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Performance of Wheat (*Triticum aestivum* L.) in Response to Different Levels of Irrigation and Nitrogen Application

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Abstract

Balanced fertilizer management and optimum irrigation are essential for maximizing yield of wheat and at the same time excess application of water and nitrogen fertilizer are not economically efficient and can create environmental problems. Therefore, an experiment was conducted at the Central Farm, Bangladesh Agricultural University, Mymensingh from November 2018 through March 2019 to determine the optimum level of irrigation and rate of nitrogen required to achieve the maximum yield of wheat. The experiment consisted of four levels of irrigation i.e., no irrigation (I_0), one irrigation at Crown Root Initiation (CRI) stage (I_1), two irrigations at CRI and 40 Days After Sowing (DAS) (I_2) and three irrigations at CRI, 40 and 60 DAS (I_3), and four rates of nitrogen i.e., no nitrogen (N_0), application of 60 kg N ha^{-1} (N_1), application of 120 kg N ha^{-1} (N_2) and application of 180 kg N ha^{-1} (N_3). The experiment was laid out in a split-plot design with three replications where irrigation level was assigned to the main plots and nitrogen level in subplots. BARI Gom28 was used as the test variety. The maximum grain yield (4.00t ha^{-1}) was found with three irrigations at CRI, 40 and 60 DAS. Application of 180 kg N ha^{-1} gave the highest grain yield (4.54t ha^{-1}) which was the cumulative effect of highest number of effective tillers $hill^{-1}$, longest spike and highest number of grains $spike^{-1}$ in this treatment. Yield and yield contributing characters like effective tillers $hill^{-1}$, number of grains $spike^{-1}$, grain yield and straw yield were significantly influenced by interaction of irrigation and nitrogen. The highest grain yield (5.22t ha^{-1}) was obtained in three irrigations at CRI, 40 and 60 DAS with application of 180 kg N ha^{-1} which was statistically identical to two irrigations at CRI and 40 DAS with the application 120 kg N ha^{-1}. In the economic analysis of this study, the highest Benefit Cost Ratio (BCR) (2.41) was found from two irrigations at CRI and 40 DAS with application of 120 kg N ha^{-1} (I_2N_2). Therefore, the treatment combination of two irrigations at CRI and 40 DAS with application of 120 kg N ha^{-1} was effective and economic for producing higher grain yield of wheat.

Introduction

Wheat (*Triticum aestivum* L.) is the most widely cultivated food crop in the world which provides nutrition (proteins, energy and minerals) to most of the world's population (Goa et *al*., 2014; Zhang *et al*., 2017) and is well adapted to a wide range of environmental conditions. In Bangladesh, among all the major cereals, wheat ranks third which covered a land area of 0.868 million acres with the production of 1.09 million metric tons of food grains (BBS, 2018). Area under wheat is increasing because wheat requires less amount of irrigation water compared to other cereal crops like rice. But wheat is a strategic crop and is highly responsive to irrigation water during the short winter season November to March. So, for proper growth and development of wheat optimum water availability at the root zone of the plants during their growth is essential for the wheat production. In the recent years, in Bangladesh the area irrigated by surface water declined from 76% in 1981 to 23% in 2012, whereas for the same period, area irrigated by groundwater has jumped to 80% from 16% (BADC, 2013). Thus, judicious use of water in the agriculture is very important. Wheat is mainly cultivated as rained crop in Bangladesh but application of only one irrigation increase the yield of wheat by more than 40%, whereas two to three irrigations with proper water and fertilizer management practices increase wheat yield by 50-100% (Hossain *et al.,* 2006).

