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Effect of Sowing Dates on the Bacterial Leaf Spot of Bottle Gourd and Pumpkin Caused by *Xanthomonas cucurbitae*

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ABSTRACT

An experiment was conducted at Experimental Farm, College of Horticulture and Forestry, Neri, Hamirpur during May 2019 to October, 2019 cropping season to study the effect of different sowing dates viz., 17th May (1st), 7th June (2nd), 27 June (3rd) and 17th July (4th) on the development of bacterial leaf spot of bottle gourd and pumpkin caused by *Xanthomonas cucurbitae.* It was observed that the mean disease severity in both bottle gourd and pumpkin crops decreased with delay in the date of sowing from mid May (40.15 and 31.73%, respectively) to the end of June (27th June, 31.65 and 27.06%, respectively) or mid July (17th July, 23.32 and 20.13%, respectively). The disease incidence was also found to be minimum in the fourth (31.31%) and third (39.60%) dates of sowing in case of bottle gourd fruits and no incidence of the bacterial spot was recorded in case of pumpkin fruits. In the case of bottle gourd, the expected yield loss was minimum in crops sown mid July (31.44%) while in pumpkin, the fruit yield was more in mid July (9.59 kg vine^{-1}) sown crop in comparison to mid May and early June sown crops. So, it was concluded that late June and mid July sown crops of both bottle gourd and pumpkin are less vulnerable to the disease leading to reduced crop losses and higher yield.

KEYWORDS: Bacterial leaf spot, cucurbits, sowing dates, *Xanthomonas cucurbitae*

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1. INTRODUCTION

Bacterial spot of cucurbits, impelled by *Xanthomonas cucurbitae* (Ex. Bryan) Vauterin et al., 1995 (Syn. *X. campestris*pv. *cucurbitae*) is one of the most significant maladies of bottle gourd and pumpkin (Jarial et al., 2011 and Babadoost and Ravanlou, 2012). This bacterial disease was first reported as a bacterial spot on Hubbard squash in New York in 1926 (Bryan, 1930). Subsequently, the disease was identified in various cucurbits like squash from Brazil (Robbset al., 1972), Argentinia (Alippi, 1989) and North Central United States (Liu et al., 2016); cucumber from Queensland, Australia (Anonymous, 1975), Brazil (Maringoni et al., 1988), India (Sinha, 1989) and China (Li, 1990); watermelon from Georgia (Dutta et al., 2013) and Seychelles (Pruvost et al., 2009); prince melon from Hokuriku (Taketani et al., 1976); pumpkin from the United States (William and Zitter, 1996), Reunion Island (Pruvost et al., 2009), Nepal (Lamichhane et al., 2010), Ontario, Canada (Trueman et al., 2014), North Central United States (Liu et al., 2016) and Italy (Altin et al., 2020) and bottle gourd from India (Jarial et al., 2011). This bacterial disease has been accounted for causing enormous losses in cucurbits and approximately 50–60% disease severity reaches at the time of storage of fruit (Larazev, 2009). Jarial et al. (2011) reported 10.07 to 70.61% yield losses in the case of bottle gourd. About 90% of losses were recorded in the case of pumpkin by Salamanca (2014).

Bottle gourd and pumpkin are two important cucurbitaceous crops grown for kitchen and commercial purpose in sub tropical zone of Himachal Pradesh. The bottle gourd crop is so badly affected with this disease that the farmers have either stopped its commercial cultivation or reduced to a considerable level. In pumpkin, although the fruits are not affected much but, the foliar infection leads to reduction in plant vigour and fruit yield (Jarial et al., 2018). An effective technique in an area should be to devise an integrated disease management methodology (Babadoost and Zitter, 2009). Most bacterial diseases of plants are managed using integrated strategies (Jurgens and Babadoost, 2013). Jarial et al. (2015) have suggested a strategy for management of bacterial spot in bottle gourd including cultural methods, seed treatments or foliar sprays. Management strategy for any bacterial disease requires a complete knowledge of disease epidemiology so as to identify the most vulnerable stage of the host and timing of adaptation of management strategy (Sundin et al., 2016). Sowing dates of bottle gourd and pumpkin might affect the disease severity and disease incidence of bacterial spot of cucurbits. But, there is no literature available on this aspect. However, many workers have worked on effect of sowing dates on the development of other bacterial diseases (Raut et al., 2010; Rafi et al., 2013; Amin et al., 2017). The sowing time of any crop depends upon the local climatic conditions as well as the market demand of the commercial product. The climate favourable for crop cultivation is generally favourable for the pathogens too. While talking about bacterial spot in cucurbits, the disease is favoured by warm and humid climate and spreads through rain splashes (Babadoost, 2012). So variation in sowing time of the crops in such a way that the disease spread is minimized can definitely affect the final disease level and crop yields. Bottle gourd and pumpkin being tropical crops can be grown in a wide range of temperature ranging between 18 to 35°C (Dhaliwal, 2017). Therefore, present studies were conducted with an objective to study the effect of sowing dates of bottle gourd and pumpkin on disease development.

