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Influence of Super Absorbent Polymers and Irrigation Levels on Grain Yield, Water Productivity and Economics of Wheat

Shashank Tyagi[1]*, Nintu Mandal[2] and Mahendra Singh[2]
[1]Department of Agronomy, Bihar Agricultural College, Sabour, Bhagalpur (Bihar), India.
[2]Department of Soil Science and Agricultural Chemistry,
Bihar Agricultural College, Sabour, Bhagalpur (Bihar) India.

(Corresponding author: Shashank Tyagi)*
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ABSTRACT: A field experiment was conducted during *rabi* season of 2019-20 and 2020-21 at Research farm of Bihar Agricultural College, Sabour with the objective to find out the performance of different super absorbent polymers on grain yield, water productivity and economics of wheat under different irrigation levels. This experiment consisted of three irrigation levels (I_1- One irrigation at Crown Root Initiation (CRI) stage, I_2- Two irrigations at CRI & flowering stage and I_3- Three irrigations at CRI, Boot & milk stage) placed in main plot while levels of super absorbent polymers (P_1- Control, P_2- Magic hydrogel @ 5.0 kg acre^{-1}, P_3- Alsta hydrogel @ 6.0 kg acre^{-1}, P_4- Vedic hydrogel @ 3.0 kg acre^{-1}, P_5- Eco sarovar hydrogel @ 3.0 kg acre^{-1}, P_6- Stockosorb 660 hydrogel @ 8.0 kg acre^{-1}, P_7- Vaaridhar G1 hydrogel @ 1.0 kg acre^{-1}, P_8- Nano hydrogel @ 8.0 kg acre^{-1}, P_9- Solid rain hydrogel @ 6.0 kg acre^{-1} and P_{10}- Zeba hydrogel @ 5.0 kg acre^{-1}) were put in sub plots laid out in split plot design replicated thrice. Results indicated that application of solid rain hydrogel @ 6.0 kg acre^{-1} along with three irrigations recorded the higher grain yield (46.53 q ha^{-1} and 44.50 q ha^{-1}) and water productivity (1.44 and 3.70 kg m^{-3}) of wheat over control during 2020 and 2021, respectively, however, application of nano hydrogel @ 8.0 kg acre^{-1} along with three irrigations at CRI, Boot & milk stage recorded higher net return (Rs. 74469 and 68635 ha^{-1}) of wheat over control during 2020 and 2021, respectively. Moreover, application of zeba hydrogel @ 5.0 kg acre^{-1} along with three irrigations at CRI, Boot & milk stage exhibited higher B:C ratio (1.58 and 1.59) over control during 2020 and 2021, respectively.

Keywords: Economics, Irrigation, Productivity, Super absorbent polymer, Wheat.

I. INTRODUCTION

Water is considered as crucial input for agricultural production. It facilitates higher productive potential from land and significant response from agricultural inputs [9]. Poor use efficiency of water, nutrient and other agro-inputs is a serious bottleneck in realizing sustainable agricultural growth and future food security [7]. Wheat is grown on about 29.55 m ha in India with production of 101.20 m tonne and an average yield of 3424 kg ha^{-1}. Water requirement of wheat vary from 180-420 mm [4]. Yield of wheat increased significantly with increasing levels of irrigation [10]. Moisture stress is known to reduce tillering, grain number per spike and grain size [15]. Therefore, there is urgent need to reduce water requirement of the crop by improving use efficiency of irrigation water under changing climate situation. Under this scenario, the productivity of wheat can only be sustained by using water saving technologies. Several technologies have been developed for improving water productivity of wheat [12].

Hydrogel is an insoluble, cross-linked three-dimensional polymer which absorbs water more than 400 times of its weight and gradually releases it [3]. It enhances the crop productivity per unit available water, particularly in moisture stress. It also improves seed germination, seedling emergence rate and root growth that help plant to prolonged moisture stress [5]. Hydrogel reduces the leaching of herbicide, fertilizer and irrigation for crops. It promotes early flowering and tillering [14]. Significant improvement in yield and water use efficiency in wheat was reported by hydrogels [2]. Hydrogel in agriculture ensure better crop productivity in moisture stress by delaying permanent wilting point and delayed first irrigation and overall less irrigation make the crop nearly weed free.

