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Effect Of Salicylic Acid And Varieties On Incidence Of Aphid And Yield Of Mustard

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***Abstract*—Aphids are one of the vital agricultural pests and cause extensive damage to the plants and yield of crops each year. It is one of the most damaging biotic stresses of mustard plant. It is mainly host specific, sucks phloem sap, retards growth and results poor pod formation. Plants have a unique capacity to coup with different insects and pests using various compounds from nature. Salicylic acid (SA) is a phenolic compound, responses as an endogenous signal imparting systematic plant protection against plant pathogens. It also has crucial role in minimizing the infestations and effects of both biotic and abiotic stresses, for example, aphid, insects, salinity, drought, osmotic stress and other toxicity. Moreover, physiological and biochemical mechanisms within the plants are somehow controlled by SA. This study was conducted to test the incidence of aphid in mustard plant in presence of different doses of salicylic acid and different varieties as aphids are highly host specific. Here we found, higher the concentrations of SA lower the rate of infestation of aphids by improving resistant mechanisms of different mustard varieties.**

***Keywords*—Salicylic acid, Aphids, Yield and Mustard plants**

Introduction

Mustard is one of the most important oil crops of the world after soybean and groundnut [1]. During entire life cycle, crop plants have to face different exogenous stresses which retard the normal development and yield of crop plant [2]. Aphids are important agricultural pest which play a vital role for considerable yield losses by feeding crop plant as well as acting as a vector for transmitting viral diseases among individual plants [3]. [4]. [5]. [6]. The removal of photoassimilate from the phloem structure of plant devitalizes the plant completely and drastically damages the crop yield [7]. [8]. Introduction of uncontrollable pathogenic viruses [9] and phytoplasma [8] [10] bring detrimental situation of plant growth and economic yield. Incidence of Mustard aphid can even cause up to 70% yield damage because of rapid multiplication of population. It can withstand or even change some important chemicals which act as herbivores deterrents [11]. [12]. Salicylic acid ($C_7H_6O_3$) is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plant, such as stomatal closure, ion uptake, inhibition of ethylene biosynthesis, transpiration and stress tolerance [13]. Plant growth regulators (PGRs) are organic compounds, which play an essential role in many aspects of plant growth and development [14]. [15]. PGRs can improve the physiological efficiency including photosynthetic ability and can enhance the effective partitioning of accumulates from source and sink in the field crops [16]. Salicylic acid plays a significant role in plant water relations [17], photosynthesis, growth and stomatal regulation under abiotic stress conditions and also created defense mechanism against insect pests [18]. [19]. Moreover, SA creates plant tolerance capacity to different biotic and abiotic stresses by helping to gain systemic acquired resistance [20]. [21]. [22]. Exogenous application as well as synthesis of SA in plant is a part plant defense mechanism [22]. [23]. In this experiment, higher concentration (S2: 0.4 mM SA) of SA causes higher yield because of lower aphid's infestation. More aphid incidence found in control and plot with lower exogenous application of SA. Different varieties also performed differently in aphid preference for their genotypic characters. Thus, the experiment was conducted to assess the infestation level of aphid in mustard due to the application of salicylic acid on different mustard varieties and their effects on the seed yield of mustard.

Materials Methods:

Experimental period

The experiment was conducted during the period from November, 2014 to March, 2015.

Site description

The present piece of research work was conducted in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^0 74^/$N latitude and $90^0 35^/$E longitude with an elevation of 8.2 meter from sea level.

Climatic condition

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Table 1. During the experimental period the maximum temperature (27.1^0C) was recorded from February, 2015 and the minimum temperature (12.4^0C) from January, 2015, highest relative humidity (78%) was observed from November, 2014, whereas the lowest relative humidity (67%) and highest rainfall (30 mm) was recorded in February, 2015.