Again, for improving crop yields and farm profit fertilizer is considered as the principal inputs. Among all fertilizers, nitrogen is the most important plant nutrient for metabolic process, vegetative growth, plant productivity, protein production and grain quality (Haile

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et al., 2012). It has special significance in absorption of water and nutrients through improving the root system (Fageria and Barbosa, 2001). Nitrogen application at crown root initiation (CRI) stage reported as the most efficient in improving grain yield (Yadvinder-Singh *et al.,* 2007). So, efficient use of nitrogen is very important to maintain economic sustainability whereas excessive and inappropriate application of N fertilizer resulted in high N loss (Zhu and Chen, 2002). Therefore, appropriate nitrogen rate is crucial for improving wheat grain yield and nitrogen use efficiency, and reducing the negative effects of fertilization on the environment (Petersen and Mortensen, 2012). The production of wheat of this country can be accelerated through improving irrigation facilities alongside better practice of fertilizer (Shah *et al*., 2008). Therefore, the present study was undertaken to find out the optimum frequency of irrigation and rate of nitrogen required to achieve the maximum economic yield of wheat.

Materials and Methods

Experimental site

The experiment was carried out at the Central Farm, Bangladesh Agricultural University, Mymensingh. The site falls under the Agro-ecological Zone-9: Old Brahmaputra Floodplain (FAO and UNDP, 1988). The soil belongs to Sonatola series of the Old Brahmaputra Alluvial Tract, the parent material being river deposits and the soil type was non-calcareous with low fertility level and low organic matter content. The soil is more or less neutral (6.5) in reaction. The land type was medium high with silt loam in texture.

Climate

The experimental site enjoys the humid tropical climate characterized by an average temperature ranging from 19.22 to 24.35°C and rainfall during the month of March. The monthly meteorological data recorded in the weather yard, Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh during the study period are presented in Figure 1.

Treatments and design

The experiment consists of two-factors, factor A: irrigation and factor B: Nitrogen treatment. There were four levels of irrigation i.e., no irrigation (I_0), one irrigation at CRI stage (Crown Root Initiation) (I_1), two irrigations at CRI and 40 DAS (I_2) and three irrigations at CRI, 40 and 60 DAS (I_3), and four rates of nitrogen i.e., no nitrogen (N_0), application of 60 kg N ha^{-1} (N_1), application of 120 kg N ha^{-1} (N_2) and application of 180 kg N ha^{-1}(N_3). The experiment was laid out in a split-plot design with three replications. The irrigation treatments were assigned in the main plots and nitrogen treatments were in the sub-plots. Thus, the total number of unit plots was 48 (4×4×3). Size of each plot was 12 m^2 (4.0m × 3.0m).

Agronomic management

The land was prepared by 2-3 ploughing and cross ploughing by tractor drawn plough along with removal of weeds, stubbles and crop residues and trimming ails. At final land preparation, triple super phosphate, muriate of potash and gypsum were applied as 37.87, 60 and 27.78 kg ha^{-1}, respectively, considered as the recommended rate of fertilizer (BARC, 2012). All the fertilizers except urea were applied during final land preparation. Urea was applied as the sources of nitrogen, as per experimental treatments. BARI Gom28 was used as the test variety. Seeds were sown continuously on 28 November 2018 in line made by hand iron tine maintaining a line to line distance of 25 cm. After placement of seed in the furrow, seeds were covered with soil by hand. All the cultural practices (fertilizer application, weeding and drainage) were done when needed. Two weeding were done manually using *niri* at 15 and 30 days after emergence of seedlings. Irrigation was done as per experimental treatments. Grains were harvested plot-wise when about all crops reached their full maturity stage at 28 March 2019.

Data collection

From each plot, central 1m^2 area was harvested to record grain and straw yields and five hills were collected to record data of different yield and yield contributing characters at the time of harvesting. The harvested crop was brought to the threshing floor and sundried. The grains were then threshed by hand, cleaned and dried in the sun for three to four consecutive days for achieving safe moisture content of seed. Straw was also sundried for three to four consecutive days.

Statistical analysis

The recorded data were compiled and tabulated for statistical analysis. Analysis of variance was done with the help of a computer package program, MSTAT-C. The mean differences among the treatments were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984). The cost of individual head of expenditure was recorded and partial budget analysis was done.

