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Synthesis of Superabsorbent Polymer Using Agricultural Biomass for Slow Release Fertilizer Delivery In Soil

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Abstract: *Superabsorbent polymer is a polymer of hydrophilic networks that effectively absorb & retain large amount of aqueous solutions. Superabsorbent polymers are widely employed for various applications such as in sanitary products, agricultural and horticultural activities. Superabsorbent polymers are classified into two types natural and synthetic. Natural super absorbents are polypeptide and polysaccharide based whereas synthetic super absorbents are petrochemical based. The type of biomass, dosage of initiator, crosslinker and other factors responsible in changing the absorption capacity of the material are studied. A fertilizer stick was made using the superabsorbent polymer and slow release fertilizers. Trials & biodegradability studies were carried out. The study revealed that the paddy straw- SAP composite can absorb 208g/g of water and it was greatly affected by ph. Paddy straw-graphite oxide SAP composite had an absorption capacity of 326g/g in distilled water. The fertilizer stick was effective in supplying the slow release micronutrient to the plants.*

***Index Terms* - Superabsorbent polymer, fertilizer, agriculture, slow release, graphite oxide .**

I. INTRODUCTION

According to the UN reports, the current world population 7.1 billion increase to 9.3 billion by 2050. The population increase is remarkable in developing countries, especially in Africa and Asia [1]. By 2028 the population of India is expected top the world & surpasses the population of china, the current largest populated country. Along with the population growth, the demand for food is also expected to increase. In order to balance the demand – supply chain and eradicate food insecurity, it is important to improve the existing agricultural practices. However, harvesting huge amounts of crops leads to accumulation of crop residues on and off the field. The crop wastes such as stalks, leaves, fruit peels etc are used as feed for animals, biofuel production, compost or soil manure for plants, i=used in cultivation of mushrooms [2]. Due to shortage of human labour, high cost of removing the crop residue from the field and mechanized harvesting of crops the crop residues are burnt on-farm. Crop residue burning releases toxic gases, damage the environment, soil fertility is also lost by this process. Hence it is important to manage the agricultural biomass such as stalks, leaves etc., Although few agricultural wastes are used in construction activities, paper making & production of biofuels, the rate of production rate greatly exceeds the rate of utilization .

Superabsorbent polymers (SAP's) are hydrophilic networks that expand in aqueous solution and retain large amounts of water. superabsorbent hydrogels form hydrogen bonds with water molecules and thus absorption occurs. The largest use of SAP's is seen in sanitary napkins, baby & adult diapers. It is used in prevention of water penetration to power cables. SAP's are also used as artificial snow for filming purposes. Superabsorbent gels can supply water to plants and help in minimizing the leaching loss of nutrients. Based on the graft material used, Superabsorbent polymers are classified into natural and synthetic polymers. The methods of SAP synthesis are classified as physical methods & chemical methods. solution polymerization, radiation polymerization, suspension polymerization are followed by chemical modification & physical methods such as cryogenic treatment, electron beam irradiation. Aqueous solution polymerization is induced free radical polymerization. The free radical polymerization is a process that forms polymers by addition of monomers as building blocks. The cross-linker molecule forms a link between the graft material and monomer. Thus, it forms a hydrophilic network that effectively absorbs water. Aqueous polymerization is simple, cost effective, it offers easy control of reaction & results in stable mass shaped products.