2. MATERIALS AND METHODS

The study was conducted at Experimental Farm, Department of Plant Pathology, College of Horticulture and Forestry, Neri, Hamirpur, Himachal Pradesh, India (31.68°N and 76.52°E) in a randomized block design with six replications each in which commercial hybrids of bottle gourd (hybrid 1) and pumpkin (hybrid 1) were planted at 20 days interval on four different dates of sowing starting from 17th May 2019 to 17th July 2019 under natural epiphytotic condotions. The first sowing was done on 17th May, 2019 followed by the second on 7th June 2019 the third on 27th June 2019 and the fourth on 17th July 2019. Data on disease severity (%) were recorded at seven days intervals starting from the first day of symptom appearance in each sowing date upto 70 days after disease appearance as per scale given by Jarial et al. (2011). Further, the disease severity index was calculated as per the formula given by McKinney (1923). The data were further subjected for the calculation of apparent infection rate (per unit per day) and area under disease progress curve (AUDPC) as per the formulae given by Van der Plank (1963) and Shanner and Finney (1970), respectively. In case of fruit infection, data were recorded in terms of disease incidence by Johnston and Booth (1983).

Harvesting in both the crops started from July, 2019 in different dates of sowing and lasted upto October, 2019. Data were also recorded in terms of the total number of fruits observed and harvested in each vine and yield was also recorded in terms of fruit weight per vine (kg). Based on these data, average fruit weight was calculated and expected yield per vine was calculated as follows:

Expected yield per vine=Average fruit weight×Total number of fruits on the vine

Further, expected yield loss (%) was calculated as per the formula given below:

Expected yield loss (%)=(Expected yield-Actual yield)/

(Expected yield)×100

The experiment was conducted in the field in randomized block design with six replications for each treatment and statistically analyzed by using online software OPSTAT.

3. RESULTS AND DISCUSSION

As is clear from Figure 1 that initially up to 21 days after disease appearance, the disease severity level in all the sowing dates was almost equal. After 28 days of disease appearance, the disease severity level was highest on the third date of sowing. After that, the disease severity in the first and second dates of sowings increased drastically and at the end, the level was recorded to be highest on the first date of sowing i.e. the crop sown on 17th May followed by the crop sown on 7th June.

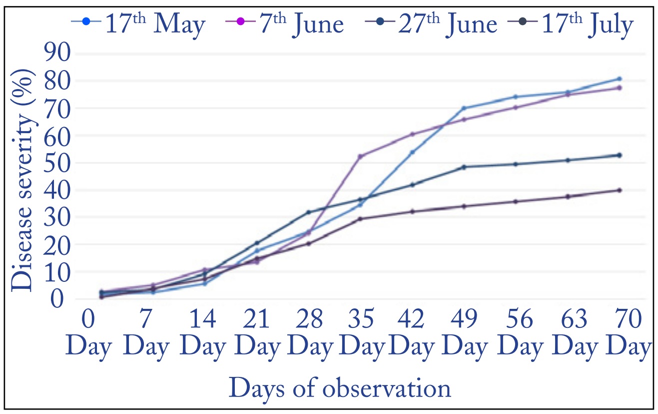

Figure 1: Progress of bacterial leaf spot of bottle gourd as influenced by different dates of sowing

The data presented in Table 1 revealed that in the case of bottle gourd, minimum disease severity (23.32%) was recorded in the fourth date of sowing followed by third (31.65%), first (40.15%) and second (41.64%) dates of sowing. Irrespective of the date of sowing, mean disease severity was minimum (1.99%) on the first day of observation i.e. 0 days after disease appearance, which increased significantly after each interval of observation and reached its maximum (62.77%) on the last day of observation i.e. 70 days after disease appearance.