Results

Crop characters and yield components

Plant height, total tillers hill^{-1}, effective tillers hill^{-1}, spike length, grains spike^{-1}, and 1000-grain weight were considered as the most important attributes of wheat plant, which responded differently by individual and combined effect of N rates and irrigation levels (Table 1, 2 and 3). The maximum plant height (78.53 cm) was obtained in I_3 treatment. The highest total tillers hill^{-1} (5.73), effective tillers hill^{-1} (4.96) and spike length (16.16cm) were obtained from I_2 treatment (Table 1). The lowest plant height, total tillers hill^{-1}, effective tillers hill^{-1} and spike lengths were found from I_0 (no irrigation). Most of the parameters except number of grains spike^{-1} showed better performance in case of 180 kg N ha^{-1} rather than other nitrogen treatments. The highest number of grains spike^{-1} (5.70) was recorded in 120 kg N ha^{-1}. The highest plant height (81.90 cm), total tillers hill^{-1} (5.93), effective tillers hill^{-1} (5.13) and spike length (16.47cm) were found in 180 kg N ha^{-1}. The lowest result was found in no nitrogen (Table 2).

Under the treatment combination, the highest results of most of the parameters were found in I_3N_3. The tallest plant (85.67 cm) was found in I_3N_3 although data obtained from I_1N_2, I_1N_3, I_2N_3 and I_3N_2 were statistically similar with I_3N_3. The lowest plant height (63.07 cm) was recorded in I_0N_0 treatment (Table 3). The maximum number of total tillers hill^{-1} (6.47), effective tillers hill^{-1} (5.50) and spike length (17.09 cm) were found in I_2N_3 which was statistically similar with I_2N_2 and I_3N_3. It was observed that the highest grains spike^{-1} (37.27) was recorded under at I_2N_2.

Grain yield

Significant variation was found in grain yield due to different levels of irrigations and nitrogen (Table 1 and 2). The highest grain yield (4.00 t ha^{-1}) was obtained from I_3 which was statistically identical to I_2. The lowest grain yield (2.70 t ha^{-1}) was recorded at I_0. Maximum grain yield (4.54 t ha^{-1}) was found from 180 kg N ha^{-1} (N_3) and the lowest grain yield (1.99 t ha^{-1}) was recorded from no nitrogen (N_0). Interaction between different levels of irrigation and nitrogen has significant effect on grain yield of wheat (Figure 2). The highest grain yield (5.22 t ha^{-1}) was obtained in I_3N_3 which was statistically identical to I_2N_2. The lowest grain yield (1.93 t ha^{-1}) was obtained in I_0N_0 treatment.

Straw yield

The highest straw yield (4.67t ha^{-1}) was obtained from I_2 (Table 1). Although data obtained from I_3 was statistically similar with I_2. The lowest straw yield (3.49 t ha^{-1}) was recorded in I_0. Straw yield was significantly affected by different rates of nitrogen (Table 2). The highest straw yield (5.54t ha^{-1}) was obtained in 180 kg N ha^{-1} and the lowest straw yield (2.67 t ha^{-1}) was recorded from no nitrogen treatment (N_0). The interaction effect of different levels of irrigation and nitrogen on straw yield of wheat was highly significant (Table 3). The highest straw yield (6.14 t ha^{-1}) was obtained from I_3N_3 which was statistically similar with I_2N_2 and I_2N_3 while the lowest straw yield (2.59 t ha^{-1}) was obtained from I_0N_0.

Economics of different irrigation and nitrogen treatments

In the partial budget analysis, it is found that the highest BCR (Benefit Cost Ratio) 2.41 was recorded from I_2N_2 and the lowest BCR (1.11) was found in I_0N_0 (Figure 3). So, it maybe concluded that two irrigations (at CRI & 40 DAS) with application of 120 kg N ha^{-1} is the best treatment for obtaining maximum yield as well as economic return of wheat.

