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Prevention of Compensatory Withering and Stem-Break in Cut Spikes of Gladiolus by Overcoming Vascular Blockage

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The relationship between flower opening and withering to uptake, loss and fresh weight characteristics of the cut spikes of gladiolus has been studied. When streptomycin or citric acid was used in the holding solution along with sucrose plus gibberellic acid, it was possible to promote uptake and thereby reduce the extent of withering that normally occurred following the opening of a large number of flowers. The percentage of flower buds opening was not affected by recutting the stalk ends or by using streptomycin or citric acid. In comparison, the longevity of individual flowers was increased because of enchanced sucrose uptake. Stem-break was also not observed in the recut spikes or in spikes treated with streptomycin or citric acid. In gladiolus, the opening buds not only draw out water from the older flowers and cause their compensatory withering but also extract water from the flowering axis and peduncle and cause stem collapse.

Key Words: Citric acid, Cut flowers, Flower longevity, Flower withering, Gibberellic acid, Gladiolus, Stem-break, Streptomycin, Sucrose, Vascular blockage

Introduction

Studies on the opening of bud-cut flowers have recently gained importance on account of advantages of easy handling, lowered freight charges and minimal damage (Halevy & Mayak 1974 and Rao & Mohan Ram 1981). Several workers have succeeded in inducing bud-cut flowers to open (Holley & Cheng 1967, Hardenburg et al. 1970 and Marousky 1971). In gladiolus, bud opening can be caused by treatment of freshly harvested spikes with high concentrations of sucrose (Mayak et al. 1973 and Rao 1979) or sucrose plus silver nitrate (Kofranek & Halevy 1976). As a post-storage treatment, however, combined treatment with gibberellic acid (GA) and sucrose markedly promotes bud opening in spikes maintained earlier for 24 hr at room temperature or chilled for one week (Rao & Mohan Ram 1979, 1982). Whereas enhanced opening is achieved by these treatments, the shelf-life of the spike would depend on the number of open flowers on the spike over a given period. The observation that flowers open and wither in flushes on the spike and that premature withering occurs in spikes in which water uptake is impaired suggested the operation of correlative influences of flower opening on withering and vice-versa (Rao 1979). In this paper, the relationship between opening and withering of flowers with uptake

and loss and fresh weight characteristics of the spike have been studied.

Material and Methods

Spikes of *Gladiolus natalensis* Hort. were harvested at the National Botanical Research Institute, Lucknow (500 km from Delhi) (when the corolla was visible just above the outer bract), packed in cardboard boxes in upright position and brought to Delhi by train overnight. Experiments were set up 24 hr after harvest. Twenty spikes were placed in each of the following: water; sucrose (0.5 M); GA (10^{-5}M); sucrose+GA; sucrose+GA+streptomycin (25 ppm) and sucrose+GA+citric acid (10mM). Two sets were maintained for each treatment, one in which the spikes were not subject to recutting (referred to as *uncut* spikes) and the other in which 1cm from the base of the spikes was removed every alternate day during the experimental period (referred to as the *recut* spikes). The spikes were held individually in glass tubes (2.5×15.0 cm). The test solutions were prepared using glass distilled water and the liquid replenished whenever necessary. The experiments were conducted at 20±2°C with 14 hr daily illumination by cool white daylight fluorescent tubes (500 lux).

The number of flowers opening and withering per spike was recorded daily. Individual flower longevity (the period between flower opening and withering) was read off from graphs plotted for total opening and total withering of flowers everyday of experimentation. Each day the weight of the tube containing the solution along with the spike (A), and the weight of the tube with the solution only (without the spike) (B) were recorded. The difference between these weights gave the change in fresh weight of the spike, the difference between consecutive measurements of weight A gave the rate of uptake of the solution and the difference between the rate of uptake and change in fresh weight gave the rate of loss of water. Tubes containing the test solutions but without spikes were kept as controls to measure the loss by evaporation for which the values given in this paper are corrected. Confidence intervals (CI) of the means were determined at $P \leqslant 0.05$.