Table 1: Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2013 to March 2014

Month	*Air temperature (°c)		*Relative	Total Rainfall	*Sunshine
	Maximum	Minimum	humidity (%)	(mm)	(hr)
November, 2013	25.8	16.0	78	00	6.8
December, 2013	22.4	13.5	74	00	6.3
January, 2014	24.5	12.4	68	00	5.7
February, 2014	27.1	16.7	67	30	6.7
March, 2014	28.1	19.5	68	00	6.8

* Monthly average,

* Source: Bangladesh Meteorological Department, Agargoan, Dhaka – 1212

Characteristics of soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ-28) and the general soil type is Shallow Red Brown Terrace soil. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of silty clay with pH and organic matter 6.1 and 1.13, respectively. The results showed that the soil composed of 27% sand, 43% silt and 30% clay, which have been presented in Table 2.

Treatment of the experiment

The experiment comprised of two factors. **Factors A:** Levels of salicylic acid (3 levels: S_0: 0 mM SA (control); S_1: 0.2 mM SA and S_2: 0.4 mM SA. **Factor B:** Mustard varieties (5 mustard varieties: V_1: BARI Sarisha-1; V_2: BARI Sarisha-13; V_3: BARI Sarisha-14; V_4: BARI Sarisha-15 and V_5: BARI Sarisha-16. There were in total 15 (3×5) treatment combinations such as S_0V_1, S_0V_2, S_0V_3, S_0V_4, S_0V_5, S_1V_1, S_1V_2, S_1V_3, S_1V_4, S_1V_5, S_2V_1, S_2V_2, S_2V_3, S_2V_4 and S_2V_5.

Experimental design

The two-factor experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The experiment area was divided into three equal blocks. Each block contained 15 plots where 15 treatments combination were allotted at random. There were 45-unit plot altogether in the experiment. The size of each plot was 2.0 m × 1.0 m.

The distance maintained between two blocks and two plots were 1.0 m and 0.5 m respectively.

Counting of aphid

The mustard plants were closely examined at regular intervals at flowering and fruiting stage. Aphid from 10 plants were recorded at early, mid and late flowering and fruiting stage and converted per plant. The insect population was collected by a needle brush in a Petri dish.

Determination of plant infestation

All the healthy and infested plants were counted from 1 m^2 selected area from middle place of each plot and examined. The collected data were divided into flowering and fruiting stage. The healthy and infested plants were counted and the percent plant damage was calculated using the following formula:

$$\text{Plant infestation (\%)} = \frac{Number\ of\ plant\ infested}{Total\ number\ of\ plants} \times 100$$

Table 2: Characteristics of the soil of experimental field analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

Morphological features	Characteristics	Physical and chemical properties	Value
Location	Agronomy field, SAU, Dhaka	% Sand	27
AEZ	Madhupur Tract (28)	% Silt	43
General Soil Type	Shallow red brown terrace soil	% Clay	30
Land type	High land	Textural class	Silty-clay
Soil series	Tejgaon	pH	5.6
Topography	Fairly leveled	Organic carbon (%)	0.45
Flood level	Above flood level	Organic matter (%)	0.78
Drainage	Well drained	Total N (%)	0.03
		Available P (ppm)	20.00
		Exchangeable K (me/100 g soil)	0.10
		Available S (ppm)	45

Source: SRDI, Khamarbari, Farmgate, Dhaka

Procedure of data collection

Plant height

The plant height was measured at harvest with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm.

Number of siliqua plant^{-1}

Numbers of total siliqua of selected plants from each plot were counted and the mean numbers were expressed as plant^{-1} basis. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot.

Length of siliqua

Length of siliqua was taken from randomly selected ten siliquae and the mean length was expressed on siliqua^{-1} basis.

Weight of 1000 seeds

One thousand cleaned, dried seeds of mustard were counted from each harvest sample and weighed by using a digital electronic balance and weight was expressed in gram (g).

Seed yield

The seeds collected from 1 square meter of each plot were sun dried properly. The weight of seeds was taken and converted into yield in t/ha.

