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Electron beam degraded oligo-alginate enhances the morphological and yield parameters of wheat

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Abstract

A study on the effect of oligo-alginate produced by electron-beam on the growth and yield of wheat was carried out. A 700kGy dose of irradiation was used to degrade the dry powder of alginate and 100, 200 & 300 ppm concentration of aqueous solution was prepared. The foliar spray treatment was administered at the seedling, pre-flowering and grain-filling stage of wheat plants. The enhancement in the plant height, length of flag leaf and dry weight accumulation was observed by the treatment of oligo-alginate. Also, 1000 seed weight and yield/spike were also increased. The present study establishes that the foliar spray of 200 and 300ppm of oligo-alginate produced by 700 kGy of electron-beam irradiation at seedling, pre-flowering and grain-filling stage enhanced the yield/spike. The increase in yield was because of overall growth stimulation of the plant, particularly the yield contributing characters such as dry weight and 1000 seed weight.

Keywords: oligo-alginate, biopolymer, electron beam, wheat

INTRODUCTION

Recently, the research community of the world faced the problem of an increase in the population has led global increase in the demand for agro-chemical residue-free fresh agricultural products and food grains in the last few decades. During that decades large amounts of chemical fertilizers and insecticides were used for the production of higher yields which caused degradation of soil microflora, reduction in biodiversity, showed drastic effects on the environment and human health and also notable presence of its residue in the food chain and environment (Wang et al. 2015, Nelson et al. 2019). Now, people have tremendous awareness about that problem and are also facing health issues. So there is a great demand for good quality and chemical residual-free crop products. Thus, it is imperative to develop a method which would increase the yield of the crop and provide resilience against stresses (Wang et al. 2015).

Employing natural products, especially natural biopolymers like Alginate to enhance the growth and yield of crop plants is seen as a sustainable solution to the problem (Dzung et al. 2011). In addition to being bio-compatible, bio-degradable and eco-friendly; these molecules are abundant and easily obtained from natural resources (Mollah et al. 2009, Khan et al. 2011, El-Rehim et al. 2011). Natural polysaccharides as a class of natural macromolecules have the potential to work as bio-elicitors (Prashanth and Tharanathan, 2007). During the last decades, these natural polymers have been reported as a yield enhancer, plant growth promoter in several crops.

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Alginate is composed of α-L-guluronic acid (poly G) and β-D-mannuronic acid (poly M) attached by random 1,4-glycoside linkage (Sen 2011, Luan et al. 2012). It is extracted from brown seaweeds and some members of Pheophyceae e.g. *Sargassum* spp., *Laminaria* spp. etc. (Luan et al. 2009). Alginate is a heavy molecular weight natural bioactive polymer. However, their low molecular weight oligos obtained upon the degradation are more effective compared to the polymer itself (Nagasawa et al. 2000, Hien et al. 2000). The electron beam irradiation treatment to degrade the bio-polymer is a quicker, environmentally safe and cost-effective method to obtain the oligos and it is the same process as gamma-ray degradation. The high-energy electron beam breaks the glycosidic bonds present between the monomers making up the polymer to produce oligos.

Many workers reported the bioactivity of radiation-degraded oligo-alginate in agricultural products in last few decades. The irradiation of 1% carrageenan solution by electron beam using 2.5MeV accelerator found that the H_2O_2 enhanced the degradation of carrageenan (Abad et al. 2017). They also reported a positive effect of electron-beam irradiated carrageenan with H_2O_2 on the growth of rice plants. Similarly, the seed dressing treatment of oligo-chitosan produced by 200kGy dose of electron beam at the rate of 0.1g/kg enhanced the growth of root and shoot in rape (Chmielewski et al. 2007).

Wheat is the staple food and main source of carbohydrates in the daily diet of over half of the world's population and the most demanding food crop from the ancient decades. Therefore, considering the effectiveness of oligo-alginate in improving growth, yield and their eco-friendly attributes an investigation was planned to study the effect of electron-beam produced oligo-alginate on the growth and yield of wheat with an aim to develop a commercial growth and yield enhancer for the wheat crop.

Material and Methods

Procurement of seed

The seed of wheat var. Lok-1 was purchased from the Agriculture College of Dr. Panjabrao Deshmukh Krushi Vidyapeeth, Nagpur, Maharashtra, India.

Raising the plants for field studies

The study was carried out in the farmer's field in triplicates. The wheat crop was grown at Wad-dhamna village in Nagpur district. The recommended practices of weeding and irrigation for wheat were carried out throughout the season. The matured crop was harvested and threshed manually.

Preparation of oligo-alginate and aqueous stock solution

The dry powder of sodium alginate (alginate) was purchased from Sigma-Aldrich, USA. The oligo-alginate was produced by electron beam irradiation with a dose of 700kGy at Raja Rammana Centre for Advanced Technology, Indore (MP). The 2% stock solution of oligo-alginate was prepared.