Results

Overall Uptake, Loss and Fresh Weight Change during the Experimental Period

The uncut control spikes (kept in water) showed significantly greater loss than uptake (table 1). A similar response was observed for spikes held in GA, although the loss was greater than that in the control. The presence of sucrose reduced both uptake and loss (cf. control). Use of GA+sucrose did not cause any difference over sucrose-treated spikes. With sucrose+GA+streptomycin, the spikes showed a substantial enhancement of uptake and loss over that with sucrose alone, sucrose+GA, sucrose+GA+citric acid and also showed greater fresh weight.

Recutting of the peduncle of the spikes placed in water or GA did not substantially alter uptake or loss (table 1). In treatments with sucrose or sucrose+GA+streptomycin there was a significantly greater uptake of the solution over that of the uncut spikes. In all the treatments containing sucrose (alone or in combination) the loss was not significantly higher than absorption, resulting in good retention. The spikes held in sucrose+GA+streptomycin showed an increase in retention to a positive value as compared to the negative value observed in the uncut spikes (table 1).

Rate of Uptake and Loss and Fresh Weight Change of Spikes

The rate of uptake, loss and fresh weight change were studied to identify any changes correlated with the rates of flower opening and withering. In the uncut water control (figure 1A) a rapid intake of water (18.5 ml)

Table 1 *Overall uptake, loss and fresh weight changes in gladiolus spikes during the experimental period*

Treatments	Recutting of peduncle	Uptake $\bar{X}$	± CI	Loss $\bar{X}$	± CI	Fresh wt.change $\bar{X}$	± CI
Water (Control)	—	43.02	3.14	52.13	2.68	—9.11	0.82
	+	48.04	3.66	55.71	3.45	—7.67	0.84
Sucrose (S)	—	33.83	1.84	40.96	2.19	—7.13	0.88
	+	43.31	2.49	46.19	3.07	—2.88	0.77
GA	—	49.14	3.87	60.31	4.28	—11.17	2.22
	+	51.04	3.16	60.01	3.72	—8.97	0.61
S+GA	—	33.04	2.11	39.48	2.70	—6.44	0.88
	+	38.64	3.18	42.16	2.93	—3.52	0.10
S+GA+streptomycin	—	44.94	2.93	47.50	2.68	—2.56	0.71
	+	54.72	5.02	55.48	4.33	—0.76	0.17
S+GA+citric acid	—	34.92	3.09	39.54	3.07	—4.62	0.10
	+	43.32	5.37	44.49	4.41	—1.17	0.54

$\bar{X}$, mean value in or calculated after 15 days of commencing the experiment
CI, confidence intervals of the mean at $P \leqslant 0.05$

was noted two days after starting the experiment and this was accompanied by marked loss. Thus, much of the water taken up was lost through transpiration. The initial increase in water uptake was later followed by a sharp decrease. Although the main period of water uptake was restricted to the initial 6 days, loss continued at a relatively high level after day 4, resulting in a decrease in fresh weight of the spike to below zero, indicating that the spike was losing more water than it was absorbing. Maximum reduction in fresh weight occurred on day 10, followed by a small increase. On this day, a slight increase in loss was also observed. Recutting of the spikes did not alter the rate of water uptake or loss until days 8 and 10 when there was higher uptake and loss over the uncut spikes (figure 1A). There were no significant differences between the uncut and recut spikes in fresh weight change.

Presence of sucrose in the holding solution caused (figure 1B) a marked decrease in uptake and loss in uncut spikes by day 2 as compared with the controls. The fresh weight change, however, remained same as that of the control till day 14. When recut, a marked increase in uptake over uncut spikes was noted after day 2 till day 6 with a pronounced increase on day 10. A significant increase in water loss occurred on day 4, in the recut spikes with another on day 10 which coincided with the period of increased uptake. A higher fresh weight caused by recutting was noted from day 4 to day 8 (figure 1B).

The uptake, loss and fresh weight by uncut spikes treated with GA (figure 1C) approximated those by the controls. With recutting, there was a significant decrease in uptake and loss on day 4 and an increase on day 10. Recutting did not influence fresh weight (figure 1C). When sucrose and GA were used together, uptake, loss and fresh weight of the spikes were similar to those occurring in spikes held only in sucrose (figure 2A). Increased uptake and loss were observed on day 10 in recut spikes.