Table 1. Effect of levels of irrigation on plant characters, yield components and yield of wheat

Level of irrigation	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	Spike length (cm)	1000- grain weight (g)	No. of grains spike^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
I_0	69.50b	4.71c	4.12c	14.70b	50.20	34.89	2.70c	3.48c
I_1	77.43a	5.40ab	4.52b	15.89a	51.11	33.78	3.14b	3.97b
I_2	77.05a	5.73a	4.96a	16.16a	51.60	35.74	3.88a	4.67a
I_3	78.53a	5.00bc	4.67ab	15.94a	50.90	34.10	3.97a	4.66a
CV (%)	5.3	10.93	7.86	2.31	2.41	8.22	6.59	8.69
Level of sig.	0.01	0.01	0.01	0.01	NS	NS	0.01	0.01

In a column figures having common letter(s) do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT; NS= Not significant; I_0 = No irrigation, I_1 = One irrigation at CRI stage, I_2 = Two irrigations at CRI and 40 DAS and I_3 = Three irrigations at CRI, 40 and 60 DAS

Table 2. Effect of levels of nitrogen on plant characters, yield components and yield of wheat

Level of nitrogen (kg ha^{-1})	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tiller shill^{-1}	Spike length (cm)	1000- grain weight (g)	Number of grains spike^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
N_0	65.88d	4.28c	3.74c	14.34d	50.59	33.29d	1.99d	2.67d
N_1	74.35c	4.96b	4.44b	15.77c	50.93	34.38c	3.05c	3.87c
N_2	80.38b	5.67a	4.94a	16.11b	51.21	35.70a	4.10b	4.76b
N_3	81.90a	5.93a	5.13a	16.47a	51.24	35.13b	4.54a	5.54a
CV (%)	2.19	6.21	4.94	2.22	2.37	1.72	7.03	7.27
Level of sig.	0.01	0.01	0.01	0.01	NS	0.01	0.01	0.01

In a column figures having common letter(s) do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT; NS= Not significant; N_0 = No Nitrogen, N_1 = Application of 60 kg N ha^{-1}, N_2 = Application of 120 kg N ha^{-1} and N_3 = Application of 180 kg N ha^{-1}

Table 3. Interaction effect of levels of irrigation and nitrogen on plant characters, yield components and yield of wheat

Irrigation × Nitrogen	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	Spike length (cm)	1000-grain weight (g)	Nu. Of grains spike^{-1}	Straw yield (t ha^{-1})
I_0N_0	63.07i	3.67g	3.13 j	13.56g	48.17	33.06h	2.59f
I_0N_1	69.80fg	4.47ef	4.07 h	14.38f	49.97	34.65def	3.17de
I_0N_2	71.67ef	5.27cd	4.47efg	15.25de	52.33	36.16b	3.68d
I_0N_3	73.47de	5.47cd	4.82cde	15.61cd	50.37	35.69bcd	4.51c
I_1N_0	64.60hi	4.20fg	3.62 i	14.54f	51.27	33.04h	2.69ef
I_1N_1	75.07cd	4.66ef	4.33fgh	16.18bc	50.97	33.32gh	3.52d
I_1N_2	84.60a	5.40cd	5.05bc	16.33b	50.33	34.35efg	4.19c
I_1N_3	85.47a	5.73bc	5.08bc	16.51ab	51.70	34.39efg	5.48b
I_2N_0	67.27gh	4.60ef	4.15fgh	14.69ef	52.63	34.39efg	2.64ef
I_2N_1	76.3c	5.67bc	4.87cd	16.29b	51.40	35.38b-d	4.24c
I_2N_2	81.00b	6.20ab	5.33ab	16.57ab	51.07	37.27a	5.74ab
I_2N_3	83.00ab	6.47 a	5.50a	17.09a	51.60	35.95bc	6.05a
I_3N_0	68.60g	4.67ef	4.09gh	14.57f	50.30	32.68h	2.77ef
I_3N_1	75.60cd	5.05de	4.52def	16.24b	51.40	34.19fg	4.28c
I_3N_2	84.27a	5.83bc	4.933c	16.29b	51.23	35.05c-f	5.44b
I_3N_3	85.67a	6.09ab	5.13abc	16.66ab	51.17	34.50ef	6.10a
CV (%)	2.19	6.21	4.94	2.22	2.386	1.716	7.27
Level of sig.	0.01	0.01	0.05	NS	NS	0.05	0.01

