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Effect of Super water absorbent (SWA) hydrogel on productivity and quality of Tomato

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ABSTRACT

In this work, superwater absorbent hydrogel (SWA) based on polysaccharide was prepared from aqueous solution of carboxymethyl cellulose (CMC)/acrylamide with radiation processing technology using Co-60 gamma source at room temperature (~ 27ºC). When SWA is mixed with soil, the morphological study i.e., plant height, weight of roots, number of branch, number of leaves and yield of fruits of tomato plant showed higher values than that of the soil without SWA. It has also been observed that with and without SWA the elemental properties of soil gave almost the same values meaning that adding SWA did not affect the properties of soil. Regarding the quality of fruit, the food value (i. e., protein, ascorbic acid, iron) of green tomato showedno significant changes with and without SWA, although the significant increase in total phenol content of green tomato grown in SWA mixed soil indicates better antioxidative quality.

Keywords: SWA,Co-60 gamma source, morphological study, harvesting

INTRODUCTION

Super absorbent hydrogels are cross-linked polymers exhibiting unusually high water uptake abilities [1]. These materials have found extensive use mostly in manufacturing of baby diapers [2], sanitary napkins [3] and in agriculture to retain moisture in the soil [4]. In arid and semiarid regions, there is an increasing interest in using water saving superabsorbent polymer (SAP) for field crop production.The problem of insufficient use of fertilizer and irrigation water by crops is most important in semiarid and arid regions in the world and application of water-saving super absorbent polymers (SAP) into the soil could be an effective way to increase both water and nutrient use efficiency in crops[5, 6]. When polymers are incorporated with soil, it is presumed that they retain large quantities of water and nutrients, which are released as required by the plant. Thus, plant growth could be improved with limited water and nutrient supply [7]. Johnson (1984) reported an increase of 171 to 402% in water retention capacity when polymers were incorporated in coarse sand (Figure 1). Addition of polymer to peat decreased water stress and increased the time to wilt [7,8]. The incorporation of superabsorbent polymer with soil improved soil physical properties [9], enhanced seed germination and emergence [8], crop growth and yields [10]and reduced the irrigation requirements of plants [11, 12].The use of hydrophilic polymer materials as carrier and regular of nutrient release was helpful in reducing undesired fertilizer losses, while sustaining vigorous plant growth [13].

Three classes of superabsorbent polymer are commonly used and are classified s natural, semi-synthetic and synthetic polymers[13]. Earlier, polymers were not used in the agricultural field due to their high prices. Recently, many polymer industries developed around northern China and the prices became comparatively cheaper (about 5 USD kg^{-1}). Thus, the application of SAP along with reduced rate in the agricultural field has become a popular water and fertilizer saving technology for many farmers in arid and semiarid regions of northern China. Therefore, polymers can retain moisture and fertilizer up to 3 to 5 years after application, which could also bring some additional economic and environmental advantages. The main objective of this study to evaluate the effectiveness of super water absorbent (SWA) in tomato plants (i.e., plant growth and tomato yield) and food values of green tomato.

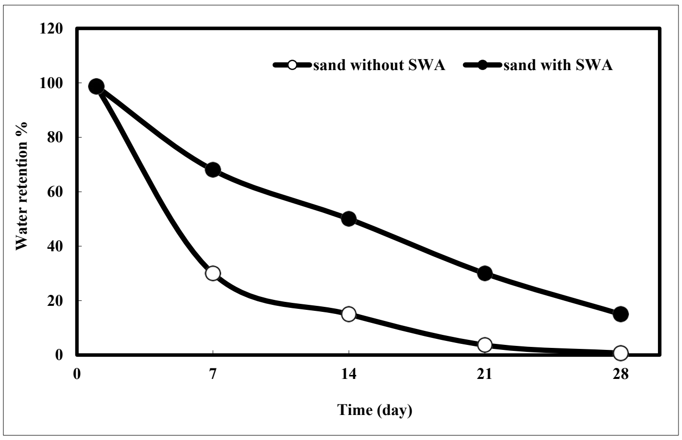

Figure 1: Water retention capacity of SWA in sand.

MATERIALS AND METHOD

Preparation of super water absorbent (SWA)

Homogeneous solutions containing 5% of Acryl amide were prepared in deionized water with different concentration of carboxymethyl cellulose (2, 3 and 5%). Then the solutions were irradiated with gamma-rays from Co-60 source by varying radiation dose from 10, 15, 20, 25, 30 and 35 kGy at room temperature. The irradiated samples were dried at room temperature and then in oven at 50°C till constant weight. The dried samples were used for the measurement of properties that is gel fraction and water absorption capacity. It was found that gel fraction depends on the concentration of carboxymethyl cellulose (CMC) and radiation dose. The maximum value of gel fraction is obtained at 25 kGy radiation dose with 3% CMC[14]. From this study it is also found that at 25 kGy, 5% acrylamide (AAm) with 3% (CMC) give the highest water absorption value [14].

Water retention of sand with and without SWA

5% AAm with 3% CMC blend hydrogel at 25 kGy has used as SWA that has apply to measure the water retention capacity in sand. In that case SWA mixed with sand in the proportion of 0.5g/kg of sand and another is only sand (without SWA).

