Control of Cherry Leaf Spot and Powdery Mildew on Sour Cherry with Alternate-Side Applications of Fenarimol, Myclobutanil, and Tebuconazole

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ABSTRACT

Jones, A. L., Ehret, G. R., Garcia, S. M., Kesner, C. D., and Klein, W. M. 1993. Control of cherry leaf spot and powdery mildew on sour cherry with alternate-side applications of fenarimol, myclobutanil, and tebuconazole. Plant Dis. 77:703-706.

We evaluated spray programs for control of cherry leaf spot (caused by *Blumeriella jaapii*) during 1989–1991 in a sour cherry (*Prunus cerasus*) orchard in northern Michigan. Tebuconazole was as effective as chlorothalonil. Myclobutanil in combination with an adjuvant was next in effectiveness, followed by fenarimol and iprodione. Trees sprayed with the sterol demethylation inhibitor (DMI) fungicides fenarimol, myclobutanil, and tebuconazole also had a lower incidence of powdery mildew on the foliage than those sprayed with chlorothalonil or iprodione. Leaf spot control obtained with the DMI fungicides applied to alternate sides of sour cherry trees every 7 days was comparable to that obtained with sprays applied to both sides every 10 days, but 25% less fungicide was used in the alternate-side programs.

Cherry leaf spot, caused by *Blumeriella jaapii* (Rehm) Arx, is the most important disease of sour cherry (*Prunus cerasus* L.) in Michigan and throughout the northeastern United States and Canada. Fruit on trees defoliated by leaf spot before harvest show poor coloration, are low in soluble solids, and are less firm than fruit on healthy trees (12). Early defoliation from leaf spot delays acclimation of wood and flower buds in the fall, hastens deacclimation in the spring, and reduces bud survival and fruit set for at least two seasons (3). Defoliation can also result in death of fruiting spurs, branches, or entire trees from low-temperature injury in winter (12).

New fungicides are needed for the control of cherry leaf spot on sour cherries. Dodine was used to control the disease in Michigan before it was replaced by captafol. From 1968 to 1988, captafol was the predominant fungicide used in spray programs for leaf spot because it gave consistently good control when applied on a 14-day interval. Since the loss of captafol, growers have not returned to dodine because of concerns about dodine-resistant strains of *B. jaapii* after nearly 40 yr of dodine usage in many Michigan orchards. Benomyl was effective for leaf spot control in Michigan until the pathogen developed resistance to it and related compounds (6). Chlorothalonil has replaced captafol for leaf spot control from petal fall to shuck split. However, label restrictions do not allow midsummer applications of chlorothalonil. The sterol demethylation inhibitor (DMI) fungicides have exhibited excellent activity against the leaf spot fungus (2,7,8,18), but attempts to substitute DMI fungicides for captafol in 14-day schedules have been unsuccessful (10).

The application of fungicides from alternate sides of trees (alternate row middles) at twice the frequency of applications to both sides of trees (complete sprays) has proved to be a successful strategy for controlling several diseases of apple (13,14). The purpose of this study was to compare alternate-side applications of DMI fungicides to cherry trees on a 7-day interval with complete sprays on a 10-day interval for their effectiveness in controlling leaf spot.

Accepted for publication 26 February 1993.

MATERIALS AND METHODS

The experiment was conducted during three growing seasons (1989–1991) in a commercial planting of 12-yr-old Montmorency sour cherry trees located adjacent to the Northwest Michigan Horticultural Experiment Station in Leelanau County. The orchard was well managed and leaf spot was well controlled in the year preceding the first year of the experiment.

The experimental area consisted of nine rows: four treatment rows each with a row of unsprayed trees (buffer row) on both sides. Each plot consisted of four trees separated from the next plot in the row by a buffer tree that was not sprayed with fungicide. Each treatment (including the untreated control) was replicated four times, once each in each row, and was applied to the same trees in each of the 3 yr.

Myclobutanil plus an adjuvant (RH-3866 40W plus Triton B1956, Rohm & Haas Co., Philadelphia, PA), tebuconazole (Elite 45DF, Miles Inc., Kansas City, MO), fenarimol (Rubigan 1EC, DowElanco, Indianapolis, IN), iprodione (Rovral 4SC in 1989, Rovral 4F in 1990–1991, Rhône-Poulenc Inc., Monmouth Junction, NJ), and chlorothalonil (Bravo 720F, ISK Biotech, Mentor, OH) were applied in 700 L of water per hectare at 2,069 kPa with a three-point-hitch Myers airblast sprayer.

