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Effect of Hydrogel and Anti-Transpirants on Growth, Yield and Quality of Strawberry in Jammu Subtropics Conditions

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ABSTRACT: The present investigation entitled "Studies of Anti-transpirants and Hydrogel on Strawberry Production under Rainfed conditions of Jammu" was undertaken at Rainfed Research Sub-Station for Sub-Tropical Fruits (RRSS), Raya Samba, SKUAST- Jammu during the year 2021-2022. The experiment was laid out in Randomized Complete Block Design (RCBD) with ten treatments each replicated thrice. In this trail, Hydrogel (1g, 2g and 3g per plant), Cycocel (500 ppm, 750 ppm and 1000 ppm) and Kaolin (2%, 4% and 6%) were applied. The vegetative, reproductive, physical, biochemical, stress and soil parameters were recorded along with relative economics in strawberry cv. Nabila. Among the different treatments, maximum plant height (20.29 cm), plant spread (33.97 cm), number of leaves per plant (23.68) and leaf area (142.71 cm^2), was observed in T_3. The minimum number of days taken to first flower (76.76 days), maximum duration of flowering (62.26 days), number of flowers per plant (24.04), number of fruits per plant (12.70), fruit weight (28.23 g), fruit length (4.56 cm), fruit breadth (3.33 cm), yield per plant (358.52 g), TSS (8.4 ºBrix), juice percentage (93.81%), total sugars (7.28%), reducing sugars (5.10%), non-reducing sugars (2.07%), ascorbic acid (66.98 mg/100g of fresh weight) and anthocyanin content (51.90 mg/100g of fresh weight) were observed with T_5. At the end of the investigation, it can be concluded that hydrogel @ 3 g per plant was best in improving growth whereas, CCC @ 750 ppm has impressive effect on fruit yield and quality. Challenges of the study might include the influence of uncontrollable environmental factors, variations in soil conditions, and potential pest and disease pressures that could have affected the experimental outcomes. The study's findings contribute to sustainable agriculture and help strawberry farmers in Jammu region to improve their production practices for better economic returns.

Keywords: Strawberry, Nabila, Hydrogel, Cycocel, Kaolin.

INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duch.) is one of the most economically profitable berry fruits consumed for its nutrient content and pleasant flavour. It is commercially cultivated worldwide for its highly appreciated sweet, aromatic and juicy fruit. The commercial strawberry, originated about 250 years ago when a few New World clones of *Fragaria chiloensis* and *Fragaria virginiana* accidentally hybridized in European gardens (Wilhelm and Sagen 1972). In India, strawberry is commercially grown in temperate, subtropical and tropical areas. As per first advance estimates, strawberry is grown over an area of around 3000 ha with a production of about 14000 MT (Anonymous, 2022) in India. Mizoram contributing major share in area i.e., 170 ha while Himachal Pradesh being the largest producer with the production of 3083 MT followed by, Jammu and Kashmir (UT) and Meghalaya, but at present strawberry is successfully cultivated in Delhi, Punjab, Maharashtra, Karnataka, Uttar Pradesh etc. In Jammu and Kashmir (UT), it is cultivated on an area of 149 ha with the production of 2827 MT (Anonymous, 2021).

Strawberry is herbaceous plant possessing shallow root system due to which it requires regular supply of water during summer months to maintain soil moisture. In Jammu subtropics, the maximum area fall under rainfed condition with erratic rainfall, poor soil quality as well as lack of irrigation facilities through canal, tube well etc. Among the factors, soil moisture is generally needed in strawberry production to achieve adequate vegetative growth, yield and fruit quality (Serrano *et al.*, 1992; Yuan *et al.*, 2004). Manage rainwater and soil moisture more effectively and using supplemental and small-scale irrigation in combination with increased use of mulches, hydrogels, spray of anti-transpirants and plant growth regulators (PGR's) to enhance the area and better access to markets. Hydrogels, which are three-dimensional networks of natural or synthetic polymers having an ability to hold high-water and nutrient content, offer greater flexibility. They are super absorbents that absorb and store water hundreds of times their own weight, i.e., 40-1500 g of water per dry gram of hydrogel (Neethu *et al.*, 2018; Das *et al.*, 2021). Whereas, anti-transpirants limit rate of transpiration by closing stomata or through reflection of light or forming a thin layer on leaf surface or by