II. RELATED WORK / LITERATURE REVIEW

In 1966 the Starch derived from wheat straw was used as graft material and a copolymer was synthesized by using acrylonitrile & ceric ammonium nitrate as initiator [3]. The US Department of Agriculture produced a hydrolyzed product (HSPAN) in 1970s [4]. In recent years, a tremendous response due to its wide variety of applications. Grafting has been done on Kenaf fibers by using meth acrylonitrile and ceric ion toluene as redox pair initiator [5]. Focher et al. Synthesized a copolymer by using steam exploded wheat straw [6]. Pineapple leaf was defatted and used for grafting [7]. Das and Saikia, modified non mulberry silk-*Antheraea assama* by chemical treatment [8]. Delignified cellulose was used in grafting of acrylonitrile by using ceric ammonium nitrate as initiator by Farag and Al-Afaleq [9]. Ghosh and Bandyopadhyay synthesized polymer using diethylene triamine-modified oxycellulose [10]. Abdel et al., synthesized polymer using rice straw and modified - maize starch Rice straw polyacrylonitrile that can be used in wastewater treatment [11]. Calabria et al., studied about slow release fertilizer comprising of biomass materials and can be used in synthesizing injection molded parts and used as granules.[12]. Housini et al. produced economically cheap hydrogels by using rice straw. Linhu et al., studied that the incorporation of GO to the composite increased the water absorption capacity and it also improved the thermal stability of the composite [14]. According to the article published by Jiajia Xi1 & Panpan Zhang f superabsorbent hydrogels act soil conditioners, help in growing drought-resistant plants by supplying the fertilizers through root mediated transfer. [15].

III. METHODOLOGY

Aqueous solution polymerization is a technique used in the synthesis of superabsorbent polymer. Aqueous solution polymerization typically makes use of an initiator, crosslinker & monomer. Peroxides, persulfates are most used initiators. In the present study a variety of agricultural biomass, initiators & their concentrations, the effect of pH was studied. In order to improve the superabsorbent properties graphite oxide was used. The agriculture biomass predominantly consisting of straws was sundried and it was crushed by using mixer.

3.1 Synthesis of Superabsorbent polymer

Appropriate amount of agricultural biomass was taken in a 4 necked flask, distilled water (30ml/g of biomass) was added to it and it was connected to an electric stirrer. A free radical initiator compound was added to the flask and it was kept under stirring for 15-20minutes. A solution was made by adding crosslinker (0.1g/g of biomass), acrylic acid (3.4g/g of biomass) using distilled water. The temperature of the reaction was maintained at 70ºC for 3 hours. The gel thus formed was collected and weighed. The pH was maintained by adding 1mol/l of KOH solution. The gel was washed using distilled water to remove the excess reactants. It was further dried in oven at 80ºC for 12-16 hours. The dried SAP powder is collected in sample covers and swelling capacity tests are conducted. The effect of pH was studied by maintaining the pH from the acidic – alkaline. The samples with different pH levels were washed with distilled water and dried in oven. Further the swelling capacity was studied by weighing 1g of sample and adding distilled water to it. Graphite flakes were exfoliated and reduced by following the modified Hummer's method of graphite oxide synthesis. Graphite oxide was dispersed in distilled water (10mg in 50ml of distilled water) followed by the addition of biomass, initiator and crosslinker as followed earlier. The product after polymerization was collected & weighed. pH of the gel is adjusted to alkaline and it was washed with distilled water. The product obtained is dried at 80ºC for 12-16 hours in an oven. Swelling capacity test was conducted.

3.2 Swelling capacity

The swelling capacity test was conducted by weighing 1g of SAP sample in a beaker. Known quantity of distilled water is added at regular intervals. The weight of the sample after absorption is measured.
Swelling capacity of sample is calculated by the following formula:
Swelling capacity=$(W2-W1)/W1 \times 100$ where W1 & W2 are weight of dry sample & swollen sample.