Body of the table revealed that significantly minimum (0.82%) disease severity was recorded in the fourth date of sowing on the first day of observation i.e. 0 days after disease appearance followed by first (1.66%), third (2.54%) and second (2.92%) date of sowing on the first day of observation. The disease severity recorded after 21 days of disease appearance on third date of sowing (20.54%) was statistically at par with disease severity recorded on the fourth date of sowing after 28 days of disease appearance (20.38%). However, significantly maximum disease severity (80.83%) was recorded on the first date of sowing after 70 days of disease appearance followed by disease severity in second (77.41%), third (52.87%) and fourth (39.97%) date of sowing after the same duration. Intermediate disease severity was recorded on the rest of the days of observation in four different dates of sowing. As far as the apparent infection rate was concerned, it was significantly minimum (0.055 unit^{-1} day^{-1}) on the third date of sowing followed by the fourth (0.058 unit^{-1} day^{-1}) date of sowing. However, a significantly maximum apparent infection rate (0.078 unit^{-1} day^{-1}) was recorded on the first date of sowing followed by that (0.070 unit^{-1} day^{-1}) on the second date of sowing. A similar trend was observed in all dates of sowing in terms of AUDPC which was significantly minimum (16.78) on the fourth date of sowing followed by the third (22.27) date of sowing. However, significantly maximum AUDPC (32.10) was recorded on the second date of sowing followed by that on the first date of sowing (27.93). The data presented in Table 2 reveal the disease incidence recorded in bottle gourd fruits in the plants sown on different dates of sowing along with the yield per vine (kg) and expected yield loss in each date of sowing. It is clear from the table that disease incidence in terms of fruit rot was significantly highest (52.17%) in plants sown on the first date followed by that in second (45.13%), third (39.60%) and fourth (31.31%) dates of sowing. The total number of fruits vine^{-1} was observed to be significantly maximum (14.33) in plants sown on the last date of sowing followed by third (12.67), first (11.50) and second (10.33) dates of sowing. However, the number of healthy fruits harvested and yield vine^{-1} were found to be significantly maximum (9.83 and 6.17 kg) in plants sown on 17th July 2019 followed by those sown on 27th June (7.50 and 4.70 kg), 7th June (5.67 and 3.42 kg) and 17th May 2019 (5.50 and 3.11 kg). Average fruit weight calculated on this basis was found to be significantly maximum (0.628 kg) in plants sown on the fourth date. Based on the total number of fruits vine^{-1} and average fruit weight, the expected yield vine^{-1} was calculated which was found to be significantly maximum (9.00 kg) in the fourth date of sowing followed by third (7.92 kg) and second (6.24 kg) date of sowing. From these calculations, expected yield loss was further calculated which was found to be maximum (52.30%) in crop sown on 17th May followed by that sown on 7th June (45.19%), 27th June (40.65%) and 7th July (31.44%).

Local climatic conditions and market demand of crop generally affect the sowing time of a particular crop directly. Also, the climate favourable for crop cultivation is generally favourable for the pathogens too. Bottle gourd and pumpkin being tropical crops can be grown in a wide range of temperature ranging between 18 to 35°C (Dhaliwal, 2017). While talking about bacterial spot in cucurbits, the disease is favoured by warm and humid climate and spreads through rain splashes (Babadoost, 2012). So variation in sowing time of the crops in such a way that the disease spread is

Table 1: Effect of sowing dates on the disease progression of bacterial leaf spot in bottle gourd

