	22.2	1.35

T C% = Total carbohydrates % - P = Protein

Table 6 - Correlation coefficient between all studied characters

	Pod length	No.of seeds/pod	No. of pod/plant	Seed weight/plant	Seed yield/fed	Straw yield/fed	Bio yield/fed	Harvest index	TC	Protein seed
Forage yield/fed	0.33	0.71**	0.62**	0.43	0.72**	0.77**	0.81**	-0.41	0.34	0.77**
Pod length		0.76**	0.66**	0.81**	0.63**	0.11	0.3	0.38	0.17	0.52*
No.of seeds/pod			0.88**	0.60**	0.89**	0.50*	0.68**	0.06	0.14	0.83**
No. of pod/plant				0.50*	0.87**	0.58**	0.73**	-0.08	0.24	0.69**
Seed weight/plant					0.55*	0.37	0.46	-0.04	0.17	0.47
Seed yield/fed						0.69**	0.85**	-0.09	0.27	0.78**
Straw yield/fed							0.97**	-0.78**	0.22	0.60**
Bio yield/fed								-0.60**	0.25	0.71**
Harvest index									-0.02	-0.15
TC										0.01

The same trend in straw and biological yields was recorded in total carbohydrates in seeds 61.5% % - 61.0% - 60.4% and 46.77%. Treatment of 0.2% hydrogel recorded the best harvest index (seed yield/biological yield) %, 0.5% came second, control was third and the lowest was 1% hydrogel.

CONCLUSION

It can be concluded that superiority of treatment 1% hydrogel in characters of straw and biological yields may be due to the highest amount of water absorbent by highest level of hydrogel 1% in soil also, long time decomposing of 1% hydrogel level compared to 0.2%, 0.5% and without hydrogel which reflected on huge canopy. Results were in accordance with obtained by; Elkaramany et al., 2015; Waly et al., 2016 and Elkaramany et al., 2016.

It can be concluded from data in table 6 that straw; biological; forage and seed yields had high correlation between them and any character had high benefits to other one from the 4 characters so, any treatment increase one character of them will reflect on other character by increasing its value also, these result was true in effect of hydrogel treatments on yield and yield components which recorded the same trend of same effect of treatment on the four characters.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

ACKNOWLEGEMENT

This work was supported by scientific project section, National Research Centre (P11030122) under title "Increasing Productivity of Some Untraditional Crops and Crop Residues for Animal Feeding".

AUTHOR CONTRIBUTIONS

MFE, Mohamed Farouk Elkaramany designed and performleed the experiments and also wrote the manuscript.

AIW, Ahmed Ibrahim Waly, performed hydrogel treatments, designed experiments and reviewed the manuscript.

AMS, Ahmed Mahmoud Shaban designed and performleed the experiments, also wrote the manuscript and reviewed the manuscript.

BAB, Bakry Ahmed Bakry performed hydrogel treatments, and data analysis. designed experiments and reviewed the manuscript.

AMY, Abdelsamad Mahmoud Younis agronomic treatments, data analysis and reviewed the manuscript.

All authors read and approved the final version.

REFERENCES

Abedi-kaupai,J. and Sohrab,F. 2004. Evaluating the application of superabsorbent polymers on soil water capacity and potential on three soil textures. Iranian Journal of Polymer Science and Technology 17, 163-173.

Bowman,D.C. and Evans,R.Y. 1999. Calcium inhibition of polyacrylamide gel hydration is partially reversible by potassium. Horticultural Science 26, 1063-1065.

Bruce,W.B. ; Edmeades,G.O. ; Barker,T.C.(2002). Molecular and physiological approaches to maize improvement for drought tolerance. J. Exp. Bot. 53,13-25.

Callaghan,T.V., Abdelnour,H. and Lindly,D.K. 1988. The environmental crisis in the Sudan: the effect of water absorbing synthetic polymers on tree germination and early survival. Journal of Arid Environments 14,301-317.

Callaghan,T.V., Lindly,D.K., Ali,O.M., Abdelnour,H. and Bacon,P.J. 1989. The effect of water-absorbing synthetic polymers on the stomata conductance, growth and survival of transplanted *Eucalyptus microtheca* seedlings in the Sudan. Journal of Applied Ecology 26, 663-672.

Chapman, H.D. and R.F. Pratt, 1978. Methods Analysis for Soil, Plant and Water. Univ. of California on the Nodulation, Plant Growth and Yield of Div. Agric. Sci., pp: 16-38.

Dubbois, M., Gilles,K.A. Hamilton,J.K. Rebers,P.A. and Sith,F. (1956). Colorimetric methods for determination of sugars and related substances. Analysis Chem., 28: 250-326.

El Kramany, M.F. ; M.M. Tawfic. ; Amany A. Bahr and M.A. Abdel Aziz (2005). Double purpose (forage and seed) of mungbean production

2- Response of two mungbean varieties to replacement part of chemical fertilizers by organic fertilizers. Egypt J. Agric. Res. 2 (1): 257-268.

El Kramany,M.F. (2001). Agronomic studies on some exotic mungbean genotypes under Egyptian conditions. Egypt J. Agron.23:1-10.