Water Retention of sand has measured using the following equation

Water Retention = Mc x 100 / Mo ………………. (i)

Where, Mc= mass of water after certain days**,** Mo= initial mass of water

Use of SWA in planting

5% Acrylamide (AAm) with 3% Carboxymethyl cellulose (CMC) blend hydrogel at 25kGy has used as super water absorbent (SWA) which has apply in agricultural purpose. SWA mixed with soil in the proportion 0.5g/kg of soil and another is only soil (without SWA). The soil sample was in Savar area, Dhaka, Bangladesh. For tomato plants, seeds were sown on 3rd November 2012 and harvested on 27th January 2013.

Biochemical analysis: Biochemical analysis of tomato fruits was analyzed at Food Technology Division, Institute of Food and Radiation Biology (IFRB), AERE, Savar, Dhaka.

Estimation of Moisture. The initial weight of the sample was taken, and then samples were dried in an oven at about 105°C for about 5 to 6h until constant weight was reached. The percentage of moisture content was determined.

Protein Determination. The protein content of the fish was determined by micro Kjeldahl method AOAC [15]. It involves the conversion of organic nitrogen to ammonium sulphate by digestion of fish flesh with concentrated sulphuric acid in a micro Kjeldahl flask. The digest was diluted, made alkaline with sodium hydroxide, and distilled.

The liberated ammonia was collected in a boric acid solution and total nitrogen was determined titrimetrically. The percentage of protein in the sample was calculated

***Estimation of Ash*:** The ash content of a sample is residue left after ashing in a muffle furnace at about 550–600°C till the residue becomes white. The percentage of ash was calculated by subtracting the ash weight from initial weight.

Total phenol content: Total phenol content was determined according to the Folin-Ciocalteu (FC) method [16]. An aliquot of sample (0.5 ml) was added to diluted 2N FC reagent (1:10) (2.5 ml). After 3-4 min, 7.5% sodium carbonate solution (2 ml) was added to the mixture and kept in dark for 2 hr at room temperature. The absorbance of the solution was measured UV visible spectrophotometer at wavelength 765 nm. Gallic acid was used as a calibration standard. The data was expressed as mg Gallic acid equivalents/100 g sample

Ascorbic acid: Ascorbic acid was determined by 2, 6-dichloroindophenol titrimetric method [17]. Briefly, sample (2 g) was homogenized with 3% metaphosphoric acid (25 ml) and was filtered through filter paper (Whatman 1, 7.0 cm). Then an aliquot (5 ml) of filtrate was titrated with the 2, 6-dichloroindophenol dye (standardized by the metaphosphoric acid) to a pink end-point. Results were expressed on a fresh weight basis as mg ascorbic acid equivalent/100 gm.

Iron:Iron was determined calorimetrically making use of the fact that ferric iron gives a blood red color with potassium thiocyanate [17].

RESULT AND DISCUSSION

Effect of SWA on water retention capacity of sand

From Figure 1, it is observed that after 7, 14 and 21 days sand without SWA, water retention is around 28, 10 & 4% respectively. It is also observed that after 28 days the sand without SWA had nearly given off all water. On the other hand the sand with 0.5% wt SWA after 7, 14 and 21 days, water retention is 70, 58 & 30% respectively. It is also observed that after 28 days the sand with SWA still retained 15% water. Therefore, the current result revealed that sand with SWA can hold more water than the sand without SWA.

Determination of pH, electrical conductivity (EC) of soil

The soil pH was determined following the procedure outlined by Islam and Weil [18], 10 g of the air-dried sample was mixed with 25 mL distilled water (soil: water at a ratio of 1: 2.5) and was stirred. The mixture was allowed to settle for 30 min. The slurry was decanted and pH was measured with calibrated pH meter (Sension1, HACH, USA). The electrical conductivity (EC) was measured using a conductivity meter (Sension5, HACH, USA) in the soil suspension having a soil: water at a ratio of 1:40, after 30 min shaking. The fundamental chemical properties of soil are presented in Table 1.

Table 1: Fundamental chemical properties of soil

Items	Value		Unit
	Soil without SWA	Soil with 0.5% SWA	
pH (H2O)	7.2	7.58	-
Electrical Conductivity (EC)	43.2	54.0	µs/cm

Elemental Analysis of soil samples using PIXE technique

The elemental analysis of soil with and without SWA is implemented by particle induced X-ray emission (PIXE) ion beam analysis technique using 3MV Tandem Accelerator of Atomic Energy Research Establishment (AERE), Institute of Nuclear Science and Technology (INST), Savar, Dhaka. Soil samples were dried and pressed to make pellet of 12 mm diameter. The prepared pellets were irradiated with proton beam of energy 2.55 MeV and of current 25 nA until 10 micro coulomb charge was registered by the current integrator. High Purity Germanium (HPGe) detector was used to detect the X-rays emitted from the irradiated soil samples. The detected signals were processed via pre-Amplifier, Amplifier and Analog to Digital Converter (ADC) and finally displayed and stored by the data acquisition software MPANT [21]. Later the GUPIXWIN [22] is used toanalyze the complex PIXE spectra to detect and calculate the elemental concentration in the sample. Table 2 displays the concentrations of different elements that were found in the soil samples together with the standard soil sample(SRM 2586 by NIST, USA) [23] for comparison.

