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Standardisation of fertigation and evaluation of chitosan on biochemical and morphological characters of seedless watermelon [*Citrullus lanatus* (Thunb.) Matsum & Nakai]

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Abstract

The experiment was conducted for standardising fertigation and evaluating biostimulant effect of chitosan on biochemical and morphological characters of triploid seedless watermelon hybrid Shonima with four levels of fertigation as mainplot treatments and foliar application of chitosan as subplot treatments. The findings revealed that the fertigation dosage of 100% RDF was the best in terms of fruit and yield characters and lycopene content, 125% RDF in terms of vine length, 50% RDF in terms of earliness in emergence of first male flower and total sugar and 75% RDF in terms of TSS where as 0.1% chitosan was found to be the best for yield and biochemical characters among three concentrations. Fertigation dosage of 100% RDF along with 0.1% chitosan spray was found to be the best treatment combination in terms of equatorial diameter of fruit, polar diameter of fruit, average fruit weight, marketable yield/plant (8.06 kg/plant), lycopene content and BC ratio (2.02).75% RDF along with foliar spray of 0.1% chitosan was best treatment for TSS and reducing sugar and 50% RDF with 0.1% chitosan spray was best for total sugar content. The crop duration was reduced during the summer season and recommended fertigation dose for Shonima was found to be 43.75:31.25:75kg NPK/ha.

Key words: Chitosan, *Citrullus lanatus*, Fertigation, Quality, Shonima, Yield

Introduction

Watermelon [*Citrullus lanatus* (Thunb.) Matsum and Nakai], one of the popular dessert vegetables belongs to the family Cucurbitaceae and comprises of nutritional components like carbohydrate (6.4g/100g), vitamin A (590 IU) and lycopene (4100 µg/100g) (Wehner, 2008). Watermelon production confines to an area of 100 hectares with a production of 840 metric tonnes in Kerala (MoA & FW, 2021). As the demand for seedless watermelon is increasing, Kerala Agricultural University has developed two triploid seedless watermelon hybrids viz., Shonima (red fleshed) and Swarna (yellow fleshed) (Pradeepkumar et al., 2013). Its exploitation on commercial scale can generate handsome income for the farmers as it's one among high value crops.

Precision farming is a farm management system where all crop production practices are done in right place at right time and in right way for optimum profitability and sustainability. Fertigation is an integral part of precision farming which maximizes yield by optimizing water and fertilizer use efficiency by reducing the quantity of fertilizer, water and labour, and thereby minimizes pollution (Sureshkumar etal., 2017).Watermelon responds well to fertigation in all aspects of growth and yield enhancement at different phases of crop like establishment phase, vegetative phase, flower initiation and at the time of harvesting.

Alkaline deacetylation of chitin gives chitosan, which is a cationic polysaccharide obtained from waste resources such as marine crustacean shells. It is insoluble in water and but dissolves in weak organic acids like lactic acid or acetic acid.Bio stimulant properties of chitosan such as improving germination, plant growth, yield, pest and disease management, etc. can be exploited in crop production.

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Chitosan stimulates plant growth, abiotic stress tolerance, and pathogen resistance by inducing several genes and enzymes (Pichyangkura and Chadchawan, 2015). Chitosan has the potential to reduce mycelial growth of soil pathogen *Fusarium oxysporum* f. sp. *radicis-lycopersici* responsible for fusarium crown and root rot in tomato cultivated in green houses (EL- Mohamedy et al., 2014)

Erratic rainfall and low productivity due to pest and disease infestation were the major limiting factors for watermelon production in Kerala. Watermelon mosaic virus, fusarium wilt and anthracnose are some of the serious diseases causing wide economic loss in watermelon production (Feher, 1993).The investigation on the effect of chitosan as a bio stimulant and its interaction with fertigation in seedless watermelon has not been attempted so far. Hence, the present study was carried out to standardise fertigation and to evaluate the response of chitosan as a bio stimulant on improving the growth, yield and quality of seedless watermelon under open conditions.

Materials and methods

The current study was carried out in the field of Department of Vegetable Science, College of Agriculture, Kerala Agricultural University, Thrissur from December 2020 to March 2021.The experimental site was located at 10° 54'N latitude, and 76° 28'E longitude with an altitude of 11.12 m above mean sea level and soil was lateritic in origin with sandy clay loam texture and acidic nature. Nutrient status of soil was analysed before raising the crop with low available potassium (91.73kg/ha), high available phosphorous (33.85kg/ha), medium organic carbon (1.08%) and deficient calcium, magnesium, sulphur and boron.