Addition of streptomycin to sucrose+GA

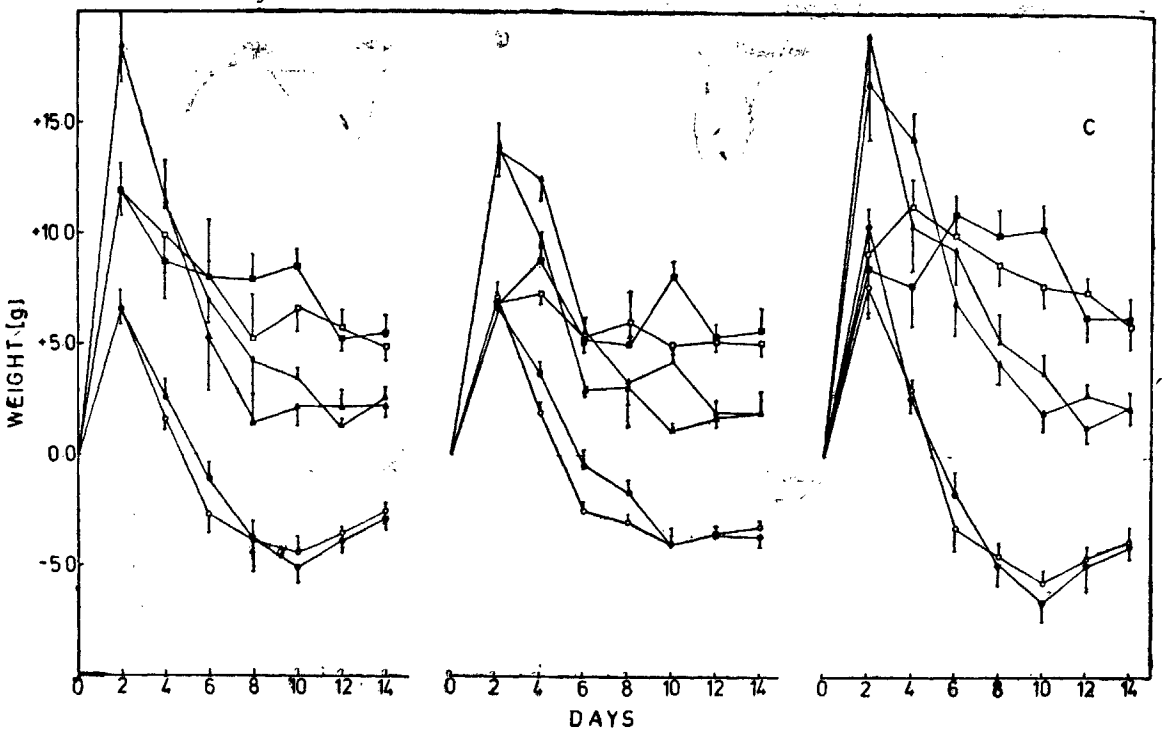

Figure 1 Rates of uptake of solution loss and fresh weight change by spikes kept in (A) water, (B) sucrose (0.5 M), and (C) GA (10^{-5} M)