In a column figures having common letter(s) do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT; NS= Not significant; I_0 = No irrigation, I_1 = One irrigation at CRI stage, I_2 = Two irrigations at CRI and 40 DAS and I_3 = Three irrigations at CRI, 40 and 60 DAS; N_0 = No Nitrogen, N_1 = Application of 60 kg N ha^{-1}, N_2 = Application of 120 kg N ha^{-1} and N_3 = Application of 180 kg N ha^{-1}

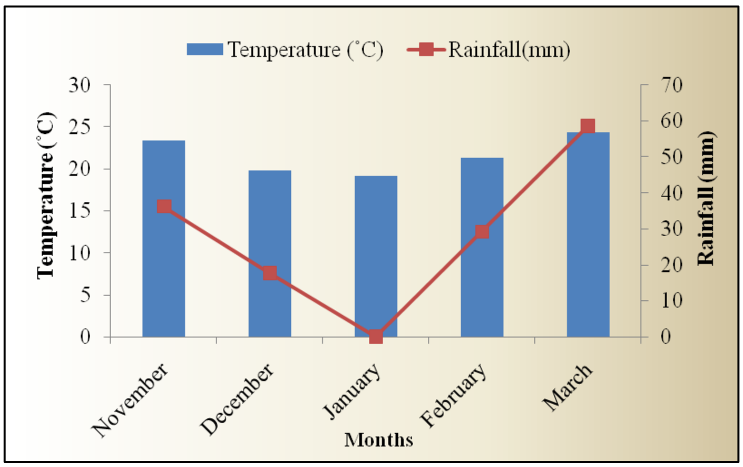

Figure 1. Distribution of monthly average temperature and rainfall of the experimental site during the period from November to March, 2019. Source: Weather yard, Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh

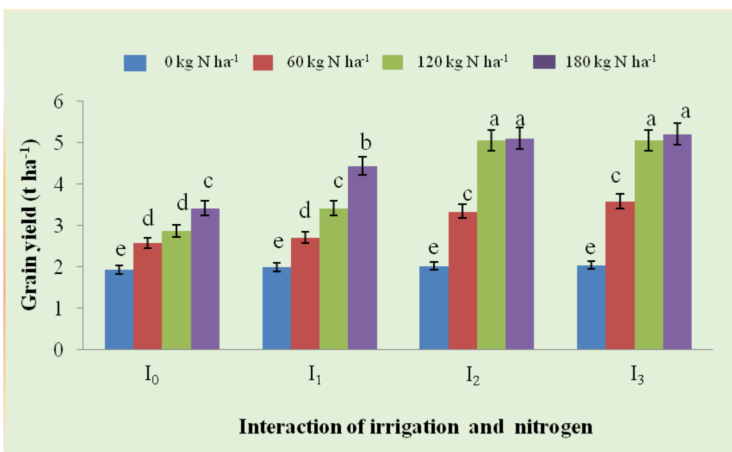

Figure 2. Interaction effect of irrigation and nitrogen on grain yield of wheat. I_0 = No irrigation, I_1 = One irrigation at CRI stage, I_2 = Two irrigations at CRI and 40 DAS and I_3 = Three irrigations at CRI, 40 and 60 DAS