The experiment design was split plot with four levels of fertigation viz.,50, 75, 100 and 125% RDF in main plot and foliar application of chitosanviz., 0.1 %, 0.2 % and 0.3%in sub plots with three replications. Control plot was maintained with a level of fertilizer application of 70:25:25 kg NPK/ha (KAU POP, 2016) and without any foliar application of chitosan. The recommended dose for fertigation in open precision farming for watermelon was 70: 50:120 kg NPK/ ha (Nisha et al., 2020). The variety grown was red fleshed triploid seedless watermelon hybrid Shonima. One row of diploid watermelon (Sugar baby) was maintained as the polliniser for every three rows of Shonima.

Experimental area was prepared by deep ploughing followed by incorporation of farm yard manure @ 25t/ha. Beds of 60cm width, 50cm height and channels of 120cm were made with row to row spacing of 2 m. Driplines were laid with one lateral per bed with online drippers spaced every 1m. Beds were covered with silver mulching sheet of 30micron thickness. Holes were punctured at 1m apart before transplanting.

Vermicompost, cocopeat and perlite in ratio of 3: 2: 1 was used for raising seedlings. Seeds germinated within 3 to 4 days and ten days old seedlings were transplanted to main field at a spacing of 1 m. Fertigation was scheduled at three days interval using water soluble fertilizers like 19:19:19, 12:61:0, 13:0:45 and urea. (Table1)

The crop duration of Shonima was reduced from 120 days to 90 days due to high temperature during the summer season. Only 25 splits of fertigation (6, 12, 7 during establishment, vegetative and fruiting stages respectively) out of 40 splits (6, 12, 22 during establishment, vegetative and fruiting stages respectively) were carried out during the cropping period. Fertigation doses given were 21.87: 15.62: 37.5kg NPK/ha (50% RDF), 32.81: 23.44: 56.25 kg NPK/ha (75% RDF), 43.75: 31.25: 75kg NPK/ha (100% RDF) and 54.68: 39.06: 93.75 kg NPK/ha (125% RDF) for 90 days duration. Three concentrations of chitosan (0.1, 0.2 and 0.3%) were prepared by dissolving required quantity of chitosan powder in 1 % acetic acid followed by addition of 1 N NaOH (buffer solution) for maintaining the pH of the solution and foliar

Table 1. Fertigation schedule at three days interval for a single plant

Fertigation doses fixed for 120 days duration	Actual Fertigation doses given as the crop duration was reduced to 90 days	Growth stages	Quantity of fertilizers applied (g) for crop duration of 90 days				Splits given for crop duration of 90 days
			19:19:19	12:61:0	13:0:45	Urea	
50% RDF (35: 20: 50kg NPK/ha)	50% RDF (21.87: 15.62: 37.50kg NPK/ha)	Establishment	2.00	0.59	3.15	0.41	6
		Vegetative	2.00	1.79	7.15	1.25	12
		Fruiting	0.64	1.21	4.39	0.84	7
75% RDF (52.50: 37.50: 90kg NPK/ha)	75% RDF (32.81: 23.44: 56.25 kg NPK/ha)	Establishment	2.00	1.19	5.15	0.83	6
		Vegetative	2.00	3.00	11.14	2.09	12
		Fruiting	0.64	1.90	6.72	1.33	7
100% RDF (70: 50: 120kg NPK/ha)	100% RDF (43.75: 31.25: 75kg NPK/ha)	Establishment	2.00	1.79	7.14	1.25	6
		Vegetative	2.00	4.19	15.12	2.92	12
		Fruiting	0.64	2.61	9.03	1.82	7
125% RDF (87.50: 62.50: 150kg NPK/ha)	125% RDF (54.68: 39.06: 93.75 kg NPK/ha)	Establishment	2.00	2.39	9.12	1.67	6
		Vegetative	2.00	5.39	19.08	3.76	12
		Fruiting	0.64	3.31	11.34	2.42	7