Two methods were followed to time the fungicide applications. In the conventional (complete-spray) method, the fungicides were applied to both sides of the trees every 10 days. In the alternate-side method, the DMI fungicides fenarimol, myclobutanil, and tebuconazole were applied to the opposite side of each tree every 7 days. The treatments were initiated at the petal fall stage of bud development and were completed on 11 August 1989, 12 July 1990, and 24 July 1991.

Leaf spot incidence and severity (as indicated by defoliation) were evaluated in early September. Ten terminal shoots from around the perimeter of each of the two center trees in every plot were sampled. Data from the two trees were averaged to give a mean value for each plot. The number of nodes with leaves missing and the numbers of healthy and infected leaves were recorded for each shoot. The percentage defoliation and the percentage of remaining leaves that

were infected were calculated and analyzed by analysis of variance.

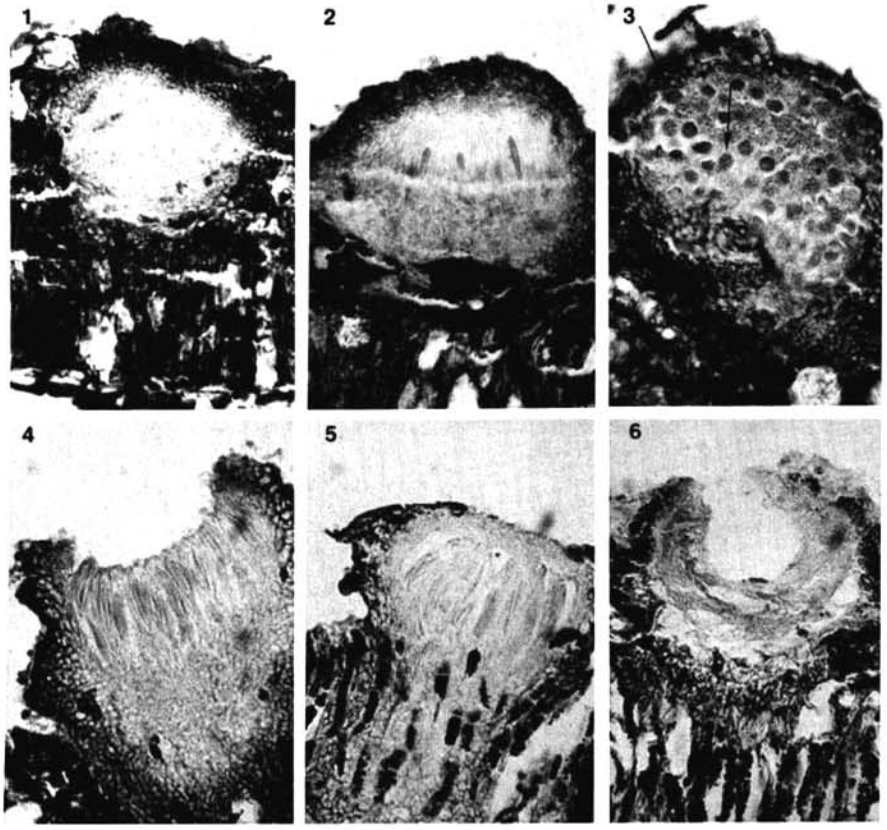
The incidence of powdery mildew was assessed in mid-July (except in 1989): as in the evaluation of leaf spot severity, the numbers of healthy and infected leaves on each of 10 terminal shoots from the perimeters of the two center trees in each plot were recorded. To determine yield, all the fruit on the center two trees in every plot was harvested with an OMC MonoBoom Tree Shaker (Orchard Machinery Company, Yuba City, CA) and conveyed onto a scale for weighing.

Primary leaf spot infection periods were determined on the basis of temperature and leaf wetness duration data collected at the Northwest Michigan Horticultural Research Station from weather monitoring equipment located about 200 m west of the orchard site. Infection periods were predicted from an environmental favorability index (1,2).

