Scientific Papers. Series B, Horticulture. Vol. LXIV, No. 1, 2020
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

STUDIES AND RESEARCH ON THE SPECIES AND VARIETIES OF HOSTA IN CULTIVATION

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Abstract

Throughout the time there have been numerous researches on the particularities of growth, flowering, hybridization, fertilization of species, varieties and cultivars of Hosta. The present article presents a brief summary of some research conducted in recent years on Hosta. The purpose of these studies is to evaluate the behavior of Hosta as perennial plants, to identify the different colours of the flowers due to the presence of anthocyanins in the tepals, the presence of volatile oils in flowers, the presence of macro and micro minerals in the leaves, to investigate the possibility of storing the seeds of Hosta, to establish the flowering period, the nectar production and flower pollination. The current review addresses the following issues: Growth, flowering and leaf character variation of Hosta; Anthocyanins of the genus of Hosta and their impacts on tepal colors; Analysis of the variation in scent components of Hosta flower by HS-SPME and GC-MS; Nectar and polen production and insect visitation on ornamentals from the genus Hosta Tratt. (Asparagaceae); Analysis of essential macro-micro mineral content of twelve Hosta taxa. Seed storage longevity of Hosta sieboldiana (Asparagaceae).

Key words: *anthocyanins, nectar, pollen, scent, tepal.*

INTRODUCTION

Hosta is considered one of the most important and most popular perennial flowers, used especially as a decorative plant for its beautiful leaves. Hostas are mainly grown for their beautiful foliage that comes with a broad range of leaf shapes, colors, sizes and textures (Mehraj & Shimasak, 2017). The multitude of varieties, hybrids and cultivars makes Hosta a permanent source of new studies for those who love these species and for researchers. The technology of Hosta plant cultivation is relatively easy, as the plant has no particular demands on environmental factors. More experiments are needed to discover new aspects of Hosta plant culture, which presents us with such a rich assortment of varieties and cultivars.

Hosta is a plant originating from Japan, China and Korea and it was first introduced in Europe in the late 1700's and in the US in the mid-1800's (Greenfell & Shadrack, 2004). The number of currently known species is about 43, and of the cultivars over 2500 (Șelaru, 2007). The names used in Romanian are "autumn lily" or "August lily", in French "Funkia" or "Hosta", in English "Funkia", "Corfu lily" or "day lily" (Băla, 2007). The scientific name of Hosta is also used as a popular name. The most widespread species are: *Hosta plantaginea* Aschers. (syn. *Funkya subcordata* