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# Yield and shelf life of chrysanthemum in response to the silicon application

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## ABSTRACT

The potted chrysanthemum is one of the main flowers produced in protected cultivation. Silicon has promoted improvements both in quantitative and qualitative aspects when supplied to some ornamental species produced in these conditions. We evaluated the response of chrysanthemum cultivars grown in pots to the application of silicon. The experiment was conducted in a greenhouse of the Universidade Federal de Viçosa, Minas Gerais state, Brazil. Treatments were arranged in a 3x2 factorial scheme (three cultivars of chrysanthemum: Coral Charm, White Reagan and Indianapolis and two doses of silicon: 0 and 800 mg kg$^{-1}$) with six replications, in an entirely randomized design. We evaluated the diameter of the flower buds and stems; length of the flower stems; height of the plants; dry matter production of roots, leaves, stems, inflorescence and shoots; total number of inflorescences; diameter of the most fully open inflorescences; Si content in the leaf tissue; and flowering cycle and shelf life. The White Reagan cultivar produced the greatest number of inflorescences (29.17) per pot and proved to be more precocious (85.83 days). There was no negative interaction between Si, Ca and K and no effect of silicon was shown on the production and shelf life of the chrysanthemum. There was an increase in the content of this element in the leaves with the application of potassium metasilicate.

**Keywords:** *Dendranthema grandiflora*, plant nutrition, metasilicate.

## RESUMO

**Produtividade e longevidade de crisântemos em resposta à aplicação de silício**

O crisântemo de vaso é uma das principais flores produzidas em ambiente protegido. O silício tem promovido melhorias tanto no aspecto quantitativo quanto no qualitativo quando fornecido a algumas espécies ornamentais produzidas nestas condições. Assim, o objetivo desse trabalho foi avaliar a resposta à aplicação de silício de três cultivares de crisântemo cultivadas em vaso. O experimento foi conduzido em casa de vegetação da Universidade Federal de Viçosa. Os tratamentos foram dispostos em esquema fatorial 3x2 (três cultivares de crisântemo: Coral Charm, White Reagan e Indianápolis e duas doses de silício aplicadas no substrato: 0 e 800 mg kg$^{-1}$) com seis repetições, em delineamento inteiramente casualizado. Foram avaliados o diâmetro dos botões e das hastes florais; comprimento das hastes florais; altura da planta; produção de matéria seca de raízes, folhas, caule, inflorescências e parte aérea; número total de inflorescências; diâmetro da inflorescência mais aberta; teor de Si nos tecidos foliares; ciclo e longevidade floral. A cultivar White Reagan produziu o maior número de inflorescências (29,17) por vaso e mostrou ser mais precoce (85,83 dias). Não houve interação negativa entre Si, Ca e K e não foi constatado efeito do silício na produção e na longevidade das inflorescências de crisântemo. Houve aumento nos teores deste elemento nas folhas com a aplicação do metasilicato de potássio.

**Palavras-chave:** *Dendranthema grandiflora*, nutrição de plantas, metasilicato.

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Brazilian floriculture has presented significant economic growth and demanded research and techniques adapted to its reality as it has many particular characteristics. Among the branches of floriculture, the production of pot plants stands out and, according to Junqueira & Peetz (2008), the chrysanthemum has stood out in the last few years as one of the main ornamental plants grown, with commercialization of the plant in pots having a great deal of market expression. The success in cultivation of this plant is due principally to the great diversity of cultivars, with innumerable colorations and flower forms as well as different sizes and ways of rotating cultivars, always offering something new to the consumer (Barbosa, 2003).

A final product of great quality is desirable in all economic activities, but when dealing with floriculture, this is vital. Nevertheless, this increase in quality must be accompanied by maximizing profits. Aggregated value in the case of the chrysanthemum is intimately related to the aspect and quality of the leaves, stems and flowers, which according to Roude *et al*. (1991), are related to environmental and nutritional aspects. Undoubtedly, fertilization and nutrition can be managed so as to achieve greater productivity, quality and shelf life of the flowers, important differences in the stiff competition existing in floriculture (Nell *et al*., 1997).

A chemical element whose application has been widely studied in agriculture currently is silicon (Si). It is considered to be a beneficent element as it provides various positive effects for many vegetable species, principally rice and sugarcane, which include the reduction of hydric stress through providing for less transpiration, increase in the efficiency of photosynthesis by maintaining the leaves more erect and rigid, with greater interception of light; and increase in resistance to diseases, pests, cold, salinity, and toxicity from Al, Mn or Fe (Epstein, 1999; Ma *et al*., 2001; Fauteux *et al*., 2005). Many of these benefits are attributed to the layer of silica that accumulates below the cuticle.

There is evidence that the Si application influences the aesthetic quality of ornamental plants. Hwang *et al.* (2005) reported that the Si showed better quality of roses. Also, it has been noticed that Si increase the rose resistance to black spot (Gillman *et al.*, 2003). Addition of Si to the nutrient solution in hydroponic cultivation of gerbera resulted in a greater percentage of flowers of class I and thickness of flower stalks (Savvas *et al.*, 2002). Zinnia accumulates Si in relatively high concentrations; compared to other dicotyledons, there was an increase in the resistance to aphids when these plants received application of Si in the soil (Ranger *et al.*, 2009). Nevertheless, for these benefits to occur, it is necessary for the plant to absorb and accumulate Si.

Plants differ significantly in their Si uptake capacity, even among genotypes of the same species, as verified in sugarcane (Deren *et al*., 1994), and, in accordance with the Si content in the leaves, vegetable species may be classified as high, intermediate and non-silicon accumulators (Ma *et al*., 2001). In the case of chrysanthemum, this information is not yet available.

Researching ornamental plants, one of the prerequisites is that they present a reasonable shelf life after opening of the flowers, which may be altered by pre-harvest factors such as nutritional and genetic aspects. Ca, for example, is related to increase in the shelf life of flowers. Barbosa (2005) observed a linear increase in longevity of the inflorescences with an increase in doses of Ca in three cultivars of chrysanthemum raised for commercial purposes. In regard to Si, Inanaga *et al*. (1995), working with rice plants, observed that this element reduced Ca uptake and its accumulation in the shoots, competing with this nutrient in plants, forming compounds with lignin, organic acids, polyhydric alcohols and phenyl-carbohydrate compounds. Because of this, it is important to observe if chrysanthemum plants exhibit Si uptake and if this element interferes in the production and shelf life of the inflorescences through interaction with Ca. Thus, the objective of the work was to classify the cultivars of potted chrysanthemum regarding Si uptake and evaluating the productivity, quality and shelf life of the inflorescences of these cultivars due to the application of Si in the substrate through fertigation.

## MATERIAL AND METHODS

The experiment was set up in a greenhouse of the Universidade Federal de Viçosa, in 2008. An entirely randomized design was used and treatments were arranged in a 3x2 factorial, with three cultivars of chrysanthemum (Coral Charm, White Reagan and Indianápolis) and two doses of silicon (0 and 800 mg $kg^{-1}$) with six replications. The experimental unit consisted of pots, containing 0.6 kg of substrate, with three plants.

The cultivars Coral Charm and Indianapolis belong to the Decorative group and have inflorescences of coral and yellow coloration respectively. The White Reagan cultivar, of white coloration, belongs to the Marguerite daisy group.

The substrate consisted of the mixture of subsurface soil, sand, commercial substrate (Bioplant®) and vermiculite, in a proportion of 2:0.5:1:0.5 (proportion by volume). To each liter of substrate 2.5 g of simple superphosphate and 0.8 g of potassium chloride (KCl) were added.

One week after the transplanting of seedlings, the weekly application of Si began together with fertigation. A soluble formulation 15-05-15 plus Ca (5) and Mg (3) was used as fertilizer, adding micronutrients and $SO_4^{2-}$ as suggested by Barbosa (2003). As a Si source, potassium metasilicate ($K_2SiO_3$) was used, with 12% Si and 15% $K_2O$. Total Si applied was 800 mg $kg^{-1}$, in drenches, divided into eight applications which extended over seven weeks, also providing 333 mg of K. The plants that did not receive the application of $K_2SiO_3$ received KCl to provide 333 mg of K, balancing the element between the treatments. The $K_2SiO_3$ is a product with an alkaline reaction (pH>10,0); thus, the pH of the solution was adjusted to 6.0 with the addition of HCl 2 mol $L^{-1}$.

