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Effect of Gravity Drip Irrigation on Growth, Yield and Water Use Efficiency of Gladiolus in Lower Gangetic Plain of West Bengal, India

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Abstract The state of West Bengal with 2.7 per cent of geographical area and 7.5 per cent of water resources can mitigate the demands of 8 per cent of India's population. Out of various natural resources, water is considered the most precious and vulnerable input for sustaining the environment and biological activity and augmented agricultural production. The demand for fresh water resources especially groundwater is escalating due to high population growth, improved standards of living and increased requirements for the domestic, industrial and agricultural sectors. This essential resource is going to be the limiting factor for increasing crop production in future due to the competitive demands from other sectors as a result of rapid industrialization, urbanization and economic development. Drip irrigation through the trickle supply of water drops has opened new vistas in the optimal ground water management and agricultural and horticultural production scenario. To address the problem, a field experiment was conducted at the Regional Research Station, Gayeshpur, BCKV during the winter season of 2013-2014 to assess the low cost gravity drip irrigation compared with conventional surface irrigation on growth, flower quality characteristics, flower production and water use efficiency of gladiolus. The results of the study showed that the lowest irrigation water use, highest water use efficiency and water savings and maximum soil water storage was obtained in gravity drip irrigation in comparison with surface irrigation. Maximum plant growth, yield attributes and flower production was accomplished with gravity drip irrigation at 1.0 ETo which were competitive with gravity drip irrigation at 0.8 ETo. Spike yield reached maximum at 118 mm water use through gravity drip system which is interesting from groundwater management point of view.

Keywords Groundwater, Drip irrigation, Water requirement, Flower production, Gladiolus

Gladiolus (*Gladiolus grandiflorus* L.) is an important commercial bulbous flower crop which is extensively cultivated in many countries of the world including India (Singh, 1997). It is a short cycle, easy driving crop with low implantation costs and fast payback. These factors allow for its cultivation in small areas in which commercial production of bulbs for domestic and foreign markets is also possible. This cut flower is used mainly for interior decoration. Furthermore, it has high economic value because it is one of the most important cut flowers grown in India. However, many of the imported varieties require a heavy input of fertilizers and irrigation resulting in an increase in cost of cultivation and reduction in the margin of profit (Sudhir-Chandra *et al*., 2007). The state of West Bengal, Maharashtra, Uttar Pradesh, Punjab, Hariyana and Andhra Pradesh are the main producer of this crop (Chadha, 2001). The fertilizer requirements of gladiolus are highly dependent on soil types and climatic conditions. Maximum flower yield and quality are obtained with an adequate level of fertilization. Cultivars showing rapid growth and developing large plants and large flower spikes responds more to fertilizer than those with low vigour and producing smaller plants and spike (Woltz, 2001). Smaller corms require more fertilizer than large corms mainly due to their stored reserve and partly to greater feeding ability of the extensive root system produced by large corms (Pal, 2000). To obtain high quality flowers, it is also essential to supply adequate water when it is required. The optimum use of irrigation can be scheduled based on the rooting area, and at the same time, taking care of avoiding the leaching of nutrients into deeper soil layers (Raina *et al*., 1999, 2002, 2011). Drip irrigation is often preferred over other irrigation methods because of the former's high water-application efficiency on account of reduced losses via surface evaporation and deep percolation. Because of high frequency water application, concentrations of salts remain manageable in the rooting zone (Mantell *et al*., 1985). High frequency water management by drip irrigation minimizes soil as a storage reservoir for water, provides at least daily

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requirements of water to a portion of the root zone of each plant and maintains a high soil matric potential in the rhizosphere to reduce plant water stress. In this background, the present experiment was carried out to assess the effect of different levels of low cost gravity drip irrigation compared with conventional surface irrigation on growth, flower quality characteristics, flower production and water use efficiency of gladiolus in the lower Gangetic plain of West Bengal, India.