Date of sowing	Disease severity (%) after the days of appearance							
	0	7	14	21	28	35	42	49
17th May, 2019	1.66 (7.39)	2.59 (9.26)	5.56 (13.64)	17.67 (24.85)	24.63 (29.74)	34.46 (35.93)	53.94 (47.24)	70.12 (56.84)
7th June, 2019	2.92 (9.84)	5.17 (13.14)	10.80 (19.18)	13.55 (21.59)	24.19 (29.45)	52.21 (46.24)	60.55 (51.07)	65.83 (54.20)
27th June, 2019	2.54 (9.18)	3.55 (10.85)	9.30 (17.75)	20.54 (26.93)	32.00 (34.43)	36.48 (37.14)	42.06 (40.41)	48.40 (44.06)
17th July, 2019	0.82 (5.22)	3.96 (11.47)	7.53 (15.92)	15.00 (22.77)	20.38 (26.83)	29.38 (32.81)	32.26 (34.59)	33.85 (35.56)
Overall mean	1.99 (7.91)	3.81 11.18)	8.30 (16.62)	16.70 (24.04)	25.30 (30.11)	38.13 (38.03)	47.20 (43.33)	54.55 (47.67)
CD (p=0.05) SE(d)								
Date of sowing (DS)					0.08			
Day of observation (Do)					0.14			
Interaction (DO×DS)					0.29			

Table 1: Continue...

Date of sowing	Disease severity (%) after the days of appearance					
	56	63	70	Overall mean	Apparent infection rate (unit^{-1} day^{-1})	AUDPC
17th May, 2019	74.19 (59.44)	76.05 (60.67)	80.83 (64.01)	40.15 (37.18)	0.078	27.93
7th June, 2019	70.43 (57.03)	74.98 (59.96)	77.41 (61.59)	41.64 (38.48)	0.070	32.10
27th June, 2019	49.42 (44.65)	50.96 (45.53)	52.87 (46.62)	31.65 (32.51)	0.055	22.27
17th July, 2019	35.73 (36.69)	37.62 (37.82)	39.97 (39.20)	23.32 (27.17)	0.058	16.78
Overall mean	57.44 (49.59)	59.90 (51.00)	62.77 (52.86)			
CD (p=0.05) SE(d)						
Date of sowing (DS)		0.04				
Day of observation (Do)		0.07			0.002	0.40
Interaction (DO×DS)		0.14			0.001	0.18

Figures in parentheses are arcsine transformed values

minimized can definitely affect the final disease level and crop yields. So, during the present studies, the sowing dates starting from 17th May to 17th July were evaluated to see their effect on disease development and crop yield. The results of studies revealed that disease severity of bacterial spot in bottle gourd was maximum in crop sown in mid May (17th May) and early June (7th June) as compared to those sown at end of June (27th June) and mid July (17th July). The apparent infection rate was also lesser in late sown crop than the early sown crops. This decrease in apparent infection rate can be attributed to the fact that the causal bacterium spreads through rain splashes from one plant to another (Goldberg, 2012) and the mid July sown crop completed most of its cropping period after the rainy season was over, thus reducing the rate of spread of disease. As far as yield of bottle gourd was concerned it was also more in

Table 2: Effect of sowing dates on the incidence of bacterial leaf spot and yield in bottle gourd

Date of sowing	Disease incidence (%)	Total no. of fruits observed vine^{-1} (avg.)	Number of healthy fruits harvested (avg.)	Actual yield (kg) vine^{-1}	Average fruit weight (kg)	Expected yield (kg) vine^{-1}	Expected yield loss (%)
17th May, 2019	52.17	11.50	5.50	3.11	0.567	6.52	52.30
7th June, 2019	45.13	10.33	5.67	3.42	0.604	6.24	45.19
27th June, 2019	39.60	12.67	7.50	4.70	0.626	7.92	40.65
17th July, 2019	31.31	14.33	9.83	6.17	0.628	9.00	31.44
SE(d)	1.56	0.52	0.35	0.21	0.001	0.31	
CD (p=0.05)	3.35	1.12	0.77	0.47	0.002	0.67	

late June and mid-July sown crops as compared to earlier sown crops. A definite relationship between disease level and yield could be visualized as the yield was more in those treatments in which disease levels were lesser. In the case of bottle gourd, expected yield loss was also calculated and it was also found to be minimum in crops sown in late June and mid-July. This reduction in yield in heavily infected vines can be attributed to the fact that disease affects the foliage of the plants thus directly reducing the photosynthetic area, ultimately leading to lesser fruit production. Such types of studies have not been conducted to date on this disease in any pathosystem, so the results cannot be compared with any available literature. However, many workers have studied the effect of sowing dates on the diseases caused by other *Xanthomonas*. The results obtained during present studies are in accordance with Raut et al. (2010) who reported that incidence of bacterial blight of cotton was maximum in crop sown earlier i.e. on 27 June (first), 7th July (2nd) and 17th July (third). The progress of the disease in pumpkin crop sown on four different dates has been presented in Figure 2. As is clear from Figure 2 that initially up to 14 days after disease appearance, the disease severity level in all the sowing dates was almost equal. After 21 days of disease appearance, the disease severity level was highest on the third date of sowing. After that, the disease severity in the