Ascospore discharge was determined with Rotorod samplers (Sampling Technologies, Inc., St. Paul, MN). Three samplers were placed under cherry trees that had been defoliated by leaf spot the previous year. Samplers were activated during wetness periods from rain with an electronic moisture sensor (17). Plastic rods were removed after each rain and examined under a microscope for ascospores of *B. jaapii*.

Overwintered leaves infected with *B. jaapii* were collected from the ground under trees in the test orchard to determine the maturation of apothecia. Leaf sampling began on 27 April 1990 and 26 April 1991 and continued about every 2 wk until no viable apothecia remained. No samples were collected in 1989. On each sampling date 10 leaf disks, 1 cm in diameter, were cut from the leaves with a cork borer, fixed in a mixture of 2-propanol, water, propionic acid, and formaldehyde (45:45:5:5, v/v), dehydrated in an alcohol series, embedded in Tissue Prep (melting point 56–57 C, Fisher Scientific Co., Fair Lawn, NJ), sectioned with a microtome at 12 μm, and stained according to a modified Conant's staining schedule (4). In 1991 clove oil was replaced by wintergreen oil as a solvent for orange G.

Serial sections of eight to 274 apothecia per sampling date were rated according to their internal stage of development as follows: stage 1, only paraphyses present in the lumen of the apothecium; stage 2, asci formed but no ascospores differentiated; stage 3, a few asci with ascospores formed; stage 4, many asci with ascospores formed and the apothecium open; stage 5, ascospores discharged from most asci; and stage 6, apothecium disintegrated (Figs. 1–6). The ratings were averaged to give a mean value for the developmental stage of apothecia at each sampling date.



Figs. 1–6. Apothecial development of *Blumeriella jaapii:* **(1)** stage 1, only paraphyses present in the lumen of the apothecium; **(2)** stage 2, asci formed but no ascospores differentiated; **(3)** stage 3, a few asci with ascospores formed (arrows); **(4)** stage 4, many asci with ascospores formed and the apothecium open; **(5)** stage 5, ascospores discharged from most asci; and **(6)** stage 6, apothecium disintegrated.

RESULTS

The discharge of ascospores started during bloom in 1990 and before bloom in 1991 and continued for 4–7 wk (Fig. 7). In 1990, most of the ascospores were collected during two discharge periods on 17 and 20 May. Infection periods were predicted from rains that fell on 8 May, 15 and 16 May, and 2 June. The first leaf spot lesions were observed on 8 June. In 1991, the first ascospore discharge was on 29 April. Leaf spot infection periods were predicted for 6 May, 17 May, 25 May, 28 May, and 2 June. Leaf spot lesions, first observed on 25 May, were confined to bracht leaves on flower clusters.

When the data for leaf spot infection and defoliation for 1989–1991 were analyzed by two-way analysis of variance, F values for treatment, year, and interaction effects were all highly significant ($P = 0.001$) (*analysis not shown*). The low level of leaf spot in 1989, compared with high levels in 1990 and 1991, was the apparent reason for the interaction. When the data for 1989 were excluded from the analysis, F values for treatment effects on infection and defoliation from leaf spot were highly significant, F values for year and interaction effects were not significant for the percentage of defoliation, and F values for year and interaction effects were significant for the percentage of infected leaves (Table 1). The analysis indicated that the incidence of defoliation was similar for each of the treatments in both years, but a higher percentage of leaves was infected with leaf spot for some treatments in 1990 than in 1991.

All of the fungicide treatments reduced the incidence of leaf spot compared with untreated trees (Table 2). Tebuconazole was as effective as chlorothalonil in preventing infection and defoliation from leaf spot. Myclobutanil in combination with an adjuvant was also as effective as chlorothalonil in preventing defoliation, but trees sprayed in 1990 with myclobutanil had a higher percentage of leaves infected with leaf spot than trees sprayed with chlorothalonil. Fenarimol was significantly ($P = 0.05$) less effective than chlorothalonil in preventing infection and defoliation from leaf spot. Iprodione, a non-DMI fungicide applied on a 10-day schedule, reduced the incidence of leaf spot in 1991 but was not as effective as chlorothalonil or tebuconazole in 1990. All of the spray treatments resulted in higher yields over the 3-yr period than the unsprayed control (Table 2).