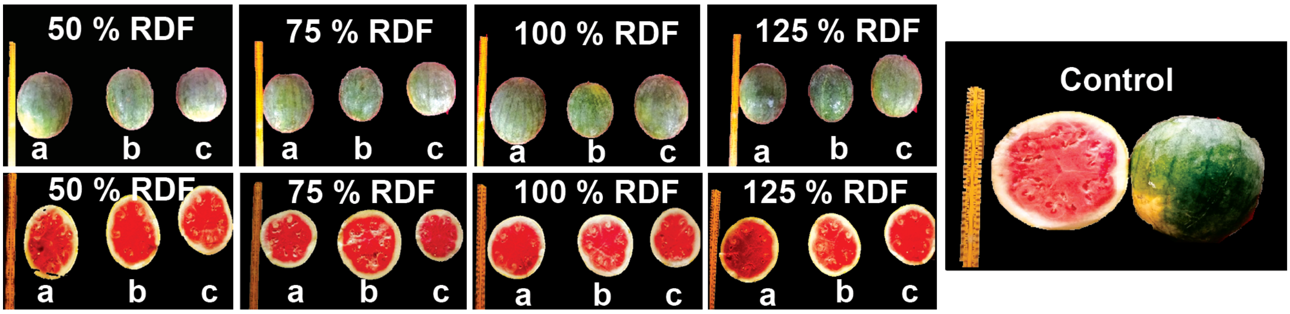

Plate 1. Influence of different treatments on fruit characters [a: 0.1 % chitosan, b: 0.2 % chitosan, c: 0.3 % chitosan]

spray has given twice at pre-flowering (35 days after planting) and fruiting stage (45 days after planting).

Days to first male and female flower opening were recorded during vegetative stage of plants, while vine length, fruit and yield characters were measured at the time of harvesting. Biochemical parameters were analysed after harvesting. Benefit cost ratio was also calculated for cultivation in one hectare. Fruits of different treatments were depicted in plate 1.

Statistical analysis was done using KAU GRAPES Software version 1.0.0 (Gopinath et al., 2020).The significant difference between main plots (fertigation levels), subplots (chitosan concentrations) and their interaction were analysed by doing analysis of variance (ANOVA). Critical difference (CD) values were calculated where ever significant difference was observed.

Results and Discussion

Vegetative and floral characters

Fertigation treatments significantly influenced vine length, the longest vine length (3.87 m) was observed in the fertigation dose of 125 % RDF. Increase in vine length with fertigation levels might be due to higher uptake of nutrients without leaching of fertilizers. Availability of more nitrogen enhanced vegetative growth which increased the chlorophyll content, stomatal conductance and photosynthetic rate (Nisha et al., 2020). Goreta et al. (2005) also reported similar results in watermelon.

Fertigation levels significantly influenced earliness in male flower anthesis in 50 % RDF (24.39 days) (Table 2). Similar findings were reported with lowest fertigation level in cucumber grown in naturally ventilated polyhouse (Singh et al., 2022). This might be due to completion of vegetative phase in a shorter duration and initiation of reproductive phase with adequate supply of nutrients as well as efficient photosynthetic activities (Bellad and Hiremath, 2018).

Vegetative characters were not significantly influenced by foliar application of different concentrations of chitosan.

Fruit and yield characters

Fruit and yield characters showed significant difference among fertigation levels (Table 3 and 4). Fertigation level of 100% RDF recorded maximum fruit equatorial diameter (16.90 cm), polar diameter (17.55 cm), average fruit weight (1.61 kg), fruits/plant (4.52) and yield/plant (5.97 kg/plant). 50% RDF recorded the lowest rind thickness (1.17 cm) and 125% RDF (68.33 days) was the earliest in first harvesting. Fruit weight of watermelon was increased with increased levels of nitrogen (Alkhader, 2019). Hedge (1987) reported

Table 2. Effect of fertigation doses, chitosan concentrations and their interaction on the vegetative and floral characters