retarding the growth and gradually hardening plants to stress (El Khawaga, 2013). Particle film applications (spraying canopies with suspended particles) of several types of clay, including kaolin, that form a film on leaves, reduce the impact of water and heat stress on crop physiology and productivity. Kaolin is a naturally occurring mineral (clay) whose major ingredient is kaolinite [$(Al_2Si_2O_5(OH)_4$] (Rosati, 2007). While growth retardant type of antitranspirants (like cycocel) reduce vegetative growth in plants (Moulana and Bahadur 2020), increase their root/shoot ratio, reduce the effect of reactive oxygen species (ROS) thus help plants to overcome the effects of stress (Rao *et al.*, 2016). Keeping these points, this experiment has been taken to promote and popularize the strawberry under restricted moisture conditions, to get better fruit quality and yield of the strawberry.

MATERIALS AND METHODS

The present investigation, "Studies of anti-transpirants and hydrogel on strawberry production under rainfed conditions of Jammu" was conducted during 2021-22 at Rainfed Research Sub-Station for Sub-Tropical Fruits (RRSS), Raya Samba, SKUAST- Jammu, J&K. (UT) which is located between 32°39″ N latitude and 74°53″ E longitude at an elevation of 327 metres above sea level. The climate of the experimental site falls under sub-tropical agro-climatic zone, where the summer is hot and dry and the winter is chilly. Maximum and minimum temperatures during summer and winter are 46°C and 3.4°C, respectively. The average temperature in the summer ranges from 24°C to 36°C, with humidity levels ranging from 54 to 81 per cent. Temperatures range from 6°C to 22°C throughout the winter months. The yearly precipitation ranges from 1000 to 1200 mm. The numerous cultural operations was performed through out the trial. Firstly, the field was initially prepared by using tools pulled by tractor and then levelled. The plots were manually prepared and depicts the filed layout. Secondly, Distributed decomposed FYM on the field evenly and was thoroughly mixed with soil. Third step to prepare bed (30 beds per plots) and kept the height upto 15 cm. Mulching is one of the key criteria for strawberry cultivation. After the bed preparation, black polythene were used as mulching material. Mother runners were planted in the center of holes made on black polythene mulch sheets. Lastly, field was irrigated when the moisture level goes down upto 50% of field capacity with the help of motor and pipe from the well. Two anti-transpirants, Cycocel (CCC) and Kaolin solutions, were prepared by dissolving in the recommended solvents based on the treatments. Weighing 0.5 g, 0.75 g, and 1 g of CCC, respectively, was used to make the CCC solutions of 500 ppm, 750 ppm, and 1000 ppm. The CCC was then dissolved in a small amount of ethanol and made up to 1000 ml using distilled water. Weighing 20 g, 40 g, and 60 g of kaolin, respectively, was used to make the 2%, 4%, and 6% kaolin solutions. The kaolin was then dissolved in a small amount of 0.2 N NaOH solution, and the volume was raised to 1000 ml using distilled water. 1 g, 2 g and 3 g of Hydrogel each were mixed with half of kg of soil then placed near the root zone of plant. In this experiment, strawberry runners were transplanted and then hydrogel was sprayed on the soil. In contrast, foliar sprays of cycocel and kaolin were sprayed 45 and 75 days after planting, respectively. The growth, flowering, fruiting and biochemical parameters of strawberry plants such as plant height, plant spread, shoot length, crown diameter, number of runners per plant, runners length, fresh and dry weight of shoot, number of leaves per plant, leaf area, petiole length, fresh and dry weight of leaves, leaf chlorophyll content, fresh and dry weight of root and average primary and secondary length of roots, days taken to first flower, duration of flowering, number of flowers per plant, number of berries per plant, berry weight, berry breadth, berry length, total yield per plant, pH, TSS, TSS: Acid ratio, total sugars, reducing sugars, non-reducing sugars and ascorbic acid were measured in this experiment. Also, the cost and return structure of best treatment were analyzed. With the help of a measuring scale, the plant height, plant spread, shoot length, runner length, petiole length, average length of primary and secondary roots, berry length, and breadth were measured. The survival percentage was calculated by dividing the total number of plants survived after planting by the total number of plants planted, multiplied by 100. The crown diameter of the plant was calculated by using the Vernier Calipers scale and it is expressed in millimeters. After properly drying the samples in an oven at 65^{o}C and weighing them in an electronic balance, the dry weights were recorded. The number of leaves, berries, flowers, and runners were counted at the end of the growing season and an average number was worked out. The chlorophyll content in strawberry leaves was determined using a chlorophyll meter SPAD-502 and expressed as a percentage. The number of days taken to flower from the date of planting was measured, and the mean number of days required to first flower was worked out. The fruit TSS was estimated by using a hand refractometer.TSS: Acid ratio, pH, total sugars (%), reducing sugars, non-reducing sugars, and ascorbic acid were calculated by the procedure described in A.O.A.C. (1995). The benefit-cost ratio for different treatments was worked out on the basis of the price of inputs used for strawberry cultivation and the price of marketable produce in the local market by using the formula given by Reddy and Ram (1996).The treatments were laid out in a factorial randomized block design with three replications and two plants per replicate. The overall significance of the difference among the treatments was tested, using critical differences (C.D.) at a 5% level of significance. The results were statistically analysed with the help of a window based computer package SPSS.