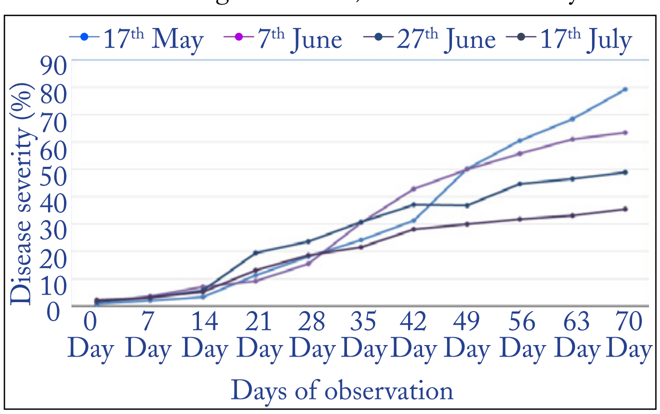

Figure 2: Progress of bacterial leaf spot of pumpkin as influenced by different dates of sowing

first and second dates of sowings increased drastically and at the end, the level was recorded to be highest on the first date of sowing i.e. the crop sown on 17th May followed by the crop sown on 7th June. However, the disease level was recorded to be lowest on the fourth date of sowing i.e. the crop sown on 17th July

The data in Table 3 revealed that in the case of pumpkin, irrespective of days of observation, significantly minimum mean disease severity (20.13%) was recorded in the fourth date of sowing followed by the third (27.06%) date of sowing. However, the maximum mean disease severity (31.73%) was recorded on the first date of sowing which was statistically at par with the mean disease severity recorded in the second (30.92%) date of sowing. Irrespective of the date of sowing, mean disease severity was minimum (1.50%) on the first day of observation i.e. 0 daysafter disease appearance which increased significantly at each interval of observation and reached the maximum (56.66%) on the last day of observation i.e.70 days after disease appearance. Further, the interaction of date of sowing and days of observation revealed that significantly minimum (0.72%) disease severity was recorded on the first day of observation on the first date of sowing which was statistically at par with disease severity on the first day of observation in second (1.55%) and third (1.57%) dates of sowing as well as after 7 days of disease appearance in the first date of sowing (2.13%). However, maximum disease severity (79.22%) was recorded on the first date of sowing after 70 days of disease appearance followed by disease severity (63.35%) in second, third (48.75 %) and fourth (35.33%) dates of sowing after the same duration. An intermediate level of disease severity was recorded on the rest of the days on four different dates of sowing.

It is evident from the data that the apparent infection rate was significantly minimum (0.047 unit^{-1} day^{-1}) on the fourth date of sowing followed by the third (0.058 unit^{-1} day^{-1}) date of sowing. However, the apparent infection rate was recorded to be significantly maximum (0.08 unit^{-1} day^{-1}) on the first date of sowing followed by the second (0.068 unit^{-1} day^{-1}) date of sowing. As far as AUDPC was concerned,

Table 3: Effect of sowing dates on the progression of bacterial spot in pumpkin

Date of sowing	Disease severity (%) after the days of appearance							
	0	7	14	21	28	35	42	49
17th May, 2019	0.72 (3.90)	2.13 (8.40)	3.21 (10.24)	11.17 (19.50)	18.17 (25.22)	24.15 (29.42)	31.17 (33.93)	50.18 (45.08)
7th June, 2019	1.55 (7.08)	3.52 (10.80)	7.08 (15.42)	9.22 (17.67)	15.57 (23.23)	30.41 (33.45)	42.90 (40.90)	49.83 (44.88)
27th June, 2019	1.57 (7.20)	2.99 (9.95)	5.59 (13.67)	19.40 (26.12)	23.64 (29.08)	30.60 (33.57)	37.06 (37.48)	36.81 (36.58)
17th July, 2019	2.16 (8.40)	3.07 (10.09)	5.19 (13.17)	12.99 (21.11)	18.59 (25.52)	21.51 (27.62)	27.99 (31.93)	29.96 (33.17)
Overall mean	1.50 (6.64)	2.93 (9.81)	5.27 (13.12)	13.20 (21.10)	18.99 (25.76)	26.67 (31.01)	34.78 (36.06)	41.70 (39.93)
CD (p=0.05) SE(d)								
Date of sowing (DS)					0.58			
Day of observation (Do)					0.96			
Interaction (DO×DS)					1.92			