The severity of leaf spot on trees sprayed on alternate sides every 7 days was not significantly different from that on trees sprayed on both sides every 10 days, although there was a trend toward

increased infection on trees sprayed on the 7-day schedule. Trees sprayed on the 7-day schedule in 1989, 1990, and 1991 received 1.5, 2.0, and 1.5 fewer sprays, respectively, than trees sprayed on both sides every 10 days (Table 3). Therefore, less fungicide was applied per hectare per season for treatments sprayed on opposite sides every 7 days than for treatments applied to both sides every 10 days (Table 3).

In 1990 and 1991, about 50% of the leaves on terminal shoots of trees sprayed with iprodione were infected with powdery mildew (Table 2). No interaction in the level of mildew control was detected among treatments over the 2-yr period. Trees sprayed with myclobutanil, tebuconazole, or fenarimol had significantly less powdery mildew than trees sprayed with chlorothalonil or iprodione. Among the DMI fungicides, myclobutanil combined with an adjuvant was the most effective treatment.

DISCUSSION

We evaluated a strategy for using DMI fungicides to control cherry leaf spot on sour cherries in Michigan. In this study, fenarimol was less effective than myclobutanil and tebuconazole in preventing infection and defoliation from leaf spot, which suggests that 438 ml/ha (6 fl oz/acre) is a marginal rate for fenarimol. Minimum label rates for fenarimol on apples were increased in the United States in 1992, and our results indicate that a rate increase is also needed on cherries. Chlorothalonil cannot be used on a full-season schedule like the one evaluated in this study because of label restrictions that limit its use to early-season (to shuck split) and postharvest treatments. Our results indicate that the DMI fungicides could be used to control leaf spot in summer between shuck split and harvest or in season-long programs starting at petal fall.

Our results also indicate that using DMI fungicides on sour cherries in the summer would reduce the incidence of powdery mildew on foliage. Mildew can be a significant problem on Montmorency sour cherry at harvest because infected leaves are removed when the cherries are mechanically harvested, and additional time, labor, and equipment are required to separate leaves from the fruit. Myclobutanil was slightly better than tebuconazole and fenarimol for mildew control, but the enhanced control may be due to the adjuvant added to myclobutanil but not to tebuconazole or fenarimol. Because myclobutanil is normally not applied with an adjuvant, the level of mildew control achieved in practice might be less than observed in this experiment.

Probably the most important feature of the 7-day alternate-side program is the increased protection obtained when fun-