RESULTS AND DISCUSSSIONS

The data related to the effect of hydrogel and antitranspirants on plant growth characters of strawberry is presented in Table 1. Among different treatments the maximum plant height (20.29 cm), plant spread (33.97 cm), number of leaves per plant (23.68),

leaf area (142.71 cm^2) was obtained in T_3i.e., hydrogel 3 g per plant while, the minimum plant height (14.73 cm), plant spread (23.10 cm), number of leaves per plant (18.87) and leaf area (112.59 cm^2) were observed with T_6 (Cycocel 1000 ppm) treated plants. Whereas, the minimum plant height (14.73 cm), plant spread (23.10 cm), number of leaves per plant (18.87) and leaf area (112. 59 cm^2) were observed with T_6 (Cycocel 1000 ppm). By balancing nutrient substances and promoting higher CO_2 fixation through prolonged stomata opening, the hydrogel enhances cell membrane development, leaf area and leaf number.

Table 1: Effect of hydrogel and anti-transpirants on plant growth characters of strawberry cv. Nabila.

Treatments	Plant height (cm)	Plant spread (cm)	Number of leaves per plant	Leaf area (cm^2)
T_1-Hydrogel 1g per plant	18.94	27.36	20.50	130.99
T_2- Hydrogel 2g per plant	19.35	30.54	21.18	134.30
T_3- Hydrogel 3g per plant	20.29	33.97	23.68	142.71
T_4- Cycocel 500 ppm	17.56	26.09	20.43	119.71
T_5- Cycocel 750 ppm	16.38	25.07	19.68	116.56
T_6- Cycocel 1000 ppm	14.73	23.10	18.87	112.59
T_7- Kaolin 2%	18.82	27.02	19.90	121.93
T_8- Kaolin 4%	19.11	28.66	20.94	123.33
T_9- Kaolin 6%	19.26	30.00	21.04	128.44
T_{10}- Control	17.89	26.46	20.33	120.40
Mean	**18.23**	**27.83**	**20.66**	**125.14**
SE ± m	**0.58**	**0.86**	**0.67**	**1.58**
$CD_{(P=0.05)}$	**1.74**	**2.58**	**2.02**	**4.74**