Hydrogel saved significant irrigation water by producing more crops per drop of water, reduced cost of cultivation and used fewer resources (fertilizers, chemicals, water, power, labour) without any plenty on seed yield and environmental gains in rainfed region [13]. Because of unpredictable monsoon and water availability for farming, crops suffer due to either excess water in field or inadequate water. The gel mitigates the risks, if water availability drops. Two irrigations in wheat can be saved by application of hydrogel without compromising grain yield [19]. Keeping these issues in view, the present investigation was carried out to assess the influence of hydrogel on grain yield, water productivity and profitability of wheat under different irrigation levels.

II. MATERIALS AND METHODS

A field experiment was carried out in *rabi* season of 2019-20 and 2020-21 at Research Farm of Bihar Agricultural College, Sabour, Bhagalpur situated at latitude 25°15’40” N and longitude 87°2’42” E with an altitude of 37.46 meters above mean sea level with the aim to assess the effect of super absorbent polymers and irrigation on grain yield, water productivity and economics of wheat. The soil of experiment was sandy loam in texture, having a pH 7.27, low organic carbon 0.44 %, available low N 120.53 kg ha^{-1}, available medium P 25.43 kg ha^{-1} and K 151.29 kg ha^{-1}. The experiment was laid out in split plot design with three irrigation levels viz., one irrigation, two irrigations and three irrigations in main plot and ten super absorbent polymers *viz*., P_1- Control, P_2- Magic hydrogel @ 5.0 kg acre^{-1}, P_3- Alsta hydrogel @ 6.0 kg acre^{-1}, P_4- Vedic hydrogel @ 3.0 kg acre^{-1}, P_5- Eco sarovar hydrogel @ 3.0 kg acre^{-1}, P_6- Stockosorb 660 hydrogel @ 8.0 kg acre^{-1}, P_7- Vaaridhar G1 hydrogel @ 1.0 kg acre^{-1}, P_8- Nano hydrogel @ 8.0 kg acre^{-1}, P_9- Solid rain hydrogel @ 6.0 kg acre^{-1} and P_{10}- Zeba hydrogel @ 5.0 kg acre^{-1} in subplots, replicated thrice.

To carry out the experiment, the land preparation operations *viz*., pre sowing irrigation, ploughing and levelling were done. Wheat variety, HD 2967 was sown with a recommended seed rate of 100 kg ha^{-1} on 20th November, 2019 during first year and on 22th November, 2021 during second year. The recommended dose of nitrogen, phosphorus and potash was 150-60-40 kg ha^{-1}, respectively, which was applied through urea, single superphosphate and muriate of potash. The basal fertilizers in all the treatments including all the P and K fertilizers and 1/2 N fertilizer were applied, remaining half dose of N fertilizer was top-dressed. Hydrogel at different doses, well mixed with sufficient quantity of soil was applied to allotted experimental plots in furrows just before sowing of crop. While, hydrogel applied at the time of sowing of the crop. Other management practices including weeding and hoeing were adopted as per package and practices of the crop.

Yield parameters were recorded at the time of harvest. Five plants were selected randomly from each treatment to record the observations of yield attributing characters. The crop was harvested on 22th April, 2020 and 25th April, 2021 during first and second year, respectively. The data were analysed using analysis of variance (ANOVA) technique [6]. The net returns of different treatments were calculated by subtracting total cost of cultivation from gross returns of respective treatments. B: C ratio was calculated by dividing net return with cost of cultivation.