Stover yield

The stover collected from 1 square meter of each plot was sun dried properly. The weight of stover was taken and converted into yield in t/ha.

Statistical analyses

The data obtained for different parameters were statistically analyzed to find out the effect of salicylic acid and variety on preference of aphid in mustard. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations of means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability [24].

Results and discussion

The experiment was conducted to find out the effect of salicylic acid and varieties on incidence of aphid and yield of mustard. Data were recorded on aphid infestation at flowering and fruiting stage, plant infestation at flowering and fruiting stage, yield contributing characters and yield of mustard. The results have been presented and possible interpretations are given under the following headings:

Abundance of aphid

Flowering stages

SA creates plant tolerance capacity to different biotic and abiotic stresses by helping to gain systemic acquired resistance [20]. [21]. [22]. In this experiment, different levels of salicylic acid and mustard variety in terms of number of aphid per plant at early, mid and late flowering stage gave different statistically significant data. In early stage, S_2V_2 (0.4mM SA and BARI Sarisha-13) worked significantly against aphid infestation showing less number of aphid in flowering stage, which is statistically similar with S_2V_5 (Table 3). While in mid and late stages, interaction of S_2V_2 performed well against aphid infestation than other combinations (Table 3). The nature and content of damages caused by aphid depend on the variety of aphid and host plant species [6]. Salicylic acid reduces the number of aphid on inflorescences [25].

Fruiting stages

The period of fruit formation is one of the critical and sensitive stages in concern of yield. Any stress in this time can cause drastic fall down of yield. Especially aphid infestation, because aphid have the capability of reproducing very quickly and can injure plant within a very small window of time. Cabbage aphid is most abundant and destructive on canola during capsule forming period [22].

Table 3. Interaction effect of salicylic acid and variety on number of aphid at flowering stage of mustard

Treatment	Number of aphid at flowering stage of		
	Early	Mid	Late
S_0V_1	3.67 a	3.77 a	4.47 a
S_0V_2	3.17 bcd	3.63 abc	4.37 a
S_0V_3	2.97 cd	3.67 ab	4.00 abc
S_0V_4	2.93 d	3.20 b-e	3.07 e
S_0V_5	2.87 d	3.33 a-e	3.77 bcd
S_1V_1	2.90 d	3.53 a-d	3.83 bcd
S_1V_2	2.70 d	3.10 d-f	3.37 de
S_1V_3	2.97cd	3.17 b-f	3.40 de
S_1V_4	3.20 a-d	3.30 a-e	3.70 bcd
S_1V_5	2.87 d	3.13 c-f	3.60 cd
S_2V_1	3.47 ab	3.27 b-e	3.70 bcd
S_2V_2	2.23 e	3.00 ef	3.07 e
S_2V_3	2.93 d	3.30 a-e	3.67 bcd
S_2V_4	3.43 abc	3.60 a-d	4.17 ab
S_2V_5	2.27 e	2.70 f	3.00 e
LSD (0.05)	**0.433**	**0.430**	**0.458**
Significance level	**0.01**	**0.05**	**0.01**
CV (%)	**8.71**	**7.73**	**7.47**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

S0: 0 mM SA (control)
S1: 0.2 mM SA
S2: 0.4 mM SA

V1: BARI Sarisha-1
V2: BARI Sarisha-13
V3: BARI Sarisha-14
V4: BARI Sarisha-15
V5: BARI Sarisha-16