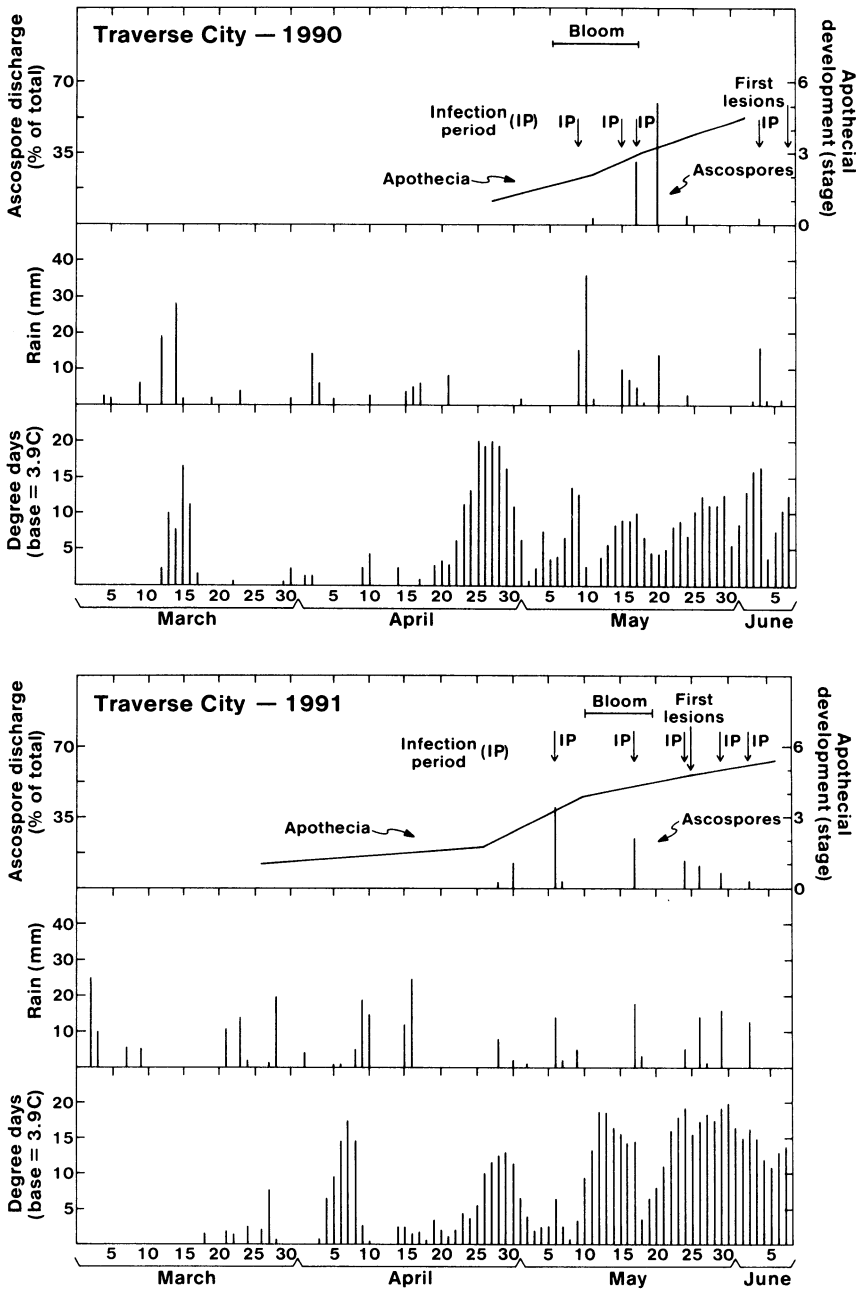


Fig. 7. Dates of primary leaf spot infection periods (IPs) in 1990 and 1991 in a sour cherry orchard near Traverse City, MI, where fungicides were evaluated for the control of cherry leaf spot. The graphs also show the stages of apothecial development in relation to the bloom period, the dates of ascospore discharge, the dates of detection of the first leaf spot lesions, rainfall, and temperature.

Table 1. Analysis of variance for the incidence of cherry leaf spot and powdery mildew on Montmorency sour cherry trees treated with eight fungicide spray programs over 2 yr (1990–1991)

	Cherry leaf spot					
	Infection (%)		Defoliation (%)		Powdery mildew (%)	
Source	df	Mean squares	df	Mean squares	df	Mean squares
Replication	3	72.3	3	283.9	3	18.1
Year	1	11,289.0*** [a]	1	4.7	1	22.8
Error	3	12.2	3	58.0	3	40.9
Treatment	7	3,052.7***	8[b]	7,966.1***	7	1,676.1***
Year × treatment	7	875.2***	7	161.5	7	48.6
Error	42	142.3	48	107.5	42	38.0

[a] Three asterisks indicate that the F value was significant at $P < 0.001$.
[b] Includes an unsprayed control.

Table 2. Control of cherry leaf spot and powdery mildew on Montmorency sour cherry trees with fungicides applied with an airblast sprayer to alternate sides of trees every 7 days or to both sides of trees every 10 days[w]

Fungicide and amount of formulated product per hectare	Interval between sprays (days)	Cherry leaf spot[x]						Powdery mildew infection (%)		Total yield (kg/cm² of trunk diameter)[y]
		Infection (%)			Defoliation (%)					
		1989	1990	1991	1989	1990	1991	1990	1991	
Myclobutanil 40W (350 g) + Triton B1956 (0.03%)	10	0.0	32.0 c	9.7 b	0.9	12.6 cd	13.2 c	3.4 e	12.2 e	2.5 a
	7	0.0	40.0 c	0.9 b	1.1	12.3 cd	5.3 c	13.4 d	18.7 de	2.1 a
Tebuconazole 45DF (420 g)	10	0.0	1.2 d	0.1 b	1.4	4.1 d	3.2 c	24.0 c	26.3 cd	2.2 a
	7	0.0	6.9 d	0.1 b	1.3	5.2 cd	3.8 c	26.1 c	30.7 bc	—
Fenarimol 1EC (438 ml)	10	0.8	68.3 ab	23.6 a	1.9	16.8 cd	37.7 b	32.9 bc	29.7 bc	2.5 a
	7	2.3	76.8 a	24.7 a	0.3	58.8 b	48.3 b	39.4 b	35.1 b	2.2 a
Chlorothalonil 720F (4.68 L)	10	0.4	3.2 d	0.6 b	2.0	4.2 d	4.2 c	49.0 a	44.5 a	2.2 a
Iprodione 4SC or 4F (2.34 L)	10	0.4	51.7 bc	8.0 b	1.9	20.2 c	13.1 c	50.0 a	50.8 a	2.2 a
Untreated control	—	66.1	—[z]	—	58.3	97.9 a	98.6 a	—	52.5 a	1.5 b