The data pertaining in Table 2 showed significant effect of hydrogel and antitranspirants on flowering and fruit set of strawberry. From the different treatments minimum number of days to first flower (76.76 days), maximum duration of flowering (62.26 days) and number of flowers per plant (24.04) were observed with cycocel 750 ppm (T_5) whereas, maximum number of days to first flower (92.03 days), minimum duration of flowering (44.46 days), number of flowers per plant (18.67) were observed with T_{10} i.e., control. This might be due to diversion and accumulation of photo assimilates into the reproductive organs through cycocel activity. Longer duration of flowering by foliar spray of cycocel can be due to the increased translocation of cytokinin from roots to shoots, leading to prolonged life span of floral parts of plant due to its anti-senescence activity thereby increasing flowering duration and number of flowers (Pourmohammad *et al*., 2013).

Table 2: Effect of hydrogel and anti-transpirants on flowering and fruit set of strawberry cv. Nabila.

Treatments	Number of days to first flower (days)	Duration of flowering (days)	Total number of flowers per plant	Fruit set (%)
T_1-Hydrogel 1g per plant	84.54	50.59	20.35	51.94
T_2- Hydrogel 2g per plant	86.05	54.43	21.39	57.55
T_3- Hydrogel 3g per plant	90.71	59.00	21.47	58.69
T_4- Cycocel 500 ppm	79.85	58.17	23.71	47.36
T_5- Cycocel 750 ppm	76.76	62.26	24.04	52.83
T_6- Cycocel 1000 ppm	80.63	60.40	22.36	55.23
T_7- Kaolin 2%	82.57	50.41	19.32	47.05
T_8- Kaolin 4%	81.79	52.49	21.71	45.92
T_9- Kaolin 6%	81.15	53.26	21.84	51.42
T_{10}- Control	92.03	44.46	18.67	42.85
Mean	**83.55**	**54.55**	**21.59**	**51.08**
SE ± m	**0.23**	**1.21**	**0.14**	**1.96**
$CD_{(P=0.05)}$	**0.67**	**3.65**	**0.40**	**5.90**

The data from Table 3 reveals that effect of hydrogel and anti-transpirants showed significant effect on physical characteristics (fruit weight, fruit length and fruit breadth) of strawberry fruit. During the investigation it was observed that the maximum fruit weight (28.23 g), fruit length (4.56 cm), fruit breadth (3.33 cm), number of fruits per plant (12.70) and yield per plant (358.52 g) were observed with T_5 (Cycocel 750 ppm) meanwhile, the minimum fruit weight (20.31 g), fruit length (3.30 cm), fruit breadth (2.28 cm), number of fruits per plant (8.00) and yield per plant (162.48 g) were registered in T_{10}. The improvement in the partitioning of extra metabolites towards reproductive parts and the increased accumulation of assimilates that results from the application of cycocel could be responsible for the improvement in physical characteristics of fruit. Cycocel is also involved in enhancing the rate of photosynthesis by increasing total chlorophyll content of leaves which leads more food production within the plant thus improves fruit weight and fruit diameter (Rao *et al*., 2016).

Table 3: Effect of hydrogel and anti-transpirants on physical characteristics of strawberry cv. Nabila.