In our experiment, it is also found that in early fruiting stage aphid infestation was higher than mid and late fruiting stage (Table 4). Application of SA increase the defense mechanism of plants against both biotic and abiotic stresses. Exogenous application of SA improves systemic defenses and reduces potato aphid on tomato [26]. Statistically significant variation was recorded due to the interaction effect of different levels of salicylic acid and mustard variety in terms of number of aphid per plant at early, mid and late fruiting stage (Table 4). In almost every stage, the treatment combination S_2V_5 (0.4mM SA and BARI Sarisha-13) showed less infestation (4.30) of aphid. Interestingly, S_1V_2 (0.2 mM SA and BARI Sarisha-13) also show comparatively less aphid infestation, where S_2V_2 also gave approximately same result. Both the combination contains same variety but different SA doses. So, can also be conferred that lower doses of SA give less aphid infestation and higher yield. [31] showed that higher amount of SA can cause to salicylate intoxication. The highest number of aphid (4.83) found from the treatment combination of S_0V_1 (0 mM SA (control) and BARI Sarisha-1). So, it can be concluded that application of SA has impact on aphid infestation and yield in mustard plant.

Table 4. Effect of salicylic acid and variety on number of aphid at fruiting stage of mustard

Treatment	Number of aphid at fruiting stage of		
	Early	**Mid**	**Late**
S_0V_1	4.83 a	4.27 a	3.07 a
S_0V_2	4.77 ab	3.90 bc	2.37 bc
S_0V_3	4.67 ab	3.80 bcd	2.43 b
S_0V_4	3.87 de	3.27 f	2.37 bc
S_0V_5	4.40 abc	3.60 c-f	2.17 bc
S_1V_1	4.57 ab	3.87 bc	2.80 a
S_1V_2	3.77 e	3.43 ef	2.10 bc
S_1V_3	4.03 cde	3.47 def	2.37 bc
S_1V_4	4.30 bcd	3.67 cde	2.33 bc
S_1V_5	4.33 a-d	3.40 ef	2.10 bc
S_2V_1	4.27 bcd	3.73 b-e	2.40 bc
S_2V_2	3.73 ef	3.27 f	2.10 bc
S_2V_3	4.30 bcd	3.60 c-f	2.30 bc
S_2V_4	4.67 ab	4.07 ab	2.30 bc
S_2V_5	3.30 f	2.90 g	2.03 c
LSD $_{(0.05)}$	**0.443**	**0.308**	**0.313**
Significance level	**0.01**	**0.01**	**0.05**
CV (%)	**6.22**	**5.11**	**7.95**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Healthy and infested plants and infestation status

At flowering stage

Statistically significant variation was recorded in terms of healthy plants, infested plants and plant infestation per m^2 area at flowering stage due to different levels of salicylic acid (Table 5). The highest number of healthy plants (31.07/m^2) was found from S_2 which was closely followed (26.53/m^2) by S_1, while the lowest number (24.53/m^2) was recorded from S_0. The lowest number of infested plants (1.67/m^2) was found from S_2 which was statistically similar (1.87/m^2) to S_1, while the highest number (2.07/m^2) was recorded from S_0. The lowest infested plant (5.27%) was found from S_2 which was closely followed (6.73%) by S_1, while the highest infested plant (7.87%) was recorded from S_0. SA played an important role reducing aphid infestation in mustard plants by inducing defense mechanisms of plants. SA activates enzymes those are responsible for antioxidant defense system [27]. Different compounds accumulated for SA have considerable effect on the plants defense against different biotic stresses [28]. Aphid infestation occurs membrane depolarization which is reduced be SA [8]. [29].

Different mustard variety showed statistically significant differences in terms of number of healthy plants infested plants and plant infestation per m^2 area at flowering stage (Table 5). The highest number of healthy plants (31.44/m^2) was recorded from V_5 which was statistically similar (30.11/m^2) to V_2, whereas the lowest number of healthy plants (23.11/m^2) was found from V_1 which was closely followed (25.89/m^2 and 26.33/m^2) by V_3 and V_4 and they were statistically similar. The lowest number of infested plants (1.56/m^2) was recorded from V_5 which was statistically similar (1.67/m^2) to V_2, whereas the highest number of infested plants (2.11/m^2) was found from V_1 which was statistically similar (2.00/m^2) to V_3 and V_4. The lowest infested plant (4.91%) was recorded from V_5 which was statistically similar (5.36%) to V_2, whereas the highest infested pant (8.49%) was found from V_1 which was closely followed (7.14% and 7.21%) by V_3 and V_4 and they were statistically similar.