El Kramany,M.F. (2006). Double purpose (forage and seed) of mungbean production 1- Effect of plant density and forage cutting date on forage and seed yield of mungbean (Vigna radiata L.) Wilczek Res. J. Agric. and Bio. Sci. 2 (4): 162-165.

El Kramany,M.F. ; Zeidan,M.S. and Mirvat E. Gobarh. (2003). A comparative study on productivity of some mungbean varieties grown in sandy soil, Egypt J. Agron, 25:59-67.

El-Karamany, M.F, Waly, A, Shabaan, A. M, Bakry, A.B and Elewa,T.A. (2016). Utilization of hydrogel for reducing water irrigation under sandy soil condition 4-Yield and yield components of sunflower as affected by hydrogel and drought stress in sandy soil. . Research Journal of Pharmaceutical, Biological and Chemical Sciences RJPBCS 7(4):1056- 1063.

El-Karamany, M.F.; Waly, A.; Shaaban, A.M; Alhady, O.A and Bakry, A.B (2015).Utilization of hydrogel for reducing water irrigation under sandy soil condition 3- Effect of hydrogel on yield and yield components of sugar beet under sandy soil conditions. Research Journal of Pharmaceutical, Biological and Chemical Sciences, 6(2):1025-1032.

El-Khimsawy, K. A.; Younis, T. M.; Mohmed, F. A. and Al Alfy, M. A. (1998). A study on mungbean as a non-traditional feed- stuff for broilers. Al – Azhar J. Agric. Res. 28: 101-115.

Gomez,K.A. and Gomez,A.A.(1984). Statistical procedures for agricultural research. An International Rice Research Institute. Book John Willey and Sons Ince, New York,USA.

Hamed Abdel-Aziz Ali Omar1 ; Mohamed Farouk El karamany2 ; Sawsan Mansour Ahmed1 ; Soha Sayed Abdel-Magid1 and Bakry Ahmed Bakry2. Using Field Crop by-products for Feeding Rabbits. Bioscience Research, 2017, 14(2): 224-233.

Huttermann,A., Zommorodi,M. and Reise,K. 1999. Addition of hydrogels to soil for prolonging the survival of *Pinus halepensis* seedlings subjected to drought. Soil and Tillage Research 50, 295-304.

Jahangir Abedi Kaoupai; Sayed Saeid Eslamian and Jafar Asad Kazemi 2008. Enhancing the available water content in unsaturated soil zone using hydrogel to improve plant growth indices. Ecohydrology & Hydrology, vol.8. No.(1). 67-75.

Johnson,M.S. 1984. Effect of soluble salts on water absorption by gel-forming soil conditioners. Journal of the Science of Food and Agriculture 35, 1063-1066.

Mikkelsen,R.L. 1994. Using hydrogels to control nutrient release. Fertilizer Research 38, 53-59.

Ober,E.(2001). The search for drought tolerance in sugar beet. Brit. Sugar Beet Rev. 69:40-43.

Save,R., Pery,N., Marfa,O. and Serrano,L. 1995. The effect of hydrophilic polymer on plant and water status and survival of pine seedlings. Hort Technology 5,141-143.

Snedecor, G.W. and Cochran, W.G. (1990). "Statistical Methods" 8th ed., Iowa State Univ., Press, Ames, Iowa, USA.

Specht,A. and Harvey-Jones,J. 2000. Improving water delivery to the roots of recently transplanted seedling trees: the use of hydrogels to reduce leaf and hasten root establishment. Forest Research 1, 117-123.

Steel,R.G. and Torrie,J.H. 1980. Principles and procedures of statistics. 2nd ed. Mc Grow Hill, N.Y.

Waly, A. El-Karamany, M.F.; Shaaban, A. M; Bakry, A.B and Elewa, T.A (2015a).Utilization of hydrogel for reducing water irrigation under sandy soil condition 2-Preliminary study: yield and yield components of rice and barley in sandy soil as affected by hydrogel. Research Journal of Pharmaceutical, Biological and Chemical Sciences, 6(2): 1018-1024.

Waly, A. El-Karamany, M.F.; Shaban, A.M; Bakry, A.B and Elewa, T.A (2015b). Utilization of hydrogel for reducing water irrigation under sandy soil condition. 1-Preliminary study on the effect of hydrogel on yield and yield components of sunflower and wheat under newly reclaimed sandy soil. Research Journal of Pharmaceutical, Biological and Chemical Sciences, 6(2):1033-1039.

Waly, A. I., El-Karamany, M. F.; Shabaan, A. M.; Bakry, A. B* and Elewa, T. A. 2016. Utilization of hydrogel for reducing water irrigation under sandy soil condition 5-Yield

and yield components of potato (Solanum tuberosum L.) as affected by hydrogel and drought stress in sandy soil. Research Journal of Pharmaceutical, Biological and Chemical Sciences RJPBCS 7(4):1039-1046.

Woodhouse,J.M. and Johnson,M.S.1991. Effect of soluble salts and fertilizers on water storage by gelforming soils conditioners. Acta Horticulturae 294,261-269.