*This Standard Reference Material (SRM 2586) is intended for use in the evaluation of methods and for the calibration of apparatus used to determine the concentration of elements in soil.

Table 2: Elemental analysis of soil (in mg/kg or ppm) using PIXE technique.

Elements	Conc. values of Soil without SWA(control)	Conc. values of Soil with 0.5% SWA	Conc. values of soil Standard(*SRM 2586)
K	6671 ± 162.77	6517 ± 157.06	9760 ± 180
Ca	9565 ± 118.6	9169 ± 114.61	22180 ± 540
Ti	4119 ± 63.43	3992 ± 61.08	6050 ± 660
V	217.8 ± 37.46	247.4 ± 35.58	(160)
Cr	112.4 ± 35.08	98.05 ± 33.33	301 ± 45
Mn	516.1 ± 51.61	450.1 ± 49.47	1000 ± 18
Fe	32659 ± 101.24	31706 ± 98.29	51610 ± 890
Co	742.7 ± 34.98	682.9 ± 33.33	(35)
Ni	164.4 ± 18.10	138.8 ± 16.34	(75)
Cu	37.76 ± 17	44.36 ± 15.5	(81)
Zn	122.4 ± 17.64	123 ± 16.65	352 ± 16
As	ND	ND	8.7 ± 1.5
Sr	ND	ND	84.1 ± 8.0
Pb	ND	ND	432 ± 17

The values in parentheses are non-certified and given as information only.ND: Not detected. Error has been calculated by the software GUPIXWIN.

Effects of SWA on tomato plants and fruits

SWA used in agricultural sector to improve water holding capacity of soils and promote germination of seeds. Tomato plant height was markedly increased (110 cm) by experimental treatments (0.5% SWA) compared to control plants (Table 3). This finding is in agreement with Yazdani et al.,[19] observations, based on increasing of soybean height with application of super absorbent in soil. It was observed that number of branches and leaves and root weight were highest in tomato plant grown in super absorbent treated soil. Data analysis also showed that number of flowers and fruits significantly highest by applying 0.5% super absorbent compare to control. Johnson and Piper [20] demonstrated that the application of super absorbent polymer to growing media due to the reduced impact of water stress during the growing cycle can improve crop quality.

Table 3: Morphological data of Tomato Plant with & without SWA

%SWA (gm)	Height (cm)	No. of branch	No. of leaves	No. of flowers	No. of fruits	Weight of leaves (gm)	Weight of roots (gm)
0	63 ± 0.1	14.0 ± 0.1	98 ± 0.1	07 ± 0.1	10 ± 0.1	18 ± 0.1	07 ± 0.1
0.5	110 ± 0.1	20.0 ± 0.1	205 ± 0.1	22 ± 0.1	35 ± 0.1	53 ± 0.1	160 ± 0.1

Values are mean of three replicates

Effects of SWA on biochemical and functional quality of green tomato

Biochemical and functional composition of green tomato treated with and without SWA has shown in Table 4. Tomato planted in 0.5% SWA soil showed reduced rate of moisture content than control sample. Reduced rate of protein (2.80 g/100g) and iron content (2.91 mg/100g) was found in tomato planted in 0.5% SWA compared to control one. Ash content and ascorbic acid content was more or less same in tomato planted in soil with or without super water absorbent hydrogel. But the total phenol content as the functional antioxidant marker has been increased in tomato planted with 0.5% SWA (3.25 mg/100g) compared to control sample suggesting increased antioxidative ability.

Table 4: Biochemical and functional analysis of green tomato with and without SWA.

Treatment	Parameters					
	Moisture (g/100g)	Protein (g/100g)	Ash (g/100g)	Iron (mg/100g)	Total phenol (mg/100g)	Ascorbic acid (mg/100g)
soil without SWA or control	87.00 ± 0.29	3.29 ± 0.24	0.80 ± 0.003	4.14 ± 0.11	2.98 ± 0.07	18.0 ± 1.8
Soil with 0.5% SWA	86.31 ± 0.44	2.80 ± 0.21	0.81 ± 0.006	2.91 ± 0.05	3.25 ± 0.23	18.6 ± 1.04

CONCLUSION

From the present study it was found that adding super water absorbent (SWA) hydrogelto soil can improve the soil capability to retain water. The elemental analysis shows that by addition of SWA no significant change (a small decrease of concentration values after adding SWA is observed that is expected because by adding few more atoms changes the ppm values) has been occurred in the soil samples, which means that the nutrition level would not be affected. Another finding is that in the control soil sample and in the SWA no harmful elements (such as As, Pb, Cd, etc.) were found.The morphological study showed that plant height, weight of roots, number of branch, and number of leaves and yield of fruits growing in SWA treated soil was significantly higher than the soil without SWA. It was also observed that green tomato grown in soil with SWA has significantly higher phenolic component suggesting increased antioxidative ability.

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