1. Metrials and Methods

A field experiment was conducted during the winter season of 2013-2014 at the Central Research Farm, Regional Research Station, Gayeshpur, Bidhan Chandra Krishi Viswavidyalaya encompassing the lower Gangetic plain of West Bengal, India in order to study the response of various levels of gravity drip irrigation *vis-a-vis* conventional surface irrigation on gladiolus plant. The soil was sandy loam in texture with pH 6.9, low in available nitrogen (152.3 kg/ha) and medium in organic carbon (5.4 g/kg), available phosphorus (31.3 kg/ha) and available potassium (149.6 kg/ha) determined following the standard methods outlined by Jackson (1973). The gladiolus variety *cv.* American beauty was tested as plant material. The net plot dimension was 3.0 m x 1.0 m leaving 0.5 m *bund* width and 1.0 m irrigation channel. There were four irrigation treatments consisting of one conventional surface irrigation (I_1) and three gravity drip irrigation levels at 100 (I_2), 80 (I_3) and 60 (I_4) % of reference pan evaporation (ETo) laid out in a randomized block design with four replications. Irrigation treatments were given based on evaporation data (Ep, mm) obtained from a Class A Pan installed in the open field (Doorenbos *et al*., 1984). The pan was located on a wooden support at a height of 15 cm above the soil surface and readings were recorded daily. A separate lateral line (12 mm) was laid for each treatment. Two drippers per plant were provided on either side of plant at a distance of 30 cm. Discharge rate of emitters was 1.8 lph at a pressure of 1.2 kg/cm^2. The lateral interval was assumed to be equal to the dripper interval for each plot and the percentage wetted area was taken as 100% to compute the irrigation water to be applied (Karmeli and Keller, 1975).

The crop water requirement of banana was computed on daily basis using the following equation as suggested by (Shukla *et al.,* 2001):

$$V = Ep \times Kp \times Kc \times Sc \times Wp$$

Where, V = volume of water (litre/day/plant), E_p = open pan evaporation (mm/day), K_p = pan factor or pan coefficient, K_c = crop factor, S_c = crop spacing and W_p = wetted area (1.0). The effective rainfall was calculated by balance sheet method from the actual rainfall received and was used for daily water requirement of crop. The crop factor values used for different crop stages were computed based on the existing relative humidity and wind velocity (Doorenbos *et al*., 1984). The pan factor value was 0.7 as suggested for USDA class A pan. The irrigation frequency by drip system was once in every 3-4 days in winter based on 60, 80 and 100% of ETo. In surface method of irrigation, water was applied at IW/CPE 1.0 in splits at 7-day interval with 40 mm depth per irrigation.

Medium sized corms were planted on November 9, 2013 in lines maintaining row and plant spacing of 30 and 25 cm, respectively at a depth of 5 cm. The crop was fertilized with 100 kg N/ha from urea, 60 kg P_2O_5/ha from single super phosphate and 60 kg K_2O/ha from muriate of potash. Farmyard manure @ 5 t/ha was applied in all plots during the final land preparation. Full dose of P and K and one-third of N was applied uniformly to all plots as basal. The remaining nitrogen was top-dressed in two equal splits at 30 and 60 days after planting in both drip and surface irrigated plots. During the experiment, the necessary cultivation practices such as crop maintenance, fertilization, pinching and other cultural operations like weeding, earthing up etc and plant protection measures were equally performed in all the treatments. Gladiolus was harvested 5-times between 19 January and 10 February 2014. Statistical analysis of data was computed based on the method of Gomez and Gomez (1984).