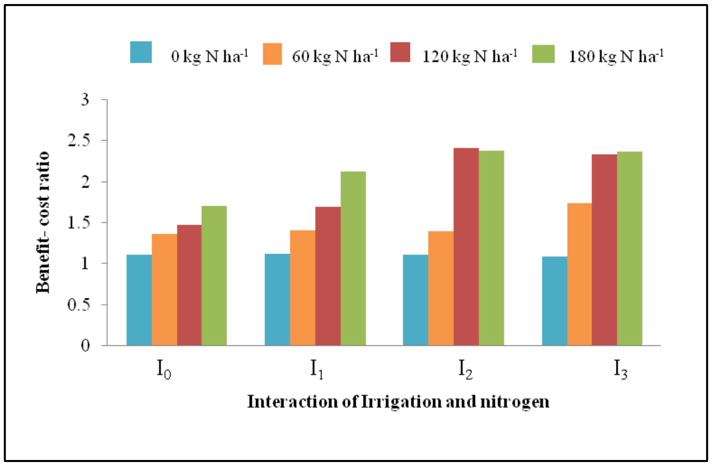

Figure 3. Benefit cost ratio (BCR) of different levels of irrigation and nitrogen in BARI Gom28. I_0 = No irrigation, I_1 = One irrigation at CRI stage, I_2 = Two irrigations at CRI and 40 DAS and I_3 = Three irrigations at CRI, 40 and 60 DAS; N_0 = No Nitrogen, N_1 = Application of 60 kg N ha^{-1}, N_2 = Application of 120 kg N ha^{-1} and N_3 = Application of 180 kg N ha^{-1}

Discussion

In our study, Plant characters like plant height, number of total tillers $hill^{-1}$, effective tillers $hill^{-1}$ and grains $spike^{-1}$ were significantly affected by different levels of nitrogen and irrigation. The difference in plant height might be due to the difference of availability of water and nitrogen. Yousaf *et al.* (2014) detected that each level of increase in nitrogen and irrigation increased plant height. It may be attributed to the effect on the encouragement of cell elongation, cell division and consequently, increased meristematic growth. This results partially supported by the findings of Rummana *et al.* (2018) who obtained the tallest plant with two irrigations at CRI and flowering stages. Similar research finding was also reported by Jan *et al*. (2002), Hussain *et al.* (2006) and Iqbal *et al.* (2014). Adequate water helps the plant to utilize the available nutrient to grow fast and taller, produce more vegetative and reproductive growth. The result of this study demonstrated that, number of tillers $hill^{-1}$ and grains $spike^{-1}$ of wheat increased with increasing nitrogen rate and irrigation levels. It was accorded with Kibe *et al.* (2006) and Malhi *et al*. (2006) who stated that increasing irrigation water during heading to flowering stages of wheat and nitrogen uptake increased tiller production of wheat. They also noted that stimulatory effects of N on tillering through cytokinin synthesis are known to result into more number of effective tillers of wheat. Supplementary irrigation upon the cessation of rains may have allowed remobilization of photo assimilates from source to sink as was evidenced by Abderrazzak *et al*. (2013). The result was supported by Ali *et al.* (2000), Hameed *et al.* (2003), Ali and Amin (2007) and Yusuf *et al.* (2014). The increase in number of grains $spike^{-1}$ might be due to availability of both nitrogen and water in the soil which may have increased floret endurance while the reduction in the control plots might be attributed to deficiency of assimilates due to water stress during grain filling (Ferrante *et al.,* 2010) and reduced number of grains $spike^{-1}$ due to flower abortion (Acevedo *et al*., 2002). Several investigators documented a beneficial effect of nitrogen application on the number of spikelets and grains $spike^{-1}$ of wheat (Mosalem *et al.,* 1997; Sorour *et al*., 1998; Sobh *et al.*, 2000). 1000-grain weight is a genetic character (Laila *et al.,* 2020) and it did not vary due to different nitrogen and irrigation treatments. Due to interactions, treatment combination of N rate of 180 kg N ha^{-1} applied with two irrigations gave maximum yield. Grain yield was the cumulative effect of highest number of effective tillers $hill^{-1}$, longest spike and highest number of spikelets $spike^{-1}$ which contributed to increase the grain yield. This finding corroborates the findings of Usman *et al.* (2013) and Yadav *et al.* (2013). The highest grain and straw yield recorded in 180 kg N ha^{-1} and similar result was found in Salam *et al*. (2017) in which they reported that application of nitrogen increases the yield significantly. Minimum grain yield was found with no irrigation and no nitrogen. This finding corroborates with the finding of Shirazi *et al.* (2014).

Conclusion

The treatment combination of two irrigations at CRI and 40 DAS with the application of 120 kg N ha^{-1} was effective in producing higher grain yield and economically more suitable than the other treatment combinations in wheat. So, to get maximum grain yield and highest economic return two irrigations at CRI and 40 DAS with application of 120 kg N ha^{-1} may be a promising technique for wheat production.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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