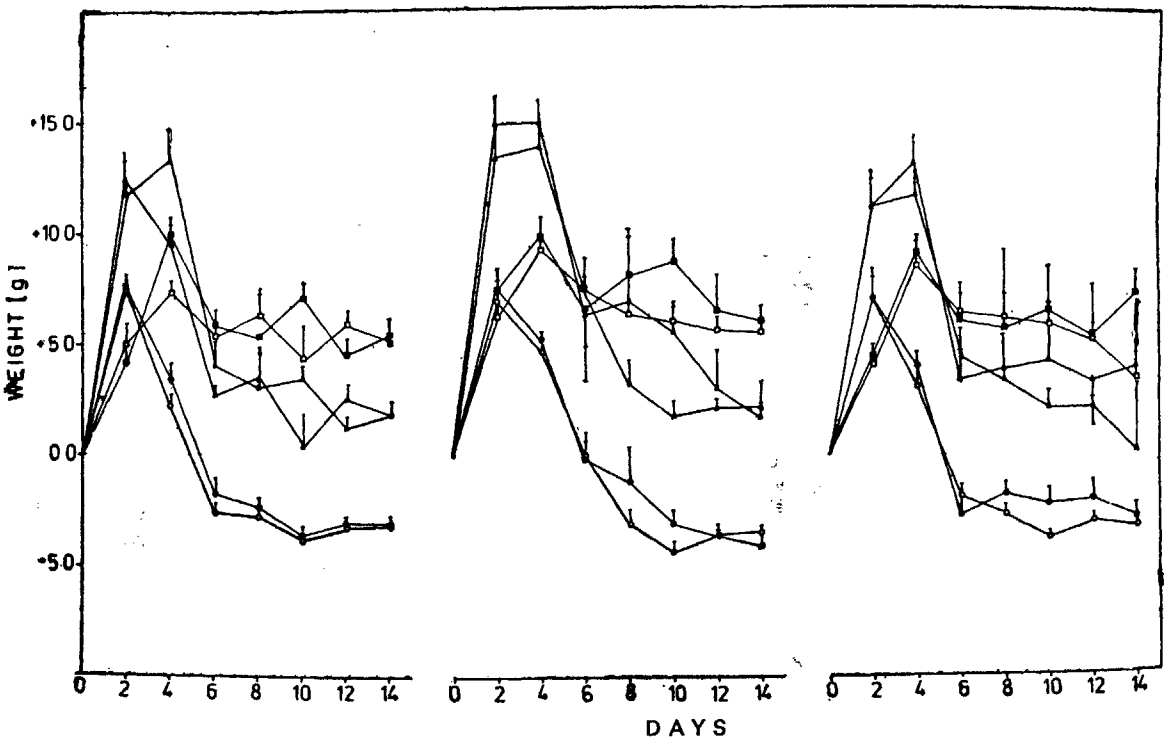

Figure 2 Rates of uptake of solution, loss and fresh weight change by spikes kept in (A) sucrose (0.5 M) + GA (10^{-5} M), (B) sucrose (0.5 M) + GA (10^{-5} M) + streptomycin (25 ppm) and (C) sucrose (0.5 M) + GA (10^{-5}) + citric acid (10 mM).
(△—△ uptake, □—□ Loss, O—O fresh weight change of uncut spikes; ◭—◭ uptake, ■—■ Loss, ●—● fresh weight change of recut spikes)

(figure 2B) resulted in continued high uptake on day 4 as compared with that in sucrose and GA alone or in concert, in which uptake markedly decreased after day 2. The high uptake was maintained even on day 6, after which it reached the level attained by spikes held in sucrose+GA. The trends of loss and fresh weight change were similar to those of uptake. On recutting these spikes, increased uptake ensued on days 2 and 4 over the uncut spikes. There was significantly greater uptake, loss and fresh weight on day 10 as compared to the condition with the uncut spikes (figure 2B).