2. Results and Discussion

2.1. Plant Growth, Biometric Variables and Flower Yield

The growth and flower quality characteristics of gladiolus such as plant height, number of spikes/plot, number of florets per spike, spike length, weight of single spike and spike yield were significantly influenced by the levels of drip irrigation and conventional surface irrigation (Table 1). A perusal of the data showed that drip irrigation at 100% of evaporation replenishment (1.0 ETo) produced the highest plant height (76.2 cm), number of spikes/plot (69.8), number of florets per spike (9.5), longer spike length (63.9 cm), higher weight of single spike (41.8 g) and spike yield (9424 kg/ha). The results were found to be at statistically par with the drip irrigation at 80% of evaporation replenishment (0.8 ETo), however, were superior to that with drip irrigation at 60% of evaporation replenishment (0.6 ETo) and conventional surface irrigation. These clearly indicate that optimal or, marginal deficit application of irrigation water through drip system on regular basis enhanced the growth and quality promoting characters and flower yield of plant. The marked reduction in quality improvement characters and spike yield in drip irrigation at 60% of evaporation replenishment (0.6 ETo) was particularly due to water stress which might have failed to fulfill the water requirement of the plant and consequently resulted in lower quality/yield characters and thereby spike yield (Begum *et al*., 2007). Significantly, the lowest plant height (60.4 cm) and number of spikes/plot (56.5) from drip irrigation at 0.6 ETo and number of florets per spike (7.7), spike length (55.2 cm) and weight of single spike (39.4 g) from the traditional surface irrigation was obtained. Quantitative values for a good gladiolus development in previously published studies reported irrigation applications as much as 50 mm per week (Howell, 1972) and 150 mm per season (Maggio *et.al.*, 1993). Howell (1972) stated that water requirements would be less in heavy soils since water could be stored for long time. It can be said that the result obtained in this study are similar to those reported by Howell (1972) and Maggio *et.al.* (1993). However, the spike yield receiving from drip irrigation at 0.6 ETo (7994 kg/ha) was on par with conventional surface irrigation documenting a yield of 7837 kg/ha. This revealed to the fact that higher degree of deficit irrigation as well as excess irrigation water application to gladiolus was not at all conducive to promote the yield augmenting parameters leading to the decreased marketable quality of flower production of gladiolus. Boodley (1981) found that water deficit in gladiolus reduced the assimilate mobilizing of the inflorescence, increased that of the corm and delayed translocation from leaves. The water stress decreased the mobilizing ability of inflorescence and increased that of corms, reduced $^{14}CO2$ fixation and slightly delayed assimilate translocation from the source leaves. The yield and quality of flowers were best when the plants were watered at an interval of 12 or 17 days and a minimum soil moisture content of 58 percent field capacity was necessary for successful gladiolus culture in sandy clay soil (El-Gamassy *et al*., 1977). The result on the flower quality obtained in this study was relatively lower than those of Karaguzel *et al*. (1999). This can be explained by the fact that, in their study, larger corms were used (10-12 cm perimeter and size 2), corms were planted earlier (24 Novenber) and additional KNO_3 were applied. The results were in the range of Eurovision variety reported by Gursan *et al.* (1986). Maggio *et al.* (1993) reported that flower weight and length were greatest when 150 mm were applied and irrigation rate had no effect on corm weights.

2.2. Water Use and Water Use Efficiency by Plant

The amount of irrigation water based on the measured evaporation values was initiated on 12 November 2013 and ended on 6 February 2014. The measured cumulative pan evaporation and water use under varied drip irrigation levels are depicted in Figure 1. The watering was done at a 3-4 day interval with 29 numbers of splits in drip irrigation system, while 5 numbers of irrigation at a depth of 40 mm was applied in surface irrigation commencing from 13 November 2013 and continued up to 2 February 2014. The daily water requirement of plant in 93-day period and the corresponding splits of irrigation under drip and surface irrigation systems during the growing period of plant were explained in Table 2. Higher daily evaporation rate as a result of higher temperature was recorded in the month of November (Fig 2). The total evaporation during the growing period was calculated as 109.1 mm based on which optimal and deficit irrigation supply to plant was introduced. During the plant growing season, the depth of irrigation water applied through drip irrigation at 60, 80 and 100 % of evaporation replenishment (ETo) was 118.40, 86.72 and 55.04 mm, respectively, whereas the corresponding figure for conventional surface irrigation was 200 mm (Table 3). The effective rainfall was 10.90 mm and the depletion of soil water storage was 15.18 and 15.48, 17.29 and 20.32 mm for surface irrigation and drip irrigation at 0.6, 0.8 and 1.0 ETo, respectively. The more soil water depletion was observed at lower soil moisture regime and *vice versa*. Water use efficiency (WUE) was calculated as the ratio of spike yield and total water used including irrigation water applied, effective rainfall and soil profile moisture contribution. Accordingly, the seasonal amount of water exploited by the plant was 144.78. 114.91 and 86.26 mm through drip irrigation at 60, 80 and 100 % of ETo, respectively and the corresponding figure for surface irrigation was 226.08 mm. The total water use and water use efficiency by plant varied with the magnitude of water application and contribution from soil water storage.