Table 5. Effect of salicylic acid and variety on health, aphid infested plant and plant infestation at flowering stage of mustard

Treatment	At flowering stage Healthy plant (No.)	Infested plant (No.)	Infestation (%)
Levels of salicylic acid			
S_0	24.53 c	2.07 a	7.87 a
S_1	26.53 b	1.87 ab	6.73 b
S_2	31.07 a	1.67 b	5.27 c
LSD $_{(0.05)}$	**1.180**	**0.224**	**0.802**
Significance level	**0.01**	**0.01**	**0.01**
Different mustard variety			
V_1	23.11 c	2.11 a	8.49 a
V_2	30.11 a	1.67 b	5.36 c
V_3	25.89 b	2.00 a	7.21 b
V_4	26.33 b	2.00 a	7.14 b
V_5	31.44 a	1.56 b	4.91 c
LSD $_{(0.05)}$	**1.523**	**0.290**	**1.035**
Significance level	**0.01**	**0.01**	**0.01**
CV (%)	**5.76**	**16.11**	**16.19**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

At fruiting stage

Statistically significant variation was recorded in terms of healthy plants, infested plants and plant infestation per m^2 area at fruiting stage due to different levels of salicylic acid (Table 6). The highest number of healthy plants (29.87/m^2) was found from S_2 which was closely followed (25.73/m^2) by S_1, while the lowest number (23.67/m^2) was recorded from S_0. The lowest number of infested plants (1.87/m^2) was found from S_2 which was statistically similar (2.13/m^2) to S_1, while the highest number (2.33/m^2) was recorded from S_0. The lowest infested plant (6.09%) was found from S_2 which was closely followed (7.83%) by S_1, while the highest infested plant (9.04%) was recorded from S_0.

Different mustard variety showed statistically significant differences in terms of number of healthy plants, infested plants and plant infestation per m^2 area at fruiting stage (Table 6). The highest number of healthy plants (30.44/m^2) was recorded from V_5 which was statistically similar (29.44/m^2) to V_2, whereas the lowest number of healthy plants (22.11/m^2) was found from V_1 which was closely followed (24.78/m^2 and 25.33/m^2) by V_3 and V_4 and they were statistically similar. The lowest number of infested plants (1.67/m^2) was recorded from V_5

which was statistically similar (2.00/m^2) to V_2, whereas the highest number (2.33/m^2) was found from V_1 which was statistically similar (2.22/m^2 and 2.33 m^2) to V_3 and V_4. The lowest infested plant (5.41%) was recorded from V_5 which was statistically similar (6.46%) to V_2, whereas the highest infested pant (9.63%) was found from V_1 which was statistically similar (8.23% and 8.54%) by V_3 and V_4 and they were statistically similar.

Table 6. Effect of salicylic acid and variety on health, aphid infested plant and plant infestation at fruiting stage of mustard

Treatment	At fruiting stage		
	Healthy plant (No.)	**Infested plant (No.)**	**Infestation (%)**
Levels of salicylic acid			
S_0	23.67 c	2.33 a	9.04 a
S_1	25.73 b	2.13 ab	7.83 b
S_2	29.87 a	1.87 b	6.09 c
LSD (0.05)	**1.140**	**0.345**	**1.201**
Significance level	**0.01**	**0.05**	**0.01**
Different mustard variety			
V_1	22.11 c	2.33 a	9.63 a
V_2	29.44 a	2.00 ab	6.46 b
V_3	24.78 b	2.22 a	8.23 a
V_4	25.33 b	2.33 a	8.54 a
V_5	30.44 a	1.67 b	5.41 b
LSD (0.05)	**1.471**	**0.446**	**1.550**
Significance level	**0.01**	**0.05**	**0.01**
CV (%)	**5.77**	**21.85**	**20.98**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Yield contributing characters and yield of mustard