[w] Numbers in each column followed by different letters differ significantly ($P = 0.05$) according to Duncan's multiple range test.
[x] Mean percentage of leaves with lesions or of nodes without leaves on 20 shoots per replicate.
[y] Total yield for 3 yr (1989–1991).
[z] Data missing because trees were severely defoliated.

Table 3. Number of applications and amount of fungicide applied to control cherry leaf spot on Montmorency sour cherry trees in 1989–1991[a]

Fungicide and amount of formulated product per hectare	Interval between sprays (days)	Complete sprays (no.)[b]			Amount of fungicide (3-yr total)
		1989	1990	1991	
Myclobutanil 40W (350 g)	10	7	6	6	2.7 kg + 1.7 L
+ Triton B1956 (0.03%)	7	5.5	4	4.5	2.0 kg + 1.2 L
Tebuconazole 45DF (420 g)	10	7	6	6	3.2 kg
	7	5.5	4	4.5	2.4 kg
Fenarimol 1EC (438 ml)	10	7	6	6	3.4 L
	7	5.5	4	4.5	2.5 L
Chlorothalonil 720F (4.68 L)	10	7	6	6	36.0 L
Iprodione 4SC or 4F (2.34 L)	10	7	6	6	18.0 L

[a] Sprays were applied with an airblast sprayer to alternate sides of trees every 7 days or to both sides of trees every 10 days.
[b] Two half-sprays were counted as a complete application.

gicide deposits are renewed frequently. Previous studies showed that DMIs were not effective on 14-day intervals for the control of leaf spot (10). On apples, about 90% of the tree is treated with fungicide when sprays are applied from one side with a high-capacity airblast sprayer (13,14), and we would expect similar coverage on sour cherry trees. Renewing fungicide coverage weekly over about 90% of the tree would compensate in part for the poorer protective activity of DMI fungicides compared to captafol.

We hypothesize that the postinfection activity of DMI fungicides and the enhancement of this activity when initial sprays are followed 1 wk later by a second application, as documented for apple scab (15), contribute to the performance of the 7-day, alternate-side schedule. Postinfection activity of DMI fungicides against leaf spot has been demonstrated (2,7,8,18). However, in plots where DMIs were applied to alternate sides of trees every 7 days, we observed some infection and defoliation from leaf spot on the side that was not resprayed within 7 days after a severe infection period. Leaf spot lesions can develop within 7 days when conditions are favorable for the pathogen (12,16) and, because of the weak postsymptom activity of DMI fungicides against leaf spot, it is very difficult to bring leaf spot under control with DMI fungicides once lesions are visible. The risk of infection on the side of the tree to be resprayed later could be minimized, however, by spraying both sides after severe infection periods.

Previous tests with iprodione indicated that it may be weak in controlling the cherry leaf spot pathogen (9). In this 3-yr study, a seasonal program of iprodione applied at a high rate exhibited leaf spot control activity similar to that of fenarimol. Iprodione has excellent activity against brown rot (5) and is often applied during the preharvest period to control brown rot on the fruit. Our results indicate that when iprodione is used to control brown rot, it is not necessary to add a second fungicide for leaf spot control. Among the DMI fungicides evaluated in this study, only tebuconazole has exhibited efficacy for brown rot control on fruit (11) and would not need to be combined with another fungicide to control both leaf spot and brown rot.

ACKNOWLEDGMENTS

Research was supported in part by the Michigan Agricultural Experiment Station and the Michigan Cherry Research Committee. We thank DowElanco for the loan of a tractor and sprayer and Cherry Ke Inc. for the use of a cherry orchard.

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