Table 1. Effect of irrigation levels on plant growth, quality attributes and flower yield of gladiolus plant

Irrigation level (I)	Plant height (cm)	No. of spikes/plot	No. of florets/ Spike	Spike length (cm)	Weight of single spike (g)	Spike yield (kg/ha)
I_1	63.1	59.7	7.7	55.2	39.4	7837
I_2	76.2	69.8	9.5	63.9	41.8	9424
I_3	74.5	67.6	9.1	62.9	41.1	9120
I_4	60.4	56.5	8.5	57.1	40.8	7994
SEm(±)	0.56	0.72	0.12	0.41	0.26	109
CD (0.05)	1.95	2.49	0.41	1.42	0.90	376

I_1: surface irrigation, I_2: drip at 1.0 ETo, I_3: drip at 0.8 ETo, I_4: drip at 0.6 ETo

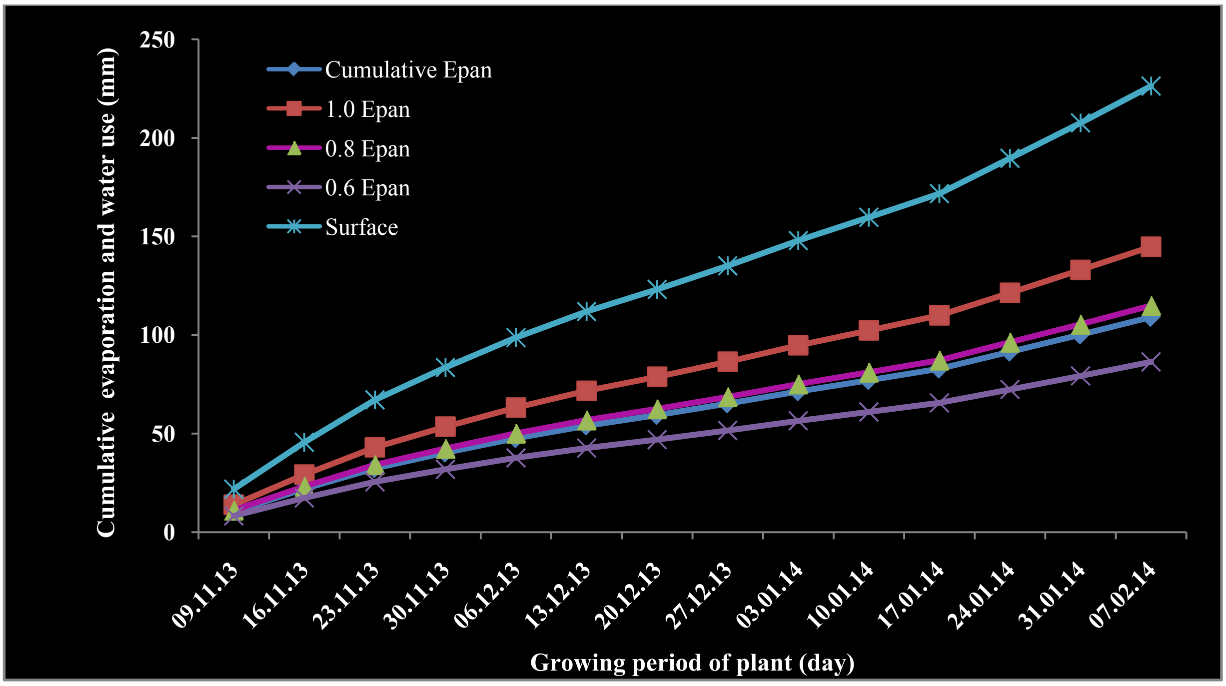

Figure 1. Cumulative pan evaporation (Epan) and water use during the period of the experiment

Table 2. Amount of irrigation water applied under drip and conventional surface irrigation methods during the experimental period

Month	Drip irrigation at 1.0 ETo			Conventional surface irrigation			
	Number of irrigation	ML day/plant	L/day/plot	Number of irrigation	Water applied (mm)	ML day/plant	L/day/plot
November	7	92	3.7	2	80	200	8.0
December	10	57	2.3	2	80	194	7.7
January	10	60	2.4	1	40	97	3.9
February	2	79	3.2	1	40	107	4.3