III. RESULTS AND DISCUSSION

Grain yield. The data on grain yield of wheat under the influence of irrigation and super absorbent polymer revealed that in 2020, solid rain hydrogel @ 6.0 kg acre^{-1} along with three irrigations (P_9I_3) in wheat exhibited significantly maximum grain yield (46.53 q ha^{-1}) of the crop which was at par with P_8I_3, P_6I_3, P_3I_3, P_2I_3 and $P_{10}I_3$ (Nano hydrogel @ 8.0 kg acre^{-1}, Stockosorb 660 hydrogel @ 8.0 kg acre^{-1}, Alsta hydrogel @ 6.0 kg acre^{-1} and Zeba hydrogel @ 5.0 kg acre^{-1} along with three irrigations) (Table 1). In 2021, stockosorb 660 hydrogel @ 8.0 kg acre^{-1} along with three irrigations (P_6I_3) in wheat exhibited significantly maximum grain yield (44.89 q ha^{-1}) of the crop which was at par with rest of the treatments except P_4I_3, P_5I_3, P_7I_3 (Vedic hydrogel @ 3.0 kg acre^{-1}, eco sarovar hydrogel @ 3.0 kg acre^{-1} and Vaaridhar G1 hydrogel @ 1.0 kg acre^{-1} along with three irrigations) and control (Table 2). Irrigation regimes have significant effect on grain yield of wheat [20]. Optimum water availability to wheat with irrigation might improve photosynthetic area of plant that cumulatively contributed to higher plant height, dry matter accumulation and CGR [11]. Thus, hydrogels release water as per crop need which resulted in higher yield.

Table 1: Interaction effect of super absorbent polymers and irrigation on grain yield (q ha^{-1}) of wheat in 2019-20.

Polymer / Irrigation	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	MEAN
I_1	25.92	30.33	30.53	27.08	26.98	32.12	26.40	31.78	32.74	28.64	**29.25**
I_2	30.80	37.50	38.54	35.41	34.91	40.00	31.95	42.07	42.80	36.59	**37.06**
I_3	33.90	44.55	45.54	35.71	36.89	45.93	34.70	45.98	46.53	43.33	**41.31**
MEAN	**30.21**	**37.46**	**38.20**	**32.73**	**32.93**	**39.35**	**31.02**	**39.94**	**40.69**	**36.19**	
	I	**P**	**P within I**	**I within P**							
SEm±	1.15	0.55	0.96	1.47							
CD (P=0.05)	4.52	1.57	3.51	5.37							

Table 2: Interaction effect of super absorbent polymers and irrigation on grain yield (q ha^{-1}) of wheat in 2020-21.

Polymer / Irrigation	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	MEAN
I_1	25.56	29.31	29.50	31.81	31.93	31.09	28.78	33.23	30.72	28.60	**30.05**
I_2	30.67	37.48	38.52	36.93	36.43	39.98	33.70	40.34	42.78	34.57	**37.14**
I_3	33.67	43.52	43.48	39.87	38.48	44.89	36.83	44.50	44.50	44.00	**41.37**
MEAN	**29.97**	**36.77**	**37.17**	**36.20**	**35.61**	**38.66**	**33.10**	**39.36**	**39.33**	**35.72**	
	I	**P**	**P within I**	**I within P**							
SEm±	0.71	0.77	1.34	1.46							
CD (P=0.05)	2.78	2.20	4.36	4.73							

Since hydrogel is likely to improve water availability to wheat, this concurrently improves nutrient uptake and photosynthetic activity resulted in increased number of grains per ear, consequently enhanced grain yield. These results are in conformity with the findings of [21, 17]. This increment in productivity with hydrogel might be due to higher growth, dry matter and yield attributes due to optimum water availability. These results are in close agreement with [1, 18].

Biological yield. Data on biological yield under influence of irrigation and super absorbent polymer revealed that in 2020, nano hydrogel @ 8.0 kg acre^{-1} along with three irrigations (P_8I_3) exhibited significantly maximum biological yield (120.01 q ha^{-1}) being at par with P_9I_3, P_2I_3 and P_6I_3 (Solid rain hydrogel @ 6.0 kg acre^{-1}, Magic hydrogel @ 5.0 kg acre^{-1} and Stockosorb 660 hydrogel @ 8.0 kg acre^{-1} along with three irrigations) (Table 3). In 2021, Magic hydrogel @ 5.0 kg/acre^{-1} along with three irrigations (P_2I_3) exhibited significantly maximum biological yield (114.02 q ha^{-1}) being at par with rest of the treatments except P_4I_3, P_5I_3, P_7I_3 (Vedic hydrogel @ 3.0 kg acre^{-1}, eco sarovar hydrogel @ 3.0 kg acre^{-1} and vaaridhar G1 hydrogel @ 1.0 kg acre^{-1} along with three irrigations) and control (Table 4).