Treatments	Vine length (cm)	Days to first male flower	Days to first female flower
Fertigation levels			
A_1 (50% RDF)	3.43	24.39	27.68
A_2 (75% RDF)	3.53	25.74	27.96
A_3 (100% RDF)	3.71	26.52	29.70
A_4 (125% RDF)	3.87	26.78	29.26
SE(m)	0.06	0.45	0.61
CD (0.05)	0.21	1.56	NS
Chitosan concentrations			
B_1 (0.1%)	3.59	25.97	29.03
B_2 (0.2%)	3.61	25.83	28.47
B_3 (0.3%)	3.71	25.76	28.46
SE(m)	0.09	0.26	0.27
CD (0.05)	NS	NS	NS
Interaction (A x B)			
A_1B_1	3.30	24.78	27.89
A_1B_2	3.41	23.78	26.89
A_1B_3	3.58	24.61	28.28
A_2B_1	3.39	25.78	28.33
A_2B_2	3.53	26.56	28.45
A_2B_3	3.67	26.89	27.11
A_3B_1	3.93	26.56	30.00
A_3B_2	3.53	26.56	29.78
A_3B_3	3.67	26.44	29.33
A_4B_1	3.74	26.78	29.89
A_4B_2	3.96	25.83	28.78
A_4B_3	3.92	25.76	29.11
Control	4.10	26.67	28.33
SE(m)	0.18	0.53	0.54
CD (0.05)	NS	NS	NS

that fruit weight and fruit number was increased with higher dosage of nitrogen. Fruit weight was related to equatorial diameter and polar diameter . Enhancement in yield attributes with fertigation in watermelon might be due to better growth, higher photosynthetic rate, increased larger sized fruits per plant (Prabhakar et al., 2013). Adequate doses of potassium might have increased the yield by enhancing transport of photosynthates to the sink (Maluki et al., 2016). Days to first harvest were influenced by fertigation doses and higher fertigation dose was found to induce early harvest in watermelon. This might be due to the sufficient availability of nutrients and increased photosynthates might be responsible for the early maturation of watermelon fruits. These results were in accordance with findings of Nisha (2017). Similar results were observed in higher fertigation doses in bittergourd (Meenakshi et al., 2007).

Chitosan concentrations significantly enhanced fruit and yield characters. Foliar application of chitosan @ 0.1 % recorded maximum equatorial diameter (16.76 cm), polar diameter (17.43 cm), average fruit weight (1.94 kg), fruits/plant (4.25) and yield/plant (6.23 kg/plant)when compared to other concentrations and control (Fig.2). Baby (2020) reported that the yield enhancement with foliar application of chitosan in ginger might be due to the increased photosynthetic rate, transpiration rate and stomatal conductance. Mondal et al. (2012) also disclosed thatfoliar spray of chitosan enhanced growth and yield of okra by increasing net photosynthetic rate. It was also found that,H_2O_2 generated by application of chitosan increased the secondary metabolite and polyphenol content in Greek oregano and enhanced its growth and development (Yin et al., 2012). Mondal et al. (2016) also reported similar results in summer tomato and Farouk et al. (2012) in cowpea.

Interaction between fertigation dosages and chitosan concentrations significantly influenced fruit and yield characters. Fertigation level of 100% RDF along with foliar application of 0.1% chitosan (A_3B_1)was the best treatment combination with maximum equatorial diameter (18.08 cm), polar diameter (18.87 cm), average fruit weight (2.38 kg), and marketable yield (8.06 kg/plant) (Table. 3). These results were agreeable with studies on the effect of chitosan and different rates of nitrogen in summer squash by Ibreaheim and Mohsen (2015). Harfoush et al. (2017) also reported the influence of chitosan and humic acid along with fertigation in potato and concluded that yield enhancement might be due to the physiological response of chitosan by improving the transportation of nitrogen.

Table 3. Effect of fertigation doses, chitosan concentrations and their interactions on fruit characteristics