The plants were maintained under extended exposure to long days for 30 days, followed by 31 short days exposure and then, days with natural light until reaching the point of commercialization.

On the 21st day after transplanting, apical pruning was carried out and on the 55th day, the elimination of the principal buds was done.

For determination of the cycle, defined as the period between transplanting and the point of commercialization of the plants (opening 2/3 of the inflorescences), three replications were separated. From these same plants, the average diameter of the flower buds, diameter of the most widely opened inflorescence, total number of inflorescences, length and diameter of the flowering stems, height of the plant and dry matter production were determined.

After the assessments described above, the shoots were cut to the level of the substrate. Leaves, stems and inflorescences and roots were separated and washed with distilled water. All the parts were dried in a laboratory oven with forced air circulation at 65ºC during 72 hours and then weighed, obtaining the dry matter production of roots, stems, leaves and inflorescences and the shoots of the plant.

The leaves were ground in a Wiley type grinder with a 0.84 mm screen and mineralized using a nitro-percloric mixture (3:1 v $v^{-1}$) for determination of the Ca content by atomic absorption spectrophotometry and the K content by flame spectrophotometry. The Si content was determined by the alkaline digestion method and dosage by the colorimetric method (Elliott & Snyder, 1991).

Shelf life was determined by the number of days between the opening of 2/3 of the inflorescences and discarding of the plants, or, in other words, more than 50% of the inflorescences in the pot wilted and with loss of coloration, using the plants from the other three replications.

The data were submitted to ANAVA using the System for Statistical and Genetic Analyses (SAEG) and the averages compared by Tukey's test at 5 % probability.

## RESULTS AND DISCUSSION

No significant differences were found for the interaction between chrysanthemum cultivars and silicon application for all characteristics evaluated. Therefore, only the main effects were evidenced (Figures 1-2; Tables 1-3).

Leaf Si content was higher in the plants that received application of this element (Figure 1). According to Blackman (1969), Si is transported from the roots to the shoots of the plant, and loss of water by transpiration in the leaves gives rise to the formation of hydrated amorphous silica, principally in the epidermal cells of the leaf tissue.

The K and Ca content were similar in the plants that received and that did not receive Si application (Figure 1). This indicates that potassium fertilization was balanced among the treatments and that Si did not interfere in the Ca uptake, different than the results observed by Inanaga *et al*. (1995) and by Zanão Júnior *et al* (2010) in rice, in which reduction in Ca content in the shoots was observed with the application of Si.

The cultivars differed in regard to the Si uptake (Figure 2). Coral Charm presented the lowest Si content in the leaf tissue (24.8 g $kg^{-1}$), while the other cultivars did not differ among themselves in regard to the content of this element. In a similar way, Winslow *et al*. (1997) found genotypic differences in the uptake of Si in the cultivation of rice and Deren *et al*. (1994) in the cultivation of sugarcane.

Differences found in the Si leaf content indicate that the cultivars behave differently in regard to the capacity for Si accumulation (Figure 2). In accordance with the Si content and the Si:Ca molar ratio found in the leaf tissue, the plants are considered Si accumulators when they present more than 10 g $kg^{-1}$ of Si and Si:Ca>1; intermediate, with Si content between 5 and 10 g $kg^{-1}$ or even above 10 g $kg^{-1}$, but with Si:Ca<1; and non-accumulators of Si when they present less than 5 g $kg^{-1}$ of Si in the leaves (Ma *et al*., 2001). In accordance with the results, all the cultivars of chrysanthemum evaluated may be classified as Si accumulators.

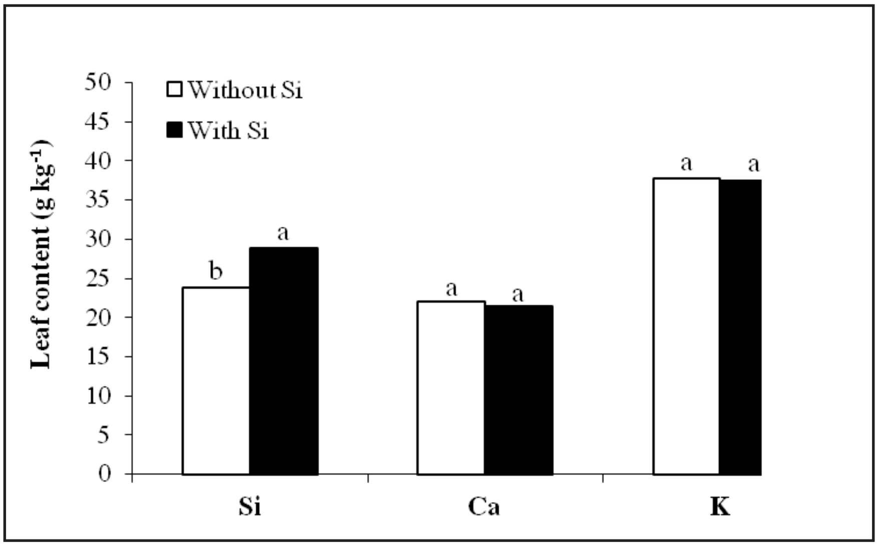


**Figure 1.** Si, Ca and K content in chrysanthemum leaf tissue as a function of Si application (average of three cultivars) [teores de Si, Ca e K no tecido foliar de crisântemo em função da aplicação de Si (média das três cultivares)]. Viçosa, UFV, 2008.
Averages followed by distinct letters differ significantly among each other by Tukey's test, $p<0.05$ (médias seguidas de letras distintas diferem significativamente entre si pelo teste de Tukey, p<0,05).

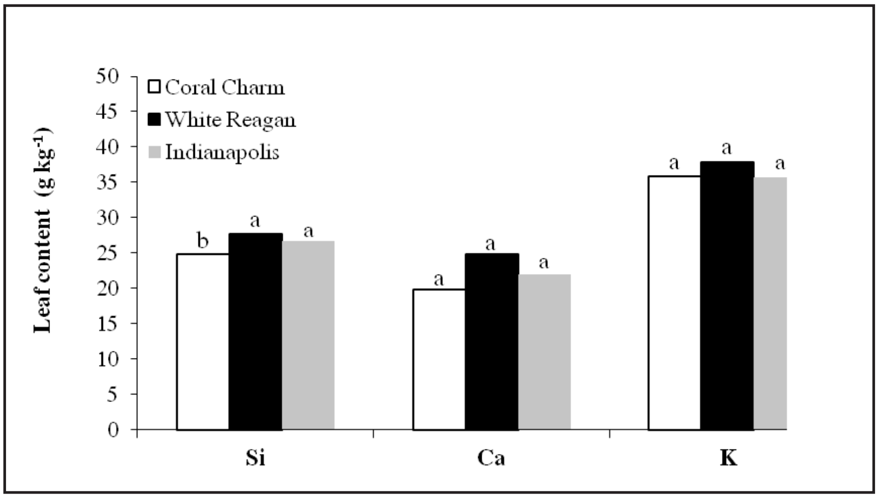


**Figure 2.** Leaf content of Si, Ca and K in chrysanthemum leaf tissue as a function of cultivar (teores foliares de Si, Ca e K no tecido foliar de crisântemo em função da cultivar). Viçosa, UFV, 2008.
Averages followed by distinct letters differ significantly among each other by Tukey's test, $p<0.05$ (médias seguidas de letras distintas diferem significativamente entre si pelo teste de Tukey, p<0,05).

There were no genotypical differences in relation to the leaf content of Ca and K (Figure 2). The content of these two macronutrients varied from 19.8-24.8 g $kg^{-1}$ and 35.7-37.8 g $kg^{-1}$, respectively, being within the range of content considered adequate for chrysanthemum, proposed by Jones Júnior *et al*. (1991), showing that there was no negative interaction between Si, Ca and K in respect to the dose of

**Table 1**. Phytotechnical characteristics evaluated in chrysanthemum plants as a function of the application of Si (average of three cultivars) [(características fitotécnicas avaliadas em plantas de crisântemo em função da aplicação de Si (média das três cultivares)]. Viçosa, UFV, 2008.