Use of sucrose+GA+citric acid (figure 2C) caused significantly greater uptake on

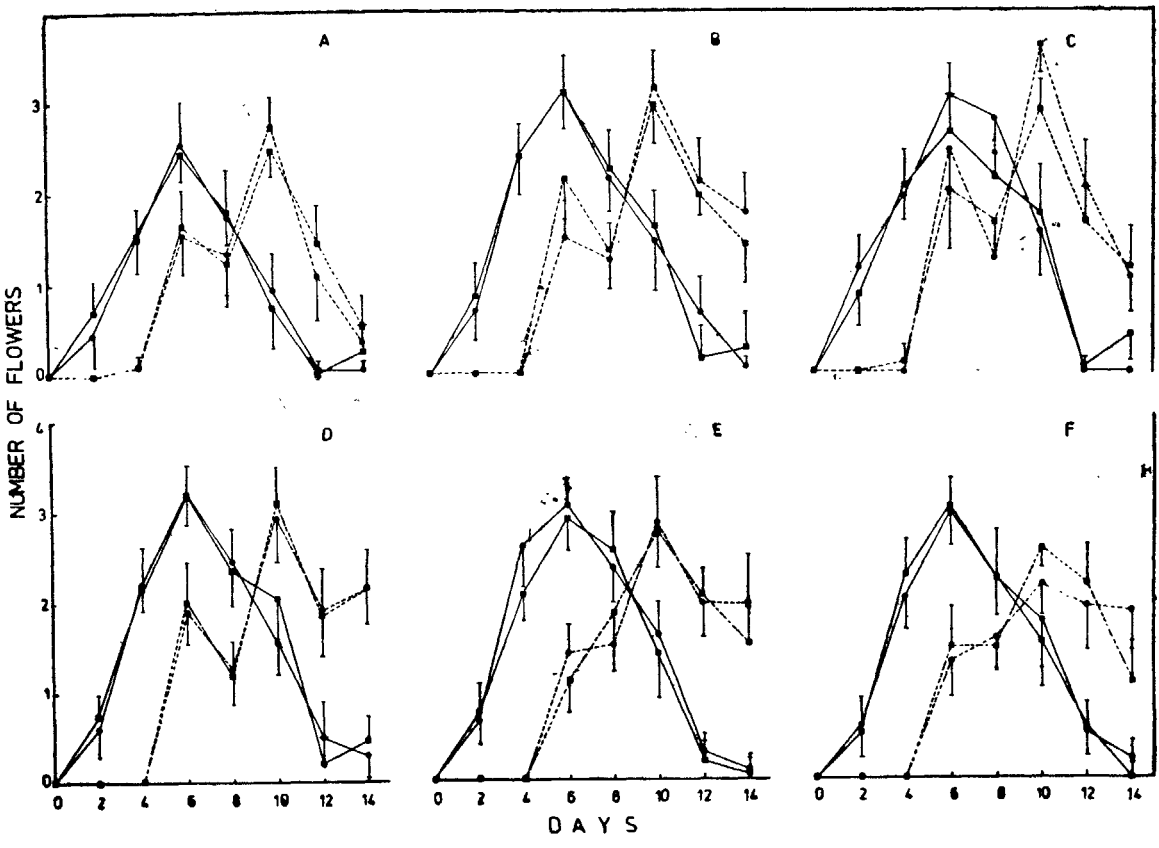

Figure 3 Rates of flower opening and withering in spikes held in (A) water, (B) sucrose (0.5 M), (C) GA (10^{-5} M), (D) sucrose (0.5 M) + GA (10^{-5} M), (E) sucrose (0.5 M) + GA (10^{-5} M) + streptomycin (25 ppm), and (F) sucrose (0.5 M) + GA (10^{-5} M) + citric acid (10 mM)
(■ —■, without recutting; ● — ● with recutting; — open flowers;.....,withered flowers)

day 4 over the sucrose+GA-treated spikes. There was no difference in the pattern of loss or fresh weight change. Recutting did not alter the extent of uptake (over that of the uncut spikes) but brought about an increase in fresh weight on day 10.

Rate of Flower Opening and Withering

In all the treatments significant flower opening was initiated on day 2 and withering on day 6 (figure 3). No marked effect of recutting on the rate of flower opening or withering was noted during the entire period of investigation. In the control, increase in flower opening was observed till day 6 after which there was a decline, reaching nearly zero on day 12 (figure 3A). Enhanced withering occurred on day 6 followed by a slight decline. This was followed by a major peak of withering on day 10 with a subsequent sharp decline.

The general trend of flower opening and withering in sucrose treated spikes was similar to that in the controls (figure 3B). However, there was greater flower opening on days 4 and 10 (for the uncut spikes) as compared to the situation in the controls (figure 3A). The uncut spikes held in GA exhibited a higher rate of flower opening over the controls on day 10 (figure 3C). Flower withering in these spikes followed a pattern similar to that in the control. Recutting resulted in greater opening on day 8 and withering on days 6, 10 and 14 over that of the control.

Addition of GA to the holding solution containing sucrose did not bring about any marked differences in the rates of flower opening and withering as compared with those in sucrose only (figures 3B, D). Further the use of streptomycin (figure 3E) or citric acid (figure 3F) along with sucrose+GA did not result in any change in the flower opening pattern. However, in the presence of streptomycin there was lower withering on day 6.