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)	Number of fruits per plant	Yield per plant (g)
T_1-Hydrogel 1g per plant	23.36	4.03	2.94	10.57	246.92
T_2- Hydrogel 2g per plant	25.49	4.07	3.01	12.31	313.78
T_3- Hydrogel 3g per plant	25.93	4.11	3.27	12.60	325.48
T_4- Cycocel 500 ppm	26.08	4.31	3.31	11.23	292.87
T_5- Cycocel 750 ppm	28.23	4.56	3.33	12.70	358.52
T_6- Cycocel 1000 ppm	25.87	4.37	3.26	12.35	319.49
T_7- Kaolin 2%	21.88	3.47	2.62	9.09	198.89
T_8- Kaolin 4%	22.49	3.52	2.76	9.97	224.23
T_9- Kaolin 6%	23.47	3.66	2.86	11.23	263.56
T_{10}- Control	20.31	3.30	2.28	8.00	162.48
Mean	**24.31**	**3.94**	**2.96**	**11.01**	**270.62**
SE ± m	**0.79**	**0.11**	**0.12**	**0.32**	**16.21**
$CD_{(P=0.05)}$	**2.41**	**0.32**	**0.37**	**0.97**	**48.69**

The results tabulated in Table 4 indicated that the influence of hydrogel and anti-transpirants had significant effect on chemical characters of strawberry fruit. Maximum TSS (8.44°Brix), juice percentage (93.81%), total sugars (7.28%), reducing sugars (5.10%), non-reducing sugars (2.07%), ascorbic acid (66.98 mg/100g fresh weight), anthocyanin content (51.90 mg/100g of fresh weight) and minimum acidity (0.29%) were observed in T_5 (Cycocel750 ppm) whereas, the lowest TSS (6.61°Brix), juice percentage (83.37%), total sugars (5.28%), reducing sugars (4.17%), non-reducing sugars (1.07%), ascorbic acid (52.18 mg/100g), anthocyanin content (36.77 mg/100g) and the maximum acidity (0.29%) were recorded in control (T_{10}). The fact that strawberry fruits from plants sprayed with cycocel @750 ppm had high percentage of juice content, total, reducing and non-reducing sugars may be related to the upregulation of genes involved in photosynthesis as well as the activity of a vital respiratory enzyme called malate dehydrogenase, which is responsible for the quick hydrolysis of starch in strawberry fruits. The rapid metabolic conversion of starch and pectin into soluble sugars and the rapid translocation of sugars from leaves to developing fruits by reducing vegetative growth of plants may also be responsible for the increase in the content of sugars and TSS in fruits.

Table 4: Effect of hydrogel and anti-transpirants on biochemical characters of strawberry cv. Nabila.

Treatments	Total soluble solids (°Brix)	Acidity (%)	Juice (%)	Total Sugar (%)	Reducing sugars (%)	Non-reducing sugars (%)	Ascorbic acid (mg/100g of fresh weight)	Anthocyanin content (mg/100g of fresh weight)
T_1-Hydrogel 1g per plant	7.66	0.39	89.77	5.75	4.47	1.25	53.57	40.27
T_2- Hydrogel 2g per plant	7.81	0.35	90.96	6.04	4.76	1.22	55.00	41.30
T_3- Hydrogel 3g per plant	8.09	0.34	91.39	6.79	5.06	1.62	58.27	43.83
T_4- Cycocel 500 ppm	8.27	0.32	92.60	6.20	4.80	1.33	62.98	46.47
T_5- Cycocel 750 ppm	8.44	0.29	93.81	7.28	5.10	2.07	66.98	51.90
T_6- Cycocel 1000 ppm	7.92	0.31	93.03	6.92	5.03	1.80	62.31	50.18
T_7- Kaolin 2%	7.23	0.38	88.53	5.59	4.35	1.18	52.87	41.26
T_8- Kaolin 4%	7.49	0.35	89.96	6.00	4.73	1.21	53.22	44.10
T_9- Kaolin 6%	7.75	0.32	91.07	6.57	4.87	1.61	56.69	44.42
T_{10}- Control	6.61	0.41	83.37	5.28	4.17	1.07	52.18	36.77
Mean	**7.73**	**0.35**	**90.44**	**6.24**	**4.73**	**1.44**	**57.41**	**44.04**
SE ± m	**0.11**	**1.54**	**0.91**	**0.11**	**0.05**	**0.03**	**1.71**	**1.19**
$CD_{(P=0.05)}$	**0.34**	**NS**	**2.69**	**0.30**	**0.14**	**0.10**	**5.11**	**3.57**