| Variables | Without Si | With Si | CV (%) |
|---|---|---|---|
| Length of flowering stem (cm) | 39.33 a | 39.22 a | 7.42 |
| Diameter of flowering stem (cm) | 0.38 a | 0.37 a | 6.51 |
| Diameter of flower bud (cm) | 1.00 a | 1.03 a | 6.34 |
| Diameter of the most open inflorescence (cm) | 6.65 a | 6.58 a | 3.85 |
| Height of plant (cm) | 48.73 a | 49.45 a | 6.42 |
| Number of inflorescences per pot | 25.11 a | 25.67 a | 15.15 |
| Production of root dry matter (g) | 2.88 a | 2.87 a | 20.60 |
| Production of leaf dry matter (g) | 7.36 a | 6.86 a | 14.49 |
| Production of stems dry matter (g) | 11.36 a | 11.50 a | 15.57 |
| Production of inflorescence dry matter (g) | 7.62 a | 7.49 a | 19.58 |
| Production of dry matter of the shoots (g) | 26.34 a | 25.84 a | 11.16 |
| Cycle (days) | 88.54 a | 88.50 a | 7.55 |
| Shelf life (days) | 26.89 a | 27.00 a | 6.21 |

Averages followed by distinct letters differ significantly among each other by Tukey's test, p<0.05 (médias seguidas de letras distintas diferem significativamente entre si pelo teste de Tukey, p<0,05).

**Table 2.** Length of flowering stem (LFS), diameter of flowering stem (DFS), diameter of flower bud (DFB), diameter of most open inflorescence (DI), plant height (PH) and number of inflorescences per pot (NI) of chrysanthemum as a function of cultivar (comprimento da haste floral (LFS), diâmetro da haste floral (DFS), diâmetro do botão floral (DFB), diâmetro da inflorescência mais aberta (DI), altura da planta (PH) e número de inflorescências por vaso (NI) de crisântemo em função da cultivar). Viçosa, UFV, 2008.

| Cultivar | PH | DI | LFS | DFS | DFB | NI (unit/pot) |
|---|---|---|---|---|---|---|
| | (cm) | | | | | |
| Coral Charm | 55.35 a | 5.15 c | 44.94 a | 44.94 a | 0.99 a | 22.50 c |
| White Reagan | 56.31 a | 6.87 b | 45.09 a | 45.09 a | 1.01 a | 29.17 a |
| Indianapolis | 48.67 b | 7.81 a | 41.10 a | 41.10 a | 1.16 a | 24.50 b |
| CV (%) | 6.42 | 3.85 | 6.51 | 6.51 | 6.34 | 15.15 |

Averages followed by distinct letters differ significantly among each other by Tukey's test, p<0.05 (médias seguidas de letras distintas diferem significativamente entre si pelo teste de Tukey, p<0,05).

Si used. Supplying different doses of Ca through a nutritive solution under hydroponic cultivation, Barbosa (1996) found Ca leaf content between 21.3 and 28.1 g $kg^{-1}$ in the Yellow Polaris cultivar, similar to those found in the present study, and Barbosa (2005) observed a difference in the uptake of this element (15-16 g $kg^{-1}$) among the cultivars Blush Hawaii, Calabria and Dark Flamengo.

For the benefits provided by Si to occur, it becomes necessary for the plant to take in and accumulate this element in its tissues. In the present study, it was observed that the Si leaf content was greater in the plants that received silicate fertilization (Figure 1). Nevertheless, this increase in Si uptake did not result in any effect in the phytotechnical characteristics evaluated (Table 1). In a similar way, Costa *et al.* (2006) and Ribeiro *et al.* (2006) did not observe effects of the application of Si on the variables of growth and production of chrysanthemum cv. Rage, respectively. They did not determine the leaf content of this element in the plants. However, Kamenidou *et al.* (2008) and Carvalho *et al.* (2009) found an increase in ornamental sunflower shoot dry matter production with the supply of Si. Hwang *et al.* (2005) evaluated the implementation of potassium metasilicate in roses cultivation (200 mg $L^{-1}$ of Si), and found that there was an increase in plant height, shoot dry matter production and height of plants.

The application of Si did not interfere in the shelf life of the inflorescences of chrysanthemum (Table 1). Calcium appears to be an important nutrient in the shelf life of the inflorescences of chrysanthemum. Barbosa (2005) observed that this element was responsible for the increase of shelf life of the inflorescences of three commercial cultivars. Thus, this lack of interference of Si in the shelf life (longevity) of the inflorescences in the present study possibly occurred because there was no negative interaction of Si with Ca, or, in other words, the uptake of Si did not reduce the Ca leaf content.