The significant increase in grain and biological yield increased with the increase in irrigation levels. The higher irrigation frequency fulfilled the timely crop water requirement, which resulted into better growth in term of plant height, which maintained better plant relation, which helped in opening of stomata and increased photosynthesis rate which ultimately resulted in higher grain yield.

Table 3: Interaction effect of super absorbent polymers and irrigation on biological yield (q ha^{-1}) of wheat in 2019-20.

Polymer / Irrigation	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	MEAN
I_1	64.80	76.74	77.84	69.59	70.16	81.91	68.64	81.04	84.47	74.47	**74.97**
I_2	74.54	93.00	101.37	90.30	91.80	104.01	83.40	110.64	105.72	94.77	**94.95**
I_3	84.74	116.72	116.12	93.20	95.17	111.60	88.49	120.01	117.71	110.50	**105.43**
MEAN	**74.70**	**95.49**	**98.44**	**84.36**	**85.71**	**99.17**	**80.18**	**103.89**	**102.63**	**93.25**	
	I	**P**	**P within I**	**I within P**							
SEm±	2.95	1.41	2.45	3.76							
CD (P=0.05)	11.60	4.00	8.97	13.78							

Table 4: Interaction effect of super absorbent polymers and irrigation on biological yield (q ha^{-1}) of wheat in 2020-21.

Polymer / Irrigation	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	MEAN
I_1	66.27	74.16	75.23	79.70	79.89	79.29	73.41	84.77	79.25	74.36	**76.63**
I_2	77.99	92.94	101.32	91.44	90.30	103.95	85.40	98.15	105.67	89.54	**93.67**
I_3	86.08	114.02	110.88	98.49	96.48	109.09	94.16	107.77	112.59	112.20	**104.18**
MEAN	**76.78**	**93.71**	**95.81**	**89.88**	**88.89**	**97.44**	**84.32**	**96.90**	**99.17**	**92.03**	
	I	**P**	**P within I**	**I within P**							
SEm±	1.70	1.56	2.70	3.07							
CD (P=0.05)	6.67	4.42	9.04	10.29							

Grain and biological yield increased significantly with increased irrigation levels. There was progressive increase in wheat grain yield with every increment in irrigation level. These results are in conformity with the findings of [21]. Hydrogel acts as a great soil conditioner and not only helps to increase yield of wheat but also reduces water requirement of crop by 38 to 40%. Almost irrigation water can be saved for wheat in irrigated condition while in rainfed condition, water stress is minimized. These results are in conformity with the findings of [17].

Water productivity. The data on water productivity of wheat under the influence of irrigation and super absorbent polymer revealed that in 2020, solid rain hydrogel @ 6.0 kg acre^{-1} (P_9) registered maximum water productivity (1.44 kg m^{-3}) which was at par with nano hydrogel @ 8.0 kg acre^{-1} (P_8) and stockosorb 660 hydrogel @ 8.0 kg acre^{-1} (P_6) (Table 5).

Table 5: Effect of polymers and irrigation on water productivity and cost of cultivation in 2019-20 and 2020-21.