Treatments	Fruit equatorial diameter (cm)	Fruit polar diameter (cm)	Fruit rind thickness (cm)	Days to first harvest	Days to final harvest
Fertigation levels					
A_1 (50% RDF)	15.05	15.61	1.17	69.00	80.11
A_2 (75% RDF)	14.79	15.34	1.28	68.67	81.55
A_3 (100% RDF)	16.90	17.55	1.27	68.55	81.55
A_4 (125% RDF)	16.01	16.74	1.20	68.33	81.55
SE (m)	0.10	0.16	0.01	0.11	0.81
CD (0.05)	0.35	0.57	0.05	0.38	NS
Chitosan concentrations					
B_1 (0.1%)	16.76	17.43	1.28	68.50	80.33
B_2 (0.2%)	15.54	16.09	1.21	68.67	81.67
B_3 (0.3%)	14.77	15.41	1.20	68.75	81.58
SE(m)	0.15	0.14	0.03	0.11	0.58
CD (0.05)	0.46	0.43	NS	NS	NS
Interaction (A x B)					
A_1B_1	16.94	17.35	1.26	69.00	77.33
A_1B_2	15.05	15.60	1.13	69.00	82.00
A_1B_3	13.17	13.89	1.12	69.00	81.00
A_2B_1	15.87	16.49	1.38	68.00	81.33
A_2B_2	14.59	15.12	1.22	69.00	81.67
A_2B_3	13.93	14.40	1.25	69.00	81.67
A_3B_1	18.08	18.87	1.34	68.67	81.33
A_3B_2	16.33	16.80	1.28	68.67	81.67
A_3B_3	16.30	16.98	1.19	68.33	81.67
A_4B_1	16.14	17.00	1.14	68.33	81.33
A_4B_2	16.20	16.85	1.22	68.67	81.33
A_4B_3	15.69	16.37	1.23	68.75	82.00
Control	16.03	16.84	1.13	68.00	81.00
SE(m)	0.30	0.28	0.06	0.22	1.16
CD (0.05)	0.91	0.86	NS	NS	NS

Biochemical characters

Biochemical characters of fruit like TSS, lycopene and total sugar content were influenced by fertilizer doses. Maximum TSS (8.64°Brix), maximum total sugar (5.38 %) andmaximum lycopene content (5.76 mg/100g) were reported in A_2, A_1 and A_3 respectively. Reducing sugar, total sugar and lycopene content of watermelon were not significantly influenced by the fertigation levels (Nisha, 2017; Sajitha and Vijayakumar, 2016). TSS of watermelon fruits was improved by higher doses of nitrogen which might be due to improved manganese uptake which enhanced the sweetness of fruit (Maluki et al., 2016). In addition, the increased doses of potassium might have contributed to starch synthesis which was converted to sugar on ripening and it was found to be responsible for improving the quality of fruits (Okur and Yagmur, 2004).

Chitosan concentrations significantly enhanced biochemical parameters of watermelon. Foliar application of 0.1% chitosan recorded maximum TSS (8.87°Brix), reducing sugar (3.54 %), total sugar (5.38 %) and lycopene content (4.96 mg/100g) compared to other chitosan concentrations and control. Synthesis of sugars, polysaccharides and vitamins were correlated with increased photosynthetic rate by foliar application of chitosan (Khan et al, 2002). Mondal et al. (2016), Basit et al. (2020) and Parvin et al. (2019) came to similar conclusions from their studies. Enhanced curcumin content of turmeric with foliar application of chitosan was due to the peroxidases activity (Anusuya and Sathiyabama, 2016).

Table 4. Effect of fertigation levels, chitosan concentrations and their interaction effect on yield characters

Treatments	Fruits/ plant	Fruit weight (kg)	Yield/ plant (kg)
Fertigation levels			
A_1 (50% RDF)	2.59	1.46	3.37
A_2 (75% RDF)	3.04	1.35	3.49
A_3 (100% RDF)	4.52	1.61	5.97
A_4 (125% RDF)	3.44	1.59	5.06
SE(m)	0.22	0.04	0.11
CD (0.05)	0.76	0.16	0.38
Chitosan concentrations			
B_1 (0.1%)	4.25	1.94	6.23
B_2 (0.2%)	3.03	1.42	3.64
B_3 (0.3%)	2.92	1.15	3.54
SE(m)	0.14	0.04	0.10
CD (0.05)	0.44	0.14	0.32
Interaction (A x B)			
A_1B_1	2.78	1.79	4.48
A_1B_2	2.44	1.33	2.78
A_1B_3	2.56	1.27	2.85
A_2B_1	4.33	1.84	5.65
A_2B_2	2.78	1.24	2.95
A_2B_3	2.00	0.96	1.88
A_3B_1	5.55	2.38	8.06
A_3B_2	4.00	1.52	5.20
A_3B_3	4.00	0.93	4.65
A_4B_1	4.33	1.74	6.73
A_4B_2	2.89	1.59	3.65
A_4B_3	3.11	1.45	4.79
Control	3.00	1.71	3.40
SE(m)	0.29	0.09	0.21
CD (0.05)	NS	0.28	0.65