Si is related to the reduction of biotic and abiotic stresses suffered by the plants. As the cultivars of chrysanthemum were not submitted to any type of stress, this may be a possible explanation for the lack of any response to the application of silicon on the characteristics evaluated. Other studies must be carried out submitting these plants to some stress factors to observe the effects of silicon, such as checking the resistance of these plants to white rust (*Puccinia horiana*) with the application of Si. According to Freire *et al.* (2002) it is considered the principal disease of chrysanthemum. It is known that Si reduces the incidence of fungal diseases in many pathosystems, including rust in crops such as soybeans, coffee and sugarcane (Dean & Todd, 1979; Lima, 2006; Martinati, 2008). Otherwise, higher Si application rates must be evaluated in future experiments.

Greatest plant height was observed in the cultivars White Reagan and Coral Charm, at 56.31 and 55.35 cm, respectively. The inflorescences of the Indianapolis cultivar presented the greatest diameter and the Coral Charm cultivar the smallest diameter. The White Reagan cultivar produced the greatest number of inflorescence in each

**Table 3.** Production of root dry matter (RDM), leaf dry matter (LDM), stems dry matter (SDM), inflorescence dry matter (IDM), dry matter of shoots (DMS), cycle and shelf life (SL) of chrysanthemum as a function of cultivar (produção de matéria seca de raízes (RDM), de folhas (LDM), de caule (SDM), de inflorescências (IDM), da parte aérea (DMS), ciclo e longevidade (SL) de crisântemo em função da cultivar). Viçosa, UFV, 2008.

| Cultivar | RDM | LDM | SDM | IDM | DMS | Cycle | SL |
|---|---|---|---|---|---|---|---|
| | (g/pot) | | | | | (days) | |
| Coral Charm | 3.01 a | 8.04 a | 9.18 a | 8.18 a | 25.41 a | 88.15 b | 27.83 a |
| White Reagan | 2.99 a | 6.89 b | 10.30 a | 6.92 b | 24.11 a | 85.83 c | 25.83 a |
| Indianapolis | 3.05 a | 6.40 b | 9.73 a | 7.35 a | 23.48 a | 91.58 a | 27.17 a |
| CV (%) | 20.60 | 14.49 | 15.57 | 15.58 | 5.12 | 7.55 | 6.21 |

Averages followed by distinct letters differ significantly among each other by Tukey's test, $p<0.05$ (médias seguidas de letras distintas diferem significativamente entre si pelo teste de Tukey, $p<0,05$).

pot. There was no difference among the cultivars for the other characteristics (Table 2). These factors, as well as all the others, are explained by genetic factors.

The cultivar Coral Charm produced more leaf dry matter than the others and together with the Indianapolis cultivar produced more inflorescence dry matter (Table 3). This fact is due to the morphology of the inflorescences since these cultivars are from the decorative group and present various layers of ligulas, in contrast with the White Reagan cultivar of the Marguerite daisy group (Barbosa, 2003). In the production of dry matter of roots, stems and shoots, the cultivars did not differ among themselves (Table 3). Since the dry matter of the shoots is a variable composed of the other three (LDM, CDM and IDM) there was compensation in the production of dry matter in the stems by the White Reagan cultivar, which produced less inflorescence dry matter, not differing from the other cultivars in the production of dry matter of the shoots.

The White Reagan cultivar was more precocious with a cycle of 85.83 days, followed by Coral Charm, with 88.15 days, while Indianapolis was the latest, with a cycle of 91.58 days (Table 3). According to Barbosa (2005), the cycle constitutes an important part in the production of chrysanthemums, mainly for specific days such as Mother's Day, Valentine's Day, All Souls Day, among others, and precocity is also a factor in reduction of costs. Shelf life did not differ among the cultivars and ranged from 25.83 and 27.83 days (Table 3).

The results show, therefore, that the chrysanthemum cvs. Coral Charm, White Reagan and Indianapolis were classified as accumulators of Si. However, this element did not alter their production and shelf life. The White Reagan cultivar produced the greatest number of inflorescences per pot and also showed more precocity.

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