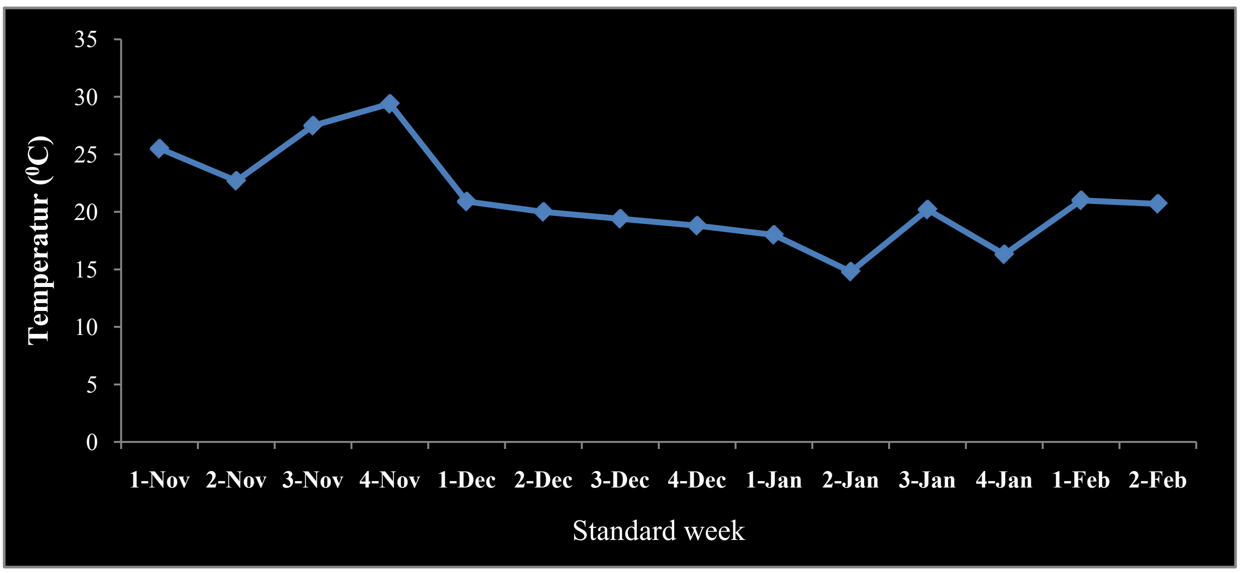

Figure 2. Mean weekly temperature during the period of the experiment

The results of the study showed that the highest water use (226.1 mm) was recorded in the conventional surface irrigation and the lowest (86.3 mm) in drip irrigation at 60% of evaporation replenishment (Table 3). On the contrary, the highest water use efficiency (92.67 kg/ha-mm) was recorded with drip irrigation at 60% of evaporation replenishment, whereas the lowest (33.66 kg/ha-mm) was obtained with surface irrigation. This implies to the fact that the water use efficiency of plant decreased progressively with the increment in water supply. The reduced flower yield and water use efficiency in conventional surface irrigation as reported in this study might be due to the losses of water and nutrients as a result of deep percolation and evaporation mechanisms beyond the crop root zone (Raina *et al*., 1999, 2011). On the other hand, the higher WUE under drip could be attributed to precise amount of water delivery in root zone without wetting the area with minimum scope for evaporation and deep percolation losses (Mantell *et al*., 1985; Raina *et al*., 2002).

2.3. Water-Yield Relations

The relationship for gladiolus spike yield with respect to the amount of irrigation water applied during the period of experimentation is illustrated in Figure 3. A second degree polynomial equation is fitted to the data of spike yield and amount of irrigation regardless of levels and methodology of water application. Coefficient of determination (R^2) value was found to be 0.99. During the 93-day plant period, spike yield reached a maximum at about 118 mm water application with a yield of 9.4 t/ha. This result reveals an interesting point from irrigation management point of view. The higher amount of water application by conventional surface irrigation is not conducive for higher marketable flower production. On the contrary, precise amount of water application in several fractions based on the crop evapotranspiration demand through drip irrigation is much beneficial in promotion of higher flower yield of gladiolus in sandy loam soil.