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This stock solution of oligo-alginate was diluted to 100, 200 and 300 ppm concentrations at the time of use. The foliar spray treatment was applied on wheat plants at the seedling stage (30DAG), pre-flowering stage (45DAG) and grain-filling stage (60DAG).

Parameters studied

The effect of foliar treatment of oligo-alginate on the plant height, length of flag leaf, dry weight of plant after maturity, length of spike, 1000 seed weight and yield per spike were studied. For this 25 treated plants were selected randomly and record these parameters after the maturity of the crop. The control plants were sprayed with water.

Statistical analysis

The mean, standard deviation and standard error were computed using MS Excel. Similarly, the Student's t-test was performed using the statistical software R (3.5.1).

Result

The treatment of the elicitors of oligo-alginate produced by electron-beam at a dose of 700kGy had affected the morphological and yield parameters of wheat. The plant height in the control was 77.3cm. The treatment of oligo-alginate A-700/200 and A-700/300, respectively increased the plant height to 86.3 cm and 80.6cm (Table 1). In contrast, all the treatments increased the length of the flag leaf. The control had a 12.87 cm length of flag leaf. This was increased to 15.79cm in response to the elicitor treatment. The treatment of A-700/300 has the maximum flag leaf length i.e., 15.79cm (Table 1). Similar to the plant height, the treatment of oligo-alginate A-700/200 and A-700/300, respectively enhanced the accumulation of dry weight of mature plants. These treatments increased the dry weight from 1.84g in control to around 2.71g (Table 1).

Similarly, the yield contributing parameters i.e. 1000 seed weight in control was 38.56g. The treatment of A-700/200 and A-700/300 increased the 1000 seed weight to 41.12g and 42.32g, respectively (Table 2). In the same manner, these two treatments of oligo-alginate i.e. A-700/200 and A-700/300 were also effective in increasing the yield/spike in this study. The treatment of A-700/200 having 1.13g and A-700/300 1.04g yield/spike as in control it was 0.81g, respectively (Fig. 1). In contrast to this all the treatments of oligo-alginate were unaffected to enhance the length of the spike of wheat (Table 2).

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Table 1. Effect of electron-beam irradiated oligo-alginate on plant height, flag leaf length and dry weight of wheat

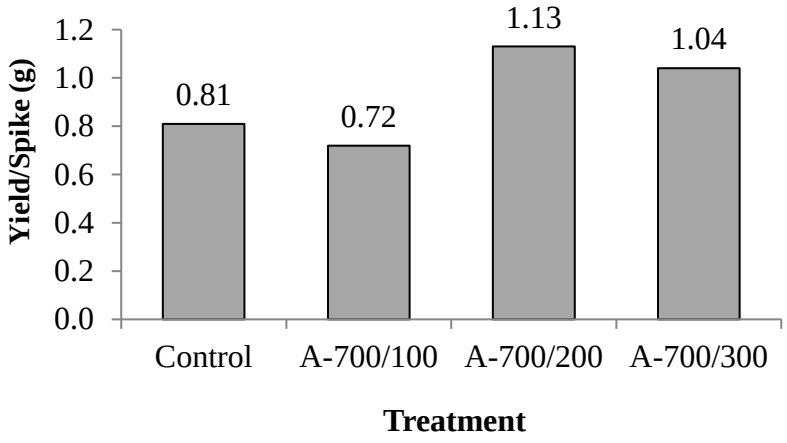
Sr. no.	Parameters	Plant height (cm)	Flag leaf length (cm)	Dry weight of plant (g)
1	Control	77.3 ± 1.67	12.87 ± 0.48	1.84 ± 0.12
2	A-700/100	70.7 ± 1.09	14.61 ± 0.70*	2.00 ± 0.08
3	A-700/200	86.3 ± 1.22*	15.43 ± 0.59*	2.53 ± 0.12*
4	A-700/300	80.6 ± 0.94*	15.79 ± 0.48*	2.71 ± 0.11*

*Significant at p = 0.05 according to Student's t-test (same for other table and figure also).

Table 2. Effect of electron-beam irradiated oligo-alginate on spike length and 1000 seed weight of wheat

Sr. no.	Parameters	Spike length (cm)	1000 seed weight (g)
1	Control	14.97 ± 0.43	38.56 ± 0.38
2	A-700/100	15.03 ± 0.48	32.03 ± 0.47
3	A-700/200	15.03 ± 0.38	41.13 ± 0.69*
4	A-700/300	14.97 ± 0.21	42.32 ± 0.30*

Fig.1 Effect of electron-beam irradiated oligo-alginate on yield/spike of wheat



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Discussion

In the present study, an electron-beam produced oligo-alginate was tested for its effectiveness in enhancing the growth and yield of wheat. The bioactivity and effectiveness directly depend on the dose of irradiation which determines the size of the elicitor molecule and concentration which shows the quantity of the elicitor molecule for inducing a range of effects in plants (Relleve et al. 2005). Since, oligo-alginate act as a ligand and stimulate the signalling mechanism in plants (Wang et al. 2015). Plants have the capacity to recognise elicitors which regulates growth and development (Relleve et al. 2005). Therefore, it was possible that the stimulatory effect was sustained throughout the crop duration because treatment was given at regular intervals which resulted in better growth and yield in wheat.