Treatments	Water productivity (kg m^{-3})		Cost of cultivation (Rs. ha^{-1})	
	2019-20	2020-21	2019-20	2020-21
Levels of irrigations				
I_1 - One irrigation	1.31	4.98	45599	46668
I_2 - Two irrigations	1.31	3.08	46599	47768
I_3 - Three irrigations	1.20	2.29	47599	48868
SEm±	0.05	0.09		
CD (P=0.05)	NS	0.35		
Super absorbent polymer				
P_1 - Control	1.08	2.88	36355	37624
P_2 - Magic hydrogel @ 5.0 kg $acre^{-1}$	1.33	3.46	45730	46999
P_3 - Alsta hydrogel @ 6.0 kg $acre^{-1}$	1.35	3.50	46030	47299
P_4 -Vedic hydrogel @ 3.0 kg $acre^{-1}$	1.17	3.51	41980	43249
P_5 -Ecosarovar hydrogel @ 3.0 kg $acre^{-1}$	1.17	3.48	40480	41749
P_6 -Stockosorb hydrogel @ 8.0 kg $acre^{-1}$	1.40	3.65	56055	57324
P_7 -Vaaridhar hydrogel @ 1.0 kg $acre^{-1}$	1.11	3.20	39855	41124
P_8 - Nano hydrogel @ 8.0 kg $acre^{-1}$	1.42	3.77	46355	46624
P_9 - Solid rain hydrogel @ 6.0 kg $acre^{-1}$	1.44	3.70	70105	71374
P_{10}- Zeba hydrogel @ 5.0 kg $acre^{-1}$	1.28	3.35	43043	44312
SEm±	0.02	0.08		
CD (P=0.05)	0.05	0.23		
Interaction				
SEm±	0.03	0.14		
CD (P=0.05)	NS	NS		

In 2021, nano hydrogel @ 8.0 kg $acre^{-1}$ (P_8) registered maximum water productivity (3.77 kg m^{-3}) which was at par with solid rain hydrogel @ 6.0 kg $acre^{-1}$ (P_9) and Stockosorb 660 hydrogel @ 8.0 kg $acre^{-1}$ (P_6). So far as irrigation level was concerned, water productivity was highest under one irrigation (I_1) (Table 5). Under less or negligible rainfall, external irrigation enhances water holding capacity of hydrogel. Where irrigation is available, this technology could reduce number of irrigations. Two irrigations are saved by hydrogel without compromising grain yield. Hydrogel can be real advantage of water saving during *rabi* season. Super absorbent polymers are used into soil to create water reserve near rhizospheric zone and are beneficial for agriculturist [8].

Cost of cultivation. The data on cost of cultivation of wheat under the influence of irrigation and super absorbent polymer revealed that three irrigation levels exhibited highest cost of cultivation of wheat among the irrigation treatments, however, as far as super absorbent polymer was concerned, cost of cultivation of wheat was recorded highest under solid rain hydrogel @ 6.0 kg $acre^{-1}$ over control (Table 5).

Net return. The data on net return of wheat under the influence of irrigation and super absorbent polymer revealed that in 2020, nano hydrogel @ 8.0 kg $acre^{-1}$ along with three irrigations (P_8I_3) in wheat exhibited significantly maximum net return (Rs. 74469 ha^{-1}) of the crop which was at par with P_3I_3, P_2I_3 and $P_{10}I_3$ (Alsta hydrogel @ 6.0 kg $acre^{-1}$, magic hydrogel @ 5.0 kg $acre^{-1}$ and zeba hydrogel @ 5.0 kg $acre^{-1}$ along with three irrigations) (Table 6).

Table 6: Interaction effect of super absorbent polymers and irrigation on net return (Rs. ha^{-1}) of wheat in 2019-20.

Irrigation \ Polymer	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	MEAN
I_1	32037	34546	35026	30272	31891	29180	30973	37988	17198	33719	**31283**
I_2	42625	51433	56437	50883	52319	49754	44805	65479	40597	53573	**50791**
I_3	50776	71506	72390	51634	55753	60908	50154	74469	50492	69599	**60768**
MEAN	**41813**	**52495**	**54618**	**44263**	**46655**	**46614**	**41978**	**59312**	**36096**	**52297**	
	I	**P**	**P within I**	**I within P**							
SEm±	3026	1450	2512	3851							
CD (P=0.05)	11880	4111	9212	14125							

Table 7: Interaction effect of super absorbent polymers and irrigation on net return (Rs. ha^{-1}) of wheat in 2020-21.