Table 3. Effect of irrigation levels on water use and water use efficiency of gladiolus

Irrigation level	Water use by plant (mm)				Water use efficiency (kg/ha-mm)
	Soil profile contribution	Effective rainfall	Irrigation water applied	Total water use*	
I_1	15.18	10.90	200.00	226.08	34.66
I_2	15.48	10.90	118.40	144.78	65.09
I_3	17.29	10.90	86.72	114.91	79.37
I_4	20.32	10.90	55.04	86.26	92.67

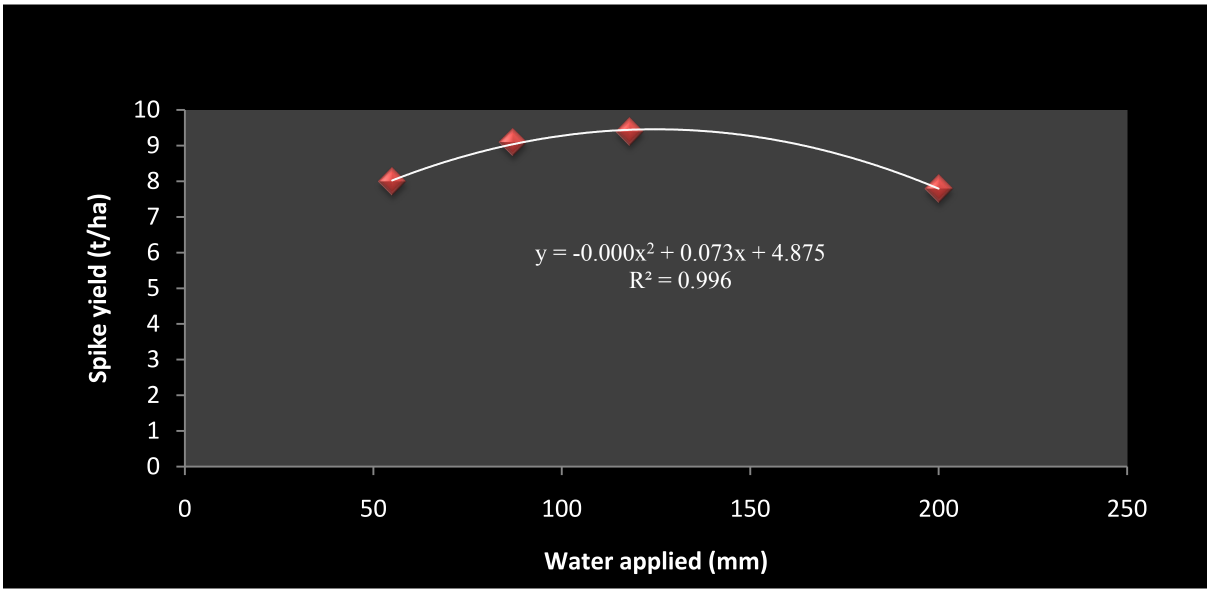

Figure 3. Relationship of spike yield and amount of irrigation during the period of experiment

3. Conclusions

The results of the study showed that the growth and quality promoting characters of plant such as height, number of spikes per plot, number of florets per spike, spike length, weight of single spike and flower or spike yield were significantly influenced by gravity drip irrigation levels and conventional surface irrigation. Drip irrigation at 100% of evaporation replenishment (1.0 ETo) produced the highest plant height (76.2 cm), number of spikes/plot (69.8), number of florets per spike (9.5), longer spike length (63.9 cm), higher weight of single spike (41.8 g) and spike yield (9424 kg/ha) which were at par with drip irrigation at 80% of evaporation replenishment (0.8 ETo), however, superior to drip irrigation at 60% of evaporation replenishment (0.6 ETo) and conventional surface irrigation. Significantly, the lowest plant height (60.4 cm) and number of spikes/plot (56.5) from drip irrigation at 0.6 ETo and number of florets per spike (7.7), spike length (55.2 cm) and weight of single spike (39.4 g) was obtained from surface irrigation. However, spike yield from drip irrigation at 0.6 ETo (7994 kg/ha) was on par with conventional surface irrigation (7837 kg/ha). The marked reduction in yield improvement parameters and spike yield under stress situations was the result of higher degree of deficit irrigation or, excess irrigation which was not at all conducive to promote the yield improvement characters leading to the decreased marketable quality of flower production. Spike yield was found maximum at 118 mm water use through low cost gravity drip system which is interesting from groundwater management point of view.

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