Table 5 Effect of fertigation doses, chitosan concentrations and their interactions on biochemical characters of fruit

Treatments	TSS (°brix)	Lycopene content (mg/100g)	Total sugar (%)	Reducing sugar (%)
Fertigation levels				
A_1 (50% RDF)	8.31	4.85	5.38	3.49
A_2 (75% RDF)	8.64	3.57	5.28	3.85
A_3 (100% RDF)	8.44	5.76	5.37	3.10
A_4 (125% RDF)	8.22	4.78	5.06	3.37
SE(m)	0.08	0.10	0.03	0.20
CD (0.05)	0.28	0.36	0.12	NS
Chitosan concentrations				
B_1 (0.1%)	8.87	4.96	5.38	3.54
B_2 (0.2%)	8.20	4.90	5.27	3.50
B_3 (0.3%)	8.15	4.36	5.15	3.32
SE(m)	0.05	0.09	0.03	0.06
CD (0.05)	0.16	0.28	0.11	0.18
Interaction (A x B)				
A_1B_1	8.73	4.99	5.67	3.57
A_1B_2	8.07	4.88	5.30	3.58
A_1B_3	8.13	4.66	5.15	3.34
A_2B_1	9.47	3.46	5.07	3.98
A_2B_2	8.13	3.46	5.64	3.65
A_2B_3	8.33	3.79	5.13	3.93
A_3B_1	9.20	6.72	5.56	3.37
A_3B_2	8.07	5.35	5.25	3.07
A_3B_3	8.07	5.21	5.28	2.86
A_4B_1	8.07	4.66	5.23	3.27
A_4B_2	8.20	5.89	4.90	3.70
A_4B_3	8.15	3.77	5.04	3.14
Control	8.00	5.19	5.10	3.50
SE(m)	0.11	0.19	0.07	0.12
CD (0.05)	0.33	0.57	0.22	0.37

Interaction effect of fertigation doses and chitosan concentrations significantly influenced biochemical characters. Treatment combination A_2B_1 (75% RDF + 0.1% chitosan) recorded maximum TSS (9.47°Brix) and reducing sugar (3.98 %), total sugar (5.67 %) was highest in A_1B_1 (50% RDF + 0.1% chitosan) and lycopene content (6.72 mg/100g) in A_3B_1 (100% RDF + 0.1% chitosan) (Tables 4 & 5). This result was in accordance with the effect of nitrogen fertigation and chitosan application in summer squash where, higher dose of nitrogen (75 kg/feddan) along with foliar application of 0.10g/L chitosan enhanced TSS content of fruits (Ibreaheim and Mohsen, 2015).

Benefit Cost Ratio

Economic analysis was done and treatment combination 100% RDF + 0.1% chitosan(A_3B_1) was found to be the best with maximum returns with benefit cost ratio of 2.02:1 (Table 6).

Table 6. Interaction effect of fertigation levels and chitosan concentrations on Benefit Cost Ratio

Treatment Combinations	Total cost of production per hectare (Rs.)	Gross Income per hectare (Rs.)	B:C ratio
A_1B_1	387276	470400	1.21
A_1B_2	426716	291900	0.68
A_1B_3	429316	299250	0.69
A_2B_1	402727	593250	1.47
A_2B_2	442167	309750	0.70
A_2B_3	444767	197400	0.44
A_3B_1	417991	846300	2.02
A_3B_2	457431	546000	1.19
A_3B_3	460031	488250	1.06
A_4B_1	433261	695100	1.60
A_4B_2	472701	383250	0.81
A_4B_3	475307	502950	1.05
Control	342158	357000	1.04

Conclusion

The crop duration of Shonima was reduced from 120 days to 90 days during summer season in the present study. The results indicated that the recommended fertigation dose for open precision farming of Shonima (90 days) in summer season is 43.75: 31.25: 75kg NPK/ha. Lower concentration of chitosan (0.1%) was found to be the best in improving the yield and quality of Shonima whereas higher concentrations found to have phytotoxic effects on plants. Fertigation with 100% RDF along with 0.1% chitosan was the best treatment combination with maximum returns. The present investigation had to be repeated in different seasons and locations for conclusive results. Open precision farming with fertigation along with spraying of chitosan improves the seedless watermelon production than conventional method.

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