Table 3: Continue...

Date of sowing	Disease severity (%) after the days of appearance					
	56	63	70	Overall mean	Apparent infection rate (unit^{-1} day^{-1})	AUDPC
17th May, 2019	60.43 (51.03)	68.46 (55.81)	79.22 (62.85)	31.73 (31.40)	0.089	21.53
7th June, 2019	55.67 (48.23)	61.04 (51.36)	63.35 (52.72)	30.92 (31.43)	0.068	21.52
27th June, 2019	44.66 (41.92)	46.62 (43.04)	48.75 (44.27)	27.06 (29.35)	0.055	22.27
17th July, 2019	31.66 (34.84)	33.02 (35.06)	35.33 (36.45)	20.13 (25.16)	0.047	14.30
Overall mean	48.11 (43.84)	52.29 (46.32)	56.66 (49.07)			
CD (p=0.05) SE(d)						
Date of sowing (DS)		0.29				
Day of observation (Do)		0.48			0.002	0.11
Interaction (DO×DS)		0.97				

Figures in parentheses are arcsine transformed values

it was significantly minimum (14.30) on the fourth date of sowing followed by the third (19.41) date of sowing. However, a maximum (21.53) AUDPC was recorded on the first date of sowing which was statistically at par with AUDPC in the second (21.52) date of sowing.

The data presented in Table 4 reveal the number of fruits harvested and fruit yield (kg) of pumpkin vine^{-1} in plants sown on four different dates. It is clear from the table that no disease symptoms were observed on any of the pumpkin fruits. However, the number of fruits harvested was definitely affected due to disease symptoms observed in leaves. The total number of fruits harvested and yield vine^{-1} in the case of pumpkin was significantly maximum in plants sown on 17th July (14.31 and 9.59 kg) followed by

Table 4: Effect of different dates of sowing on fruit yield of pumpkin

Date of sowing	Disease incidence (%)	Total no. of fruits harvested vine^{-1}	Actual yield (Kg) vine^{-1}
17th May, 2019	0.00	11.67	7.51
7th June, 2019	0.00	12.20	8.24
27th June, 2019	0.00	13.31	8.97
17th July, 2019	0.00	14.31	9.59
SE(d)		0.22	0.13
CD (p=0.05)		0.48	0.28

those sown on 27th June (13.31 and 8.97 kg), 7th June (12.20 and 8.24 kg) and 17th May (11.67 and 7.51 kg).

The results in pumpkin crop were similar to those recorded in bottle gourd except that no incidence of disease was recored on pumpkin fruits. However, as far as yield of pumkin crop was concerned, it was found to be maximum in mid July (17th July) sown crop and minimum in mid may (17th May) sown crop. There was a clear cut relationship in the disease levels and crop yield. The results of present studies are supported by Mohammed et al. (2003) who concluded that incidence of bacterial blight of cotton decreased with delayed sowing. Another similar observation was recorded by Amin et al. (2017) who reported that to escape the crop from the bacterial blight of cluster bean, sowing time played a vital role as non-monitory input and found that per cent disease severity of bacterial blight was decreased significantly with each delay in sowing and early sowing i.e. third and fourth week of July resulted in increased disease intensity significantly.

4. CONCLUSION

Disease severity decreased with delay in the date of sowing from 17th May to 17th July in both the crops. High disease severity was recorded in 17th May and 7th June sown crops. The apparent infection rate was also lesser in late sown crops. Expected yield loss was also minimum in late June and mid July sown crops as the disease affects the plant foliage thus reducing the photosynthetic area, ultimately leading to lesser fruit production.

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