Irrigation \ Polymer	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	MEAN
I_1	32273	32177	32640	42230	43993	26873	36904	43302	12231	33866	**33649**
I_2	44240	51977	57041	54217	54438	50422	48699	59058	41415	48699	**51021**
I_3	51362	69579	67810	60770	59245	59129	56310	68635	46052	72179	**61107**
MEAN	**42625**	**51244**	**52497**	**52406**	**52559**	**45475**	**47304**	**56998**	**33233**	**51581**	
	I	**P**	**P within I**	**I within P**							
SEm±	1839	1821	3155	3513							
CD (P=0.05)	7223	5164	10426	11609							

In 2021, zeba hydrogel @ 5.0 kg $acre^{-1}$ along with three irrigations ($P_{10}I_3$) exhibited significantly maximum net return (Rs. 72179 ha^{-1}) which was at par with P_2I_3, P_8I_3 and P_3I_3 (Magic hydrogel @ 5.0 kg $acre^{-1}$, nano hydrogel @ 8.0 kg $acre^{-1}$ and alsta hydrogel @ 6.0 kg $acre^{-1}$ along with three irrigations) (Table 7). Higher crop productivity might be reason for higher net returns with three irrigations. Similar results were also reported by [11].

B:C ratio. The data on B:C ratio of wheat under the influence of irrigation and super absorbent polymer revealed that zeba hydrogel @ 5.0 kg $acre^{-1}$ along with three irrigations **(**$P_{10}I_3$) in wheat recorded maximum B:C ratio (1.58 and 1.59) during 2020 and 2021, respectively, which was at par with P_8I_3, P_3I_3 and P_2I_3 (Nano hydrogel @ 8.0 kg $acre^{-1}$, Alsta hydrogel @ 6.0 kg $acre^{-1}$ and Magic hydrogel @ 5.0 kg $acre^{-1}$ along with three irrigations) (Table 8 & Table 9). Similar results of higher profitability were also reported by [16] for irrigation and [18] for hydrogel.

Table 8: Interaction effect of super absorbent polymers and irrigation on B:C ratio of wheat during 2019-20.

Irrigation \ Polymer	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	MEAN
I_1	0.91	0.77	0.78	0.74	0.81	0.53	0.80	0.84	0.25	0.80	**0.72**
I_2	1.17	1.12	1.23	1.21	1.29	0.89	1.12	1.41	0.58	1.24	**1.13**
I_3	1.36	1.53	1.54	1.20	1.34	1.07	1.23	1.57	0.71	1.58	**1.31**
MEAN	**1.15**	**1.14**	**1.18**	**1.05**	**1.15**	**0.83**	**1.05**	**1.27**	**0.51**	**1.21**	
	I	**P**	**P within I**	**I within P**							
SEm±	0.07	0.03	0.06	0.09							
CD (P=0.05)	0.27	0.09	0.21	0.32							

Table 9: Interaction effect of super absorbent polymers and irrigation on B:C ratio of wheat during 2020-21.

Irrigation \ Polymer	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	MEAN
I_1	0.88	0.70	0.71	1.00	1.08	0.48	0.92	0.95	0.17	0.78	**0.77**
I_2	1.18	1.11	1.21	1.25	1.30	0.88	1.18	1.27	0.58	1.10	**1.11**
I_3	1.33	1.45	1.40	1.37	1.38	1.01	1.33	1.44	0.64	1.59	**1.29**
MEAN	**1.13**	**1.08**	**1.10**	**1.21**	**1.26**	**0.79**	**1.15**	**1.22**	**0.46**	**1.16**	
	I	**P**	**P within I**	**I within P**							
SEm±	0.04	0.04	0.07	0.08							
CD (P=0.05)	0.15	0.11	0.23	0.25							

IV. CONCLUSION

Thus, it was concluded that solid rain hydrogel @ 6 kg $acre^{-1}$ along with three irrigations at CRI, boot and milk stage exhibited highest grain yield and water productivity of wheat. Nano hydrogel @ 8 kg $acre^{-1}$ along with three irrigations resulted in highest net return, while, B:C ratio was highest in zeba hydrogel @ 5 kg $acre^{-1}$ along with three irrigations. Hydrogel with two irrigations to wheat can be advocated as sustainable strategy for enhancing profitable productivity of wheat.

V. FUTURE SCOPE

Future research strategy may be focused on the best performing super absorbent polymer for saving of irrigation and reduction in production cost of wheat under conservation tillage practice.

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Conflict of interest. None.

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