The cost of cultivation (fixed and variable cost) for strawberry treated with hydrogel and anti-transpirants is presented in Table 5. The data in the table reveals that the highest cost of cultivation (₹1771643 ha^{-1}) incurred in strawberry plants treated with cycocel 1000 ppm (T_6) which was followed by T_5 (cycocel 750 ppm) (₹1546643 ha^{-1}) and lowest (₹871643 ha^{-1}) was in control (T_{10}). The table further revealed that the maximum average yield (26.56 t. ha^{-1}) was recorded under T_5 (cycocel 750 ppm) followed by T_3 (30.99 t. ha^{-1}) and the minimum (12.04 t. ha^{-1}) was observed in control (T_{10}). Gross return on the basis of average yield per plant was found maximum (₹3983551.57 ha^{-1}) in T_5, which was followed by T_3 (₹3616440.83 ha^{-1}) and the minimum (₹1805331.53 ha^{-1}) was recorded in T_{10}. The net returns were maximum (₹2436909 ha^{-1}) in T_5, followed by T_3 (₹2609798 ha^{-1}) while, minimum (₹933688.50 ha^{-1}) was noted in T_{10}.

Table 5: Economics of different treatments and cost: benefit ratio of strawberry cv. Nabila.

Treatments	Fixed cost (₹ ha^{-1})	Variable cost (₹ ha^{-1})	Total cost (₹ ha^{-1})	Fruit yield (t ha^{-1})	Selling rate (₹ t^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	Cost: Benefit ratio
T_1-Hydrogel 1g per plant	871643.00	45000.00	916643	18.29	150000.00	2743552.81	1826910	1: 1.99
T_2- Hydrogel 2g per plant	871643.00	90000.00	961643	23.24	150000.00	3486440.96	2524798	1: 2.63
T_3- Hydrogel 3g per plant	871643.00	135000.00	1006643	24.11	150000.00	3616440.83	2609798	1: 2.59
T_4- Cycocel 500 ppm	871643.00	450000.00	1321643	21.69	150000.00	3254107.86	1932465	1: 1.46
T_5- Cycocel 750 ppm	871643.00	675000.00	1546643	26.56	150000.00	3983551.57	2436909	1: 1.58
T_6- Cycocel 1000 ppm	871643.00	900000.00	1771643	23.67	150000.00	3549885.34	1778242	1: 1.00
T_7- Kaolin 2%	871643.00	24000.00	895643	14.73	150000.00	2209886.68	1314244	1: 1.47
T_8- Kaolin 4%	871643.00	48000.00	919643	16.61	150000.00	2491441.95	1571799	1: 1.71
T_9- Kaolin 6%	871643.00	72000.00	943643	19.52	150000.00	2928441.52	1984799	1: 2.10
T_{10}- Control	871643.00	0.00	871643	12.04	150000.00	1805331.53	933688.5	1: 1.07

FUTURE SCOPE

To ensure the reliability and generalizability of the study findings, future research should expand the scope to include different strawberry varieties and explore the effects of varying application rates and timings. Furthermore, conducting comparative studies under varying degrees of water stress and climatic conditions would provide a more comprehensive understanding of how hydrogel and anti-transpirants perform under different scenarios. Collaboration between agricultural researchers, policymakers, and local farmers is instrumental in translating research findings into practical applications. Establishing partnerships and conducting on-farm trials would facilitate knowledge transfer and aid in tailoring these technologies to suit the specific needs and constraints of strawberry growers in the Jammu region.

CONCLUSIONS

In conclusion, exploring the long-term effects, potential synergies, and economic viability of hydrogel and anti-transpirant applications in strawberry cultivation holds great promise for sustainable agriculture in Jammu's subtropical conditions. Such research endeavors can play a crucial role in promoting water-efficient farming practices, improving crop productivity, and contributing to food security in the region.

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Conflict of Interest. None.

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