Plant height at harvest and silique length

Plant height at harvest varied significantly due to different levels of salicylic acid (Table 7). The longest plant (113.79 cm) was recorded from S_2 which was statistically similar (110.02 cm) to S_1, whereas the shortest plant (103.65 cm) was observed from S_0. The longest plant (158.58 cm) was found from V_5 which was followed (108.93 cm) by V_4. On the other hand, the shortest plant (87.59 cm) was recorded from V_3 which was statistically similar (93.27 cm and 97.39 cm) by V_2 and V_1 and they were statistically similar. Same result found in both SA and variety for the length of siliqua. The result of exogenous SA application depends of the plant species, developmental stages and doses of SA [30].

Seed yield and stover yield

Aphid infestation causes removal of photoassimilate from the phloem structure of plant which devitalizes the plant completely and drastically damages the crop yield [7]. [8]. Seed yield of mustard varied significantly due to different levels of salicylic acid (Table 7). The highest seed yield (1.85 t/ha) was recorded from S_2 which was followed (1.66 t/ha) by S_1, whereas the lowest seed yield (1.44 t/ha) was found from S_0. The highest stover yield (2.86 t/ha) was recorded from S_2 which was followed (2.72 t/ha) by S_1, whereas the lowest stover yield (2.61 t/ha) was found from S_0. Statistically significant variation was recorded in terms of seed yield for different mustard variety (Table 7). The highest seed yield (2.15 t/ha) was found from V_5 which was statistically similar (2.02 t/ha) to V_2 and closely followed (1.45 t/ha) by V_4, while, the lowest seed yield (1.31 t/ha) was recorded from V_1 which was statistically similar

(1.33 t/ha) to V_3. The highest stover yield (2.97 t/ha) was found from V_5 which was statistically similar (2.85 t/ha and 2.81 t/ha) to V_2 and V_3, while, the lowest stover yield (2.32 t/ha) was recorded from V_1 which was followed (2.72 t/ha) by V_4.

Table 7. Effect of salicylic acid and variety on yield contributing characters and yield of mustard

Treatment	Plant heigh tat harvest (cm)	Length of siliqua (cm)	Seed yield (t/ha)	Stover yield (t/ha)
Levels of salicylic acid				
S_0	103.65 b	5.35 b	1.44 c	2.61 b
S_1	110.02 ab	6.08 a	1.66 b	2.72 b
S_2	113.79 a	6.35 a	1.85 a	2.86 a
LSD $_{(0.05)}$	7.372	0.320	0.100	0.140
Significance level	0.05	0.01	0.01	0.01
Different mustard variety				
V_1	97.39 c	4.97 d	1.31 c	2.32 c
V_2	93.27 c	6.36 ab	2.02 a	2.85 ab
V_3	87.59 c	5.51 c	1.33 bc	2.81 ab
V_4	108.93 b	6.15 b	1.45 b	2.72 b
V_5	158.58 a	6.66 a	2.15 a	2.97 a
LSD $_{(0.05)}$	9.517	0.413	0.130	0.181
Significance level	0.01	0.01	0.01	0.01
CV (%)	9.03	7.22	8.11	6.83

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Conclusion

Salicylic acid is a phenolic compound known as plant hormone that acts in defense mechanism in plant body and response to both biotic and stresses. Different level of SA had considerable effects on the reduction of number of aphid on mustard. SA enhanced the growth and yield of mustard plant. Different varieties also showed different level of aphid infestation separately or in combination of SA. So, from the present observation it can be concluded that the application of salicylic acid enhanced the activity of plant defense mechanism and reduce the number of aphid in several stages of mustard plant. Considering the situation of the present experiment, further studies are needed to conduct advance research on investigation of systemic acquired resistance in mustard with salicylic acid in relation to aphid infestation.

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