Table 2 *Effect of sucrose(S), GA and their interaction with streptomycin/citric acid on the percentage of flower buds opening*

Treatments	Without recutting		With recutting	
	$\bar{X}$	± CI	$\bar{X}$	± CI
Water (Control)	85.9	6.2	78.1	8.6
S	97.6	3.0	97.2	2.1
GA	95.5	2.9	92.5	4.5
S+GA	95.8	2.0	97.2	4.0
S+GA+streptomycin	96.9	2.6	98.6	1.7
S+GA+citric acid	97.0	2.3	96.4	3.3

$\bar{X}$, mean values of 20 replicates
CI, confidence intervals of the means $P \leqslant 0.05$

Table 3 *Effect of sucrose (S), GA and their interaction with streptomycin/citric acid on flower longevity*+*

Treatments	Without recutting	With recutting
Water (Control)	3.0	2.7
S	3.5	3.9
GA	3.0	3.1
S+GA	3.5	3.5
S+GA+streptomycin	3.8	4.0
S+GA+citric acid	3.8	3.9

*in days
+values represent mean longevity of flowers at positions 1–7 (base upwards)

Percentage of Flower Buds Opening

No difference in percentage of flower buds opening was observed between the uncut and recut spikes in the control or in any individual treatment (table 2). Flower opening was higher and more or less similar in all the treated spikes over the controls.

Flower Longevity

In the uncut spikes the average life of the flowers between nodes 1 to 7 was the lowest in the control (3.0 days) (table 3). GA treatment did not improve longevity. Use of sucrose or sucrose in combination with GA increased flower longevity over that of the control. Addition of streptomycin or citric acid further increased flower longevity by 0.8

day over that in the control. Recutting caused a marginal increase in flower longevity from 3.5 to 3.9 days in sucrose treatment. Sucrose +GA treated spikes failed to show improvement in longevity on recutting. With recutting there was a slight increase in flower longevity in spikes treated with sucrose+GA along with streptomycin or citric acid.

Discussion

In general a reduction in the fresh weight of the spike to a level below the initial weight resulted from continued high water loss in comparison to uptake. Such a decrease in uptake is known to be caused by progressive vascular blockage (see also Aarts 1957, Durkin & Kuc 1966, Marousky 1969, 1972, and Gilman & Steponkus 1972). A large number of flowers opened in gladiolus, (present work) on the day when negative fresh weight was recorded. A peak of withering was also noted on this day in the control, GA, sucrose and sucrose +GA treated spikes. In comparison, no peak of withering (or at best only a plateau) was observed in spikes supplied with streptomycin or citric acid. This is considered an instance of internal competition for water in which owing to lowered uptake through the cut end the opening buds extract water from the older flowers and promote their withering. It is logical to presume that streptomycin and citric acid promote uptake and thereby reduce compensatory withering by checking microbial activity at the cut end of the spikes. On recutting the peduncle, higher loss and uptake were noted on day 10 over the uncut spikes. This indicates that the peak of withering on day 10 had caused stress conditions in the spike due to vascular blockage. It also resulted in an enhanced rate of opening in the sucrose treated spikes over the control.

The increased uptake caused by recutting or use of streptomycin or citric acid did not affect the overall percentage of flower buds opening. The process of blooming, therefore, appears to be fairly independent of free water availability through the cut end, as the flowers are able to obtain water from the withering flowers. Thus the changes in water uptake observed in the present study were probably compensatory, primarily to equalize internal stress. On the other hand, reduction in vascular blockage through the use of streptomycin or citric acid or by recutting increased flower longevity (present work) probably through increased uptake of solution containing sucrose. Sucrose is known to bring about enhanced opening and flower longevity (Bravdo et al. 1974, Kofranek & Halevy 1976 and Rao & Mohan Ram 1981).

Stem-break (collapsing of the peduncle) which is known to be strongly influenced by water balance (Burdett 1970, Sacalis 1974 and van Meeteren 1978), was not observed in treatments with streptomycin and citric acid or in the recut spikes. This observation suggests the involvement of microbial activity in vascular blockage. The increment in uptake with the use of streptomycin or citric acid over that in spikes kept in sucrose+GA also supports the above presumption. Antibiotics inhibit microorganisms in cut flowers and prevent vascular blockage (Serini & Banfi 1974 and Dansereau & Vines 1975). A beneficial effect of citric acid on the prolongation of vase-life of lupine has also been noted earlier (Mohan Ram & Rao 1977). The observation that roses held at low *p*H conducted more water than those at high *p*H was attributed to prevention of bacterial growth (Marousky 1971, 1972). Thus, in gladiolus, stem-break may result from reduced uptake caused by vascular blockage and from a strong water requirement by the young opening flowers. The latter not only draw out water from the older flowers and cause their withering but are also able to extract water from the flowering axis and peduncle and cause stem collapse.

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