Luan et al. (2009), Mollah et al. (2009) and later, El-Sawy et al. (2013) reported that the application of gamma-irradiated sodium alginate improves the growth in barley, soybean, amaranthus and in maize. Abad et al. (2017) also observed that foliar treatment of electron-beam irradiated carrageenan given at 12-14(DAT), 30-35(DAT) and 45-50(DAT) increased the yield of rice. Relleve et al. (2005) reported an increment in the fresh biomass and shoot height of potato grown in tissue culture conditions supplemented with oligo-carrageenan degraded by electron-beam. Similarly, Chmielewski et al. (2007) observed an increase in the growth of over-ground parts, diameter of root and mass of root by the seed dressing treatment of oligo-chitosan to rape plant produced by electron-beam irradiation.

In this study, the increased plant height and length of flag leaf were recorded in wheat plants treated with a dose of 700kGy of electron-beam irradiation at 200 and 300 ppm concentrations. Relleve et al. (2005) and Wang et al. (2015) opined that the oligo-alginate act as a signal molecule and thereby regulate the growth and development of plants. Therefore, they may stimulate the plant height and length of the flag leaf of wheat. In addition, the flag leaf of wheat plays a significant role in the plant's growth and development; especially their role is vital during the grain-filling stage. It performs approximately 80% of total photosynthesis and serves as a source of photosynthate during the flowering stage of the crop and supplies it to the developing seeds (sink) (Hu et al. 2020). Thus, an increase in the performance of the flag leaf might contribute to the growth of the plant. The large leaf area is expected to produce more photosynthate and thus increase in the leaf area due to the oligo treatment might contribute to the growth of a plant.

Hien et al. (2000) suggested that foliar spray treatment of oligo-alginate increased the physiological and biochemical functions of plants at certain concentrations leading to an enhancement in the dry matter accumulation. Abad et al. (2017) and Tang et al. (2022), on the contrary, reasoned that the fresh weight of the plant, in response to the treatment, increases due to enhanced root growth. This

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enhancement in root growth increases the nutrient uptake and thus influences the fresh and dry weight of the plant. They also opined that the oligo-chitosan molecules of different molecular weights may activate different signalling pathways. This, in turn, modulates the carbon and nitrogen metabolism in plants.

As discussed above, the flag leaf contributes to a large portion of the total photosynthate produced by the plant. Therefore, the increase in leaf area may contribute to the fresh and dry weight of the plant through an increase in photosynthate production. Thus, the treatments in which the leaf area was increased in the present study might be one of the contributors to the increase in the dry weight of the plant in response to the treatment of oligo-alginate. Additionally, another possibility was that the root growth was also increased in response to the treatment due to which more nutrients were absorbed and accumulated in the plants. Therefore, the higher dry weight of wheat plants was observed in this study.

Hu et al. (2020) have pointed out the importance of flag leaf in rice and wheat, which is the major source of photosynthate to the developing seed. Therefore, the increase in the test weight of seed in the present study could be due to the increased efficiency of the flag leaf to photosynthesise in response to the oligo treatment. Another factor, either independent or supplementary, influencing the seed test weight is the efficient translocation and accumulation of food reserves in the seed after the treatment (Veerappan et al. 2019).

The yield of any crop is a complex quantitative trait depending on various components such as the number of flowers, number of seeds, seed test weight etc. Veerappan et al. (2019) opined that foliar spray of sprout extract in rice might have improved the photosynthesis in plants and also must have improved the transportation of photo-assimilates to developing seeds. Both these factors presumably were responsible for the increased yield recorded in their study. Therefore, the increased yield/spike recorded in the present investigation might be due to the improvement in the yield contributing parameters of the plants i.e. 1000 seed weight, along with the better water and nutrient absorption by the plant and spurt in the metabolism.

Conclusion

The present investigation demonstrates the profound effect of oligo-alginate on the growth and yield of wheat. The treatment i.e. foliar spray of 200 and 300ppm oligo-alginate produced by 700kGy dose of electron-beam at seedling stage (30 DAG), pre-flowering stage (45DAG) and grain filling stage (60DAG) increases the yield of wheat. Therefore, we recommend the foliar spray of 200 and 300ppm of oligo-alginate produced by 700kGy of electron-beam irradiated to wheat crop to increase yield.

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