3.3 Fertilizer stick

Micronutrients such as iron, magnesium, zinc, boron, potassium, phosphorous, calcium are required by the plants in minute quantities & they play an important role in plant growth. Hence slow release salts of these nutrients are chosen, a fertilizer stick was made by combining these salts along with superabsorbent powder by the addition of a binding agent to maintain the integrity of the stick. The pH of the stick was 4.1 and it was soluble in water. The percentage of each micronutrient is as follows:

Sulphur	0.03 - 0.1%
Magnesium	0.2%
Calcium	0.5%
Potassium	1-1.5%
Chlorine	0.1mg
Boron	0.02mg
Manganese	0.05mg
Zinc	0.2mg
iron	0.01mg

Table 1: micronutrient requirement

Field trails were carried out by choosing button rose plant (10'clock flower plant). 3 fertilizer sticks consisting 1gm of fertilizer were placed 2 cm apart and 4cm in depth to the plant. The number of sticks to be placed were determined according to the diameter of the pot, to facilitate the slow release of nutrients. One plant with similar growth condition was maintained as control (i.e. without any fertilizer). The growth of the plants was monitored for few days and the results were observed.

3.4 Biodegradability studies

Soil burial method was followed to study the degradation of the SAP-fertilizer stick. The fertilizer sticks of 1 g were placed under the soil and the soil was kept moist with water and stored outside the room throughout the test period.

IV. RESULTS AND DISCUSSION

Superabsorbent polymer was synthesized from paddy straw, sodium carboxymethyl cellulose, wheat bran. The table below indicates the result for swelling capacity test conducted for each type of graft material.

Sl no	Graft material	Swelling capacity (%)
1	Paddy straw	208
2	Wheat bran (coarsely powdered)	150
3	Wheat bran (finely powdered)	138
4	Sodium carboxy methyl cellulose	170
5	Pre-treated newspaper	Didn't absorb water
6	Paddy straw-graphite oxide SAP composite	326

Table 2: swelling capacity of SAP-graft composites.

Initiator 1 resulted in superabsorbent gel formation indicated that the initiator is effective in producing free radical groups on the graft material, whereas initiator 2 didn't result in gel formation.

4.1 Effect of pH

When the pH of the gel was 3.4 it was adjusted to 4-12 pH ranges in order to study the effect of pH. It was observed that the absorption capacity was maximum when the pH of the sample was 10. The gel formed after the reaction had 3.4pH which was adjusted to 10 by adding 1mol/l of freshly prepared KOH solution.

Fig. 1 a) Superabsorbent polymer dry powder obtained from paddy straw sample.

Fig. 1 b) Paddy straw-graphite oxide SAP gel composite

4.2. Field trails of fertilizer stick

It was noticed that the control plant didn't show more growth. The test plant with fertilizer stick showed more growth and it was lush green in colour. The fertilizer stick was completely biodegraded for 60days. It was also observed that test plant had a greater number of branches and flowers bloomed earlier compared to control plant.

Fig. 2 a) control plant image on day 1

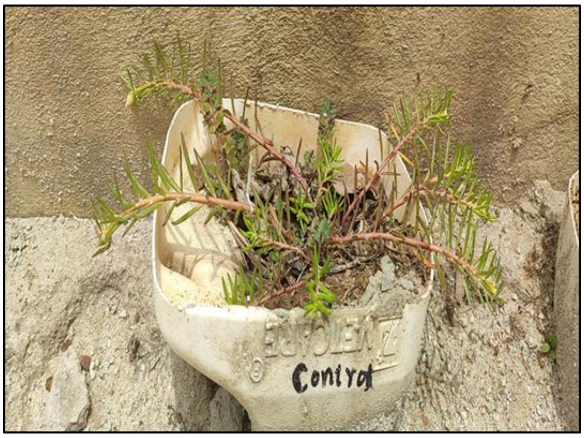

Fig 2 b)control plant image on day 25

Fig 2 c) test plant image on day 1

Fig 2 d) test plant image on day 25

V. CONCLUSION

Through the research it was concluded that the SAP-fertilizer stick was efficient in supplying the fertilizer in a slow release manner for 60 days. It also resulted in good growth of plant and new branches were formed. Early blooming of flowers was observed in test plant compared to the control. Hence, it was concluded that the SAP- fertilizer stick promoted plant growth. However, the absorption capacity of SAP decreased gradually during the field test process

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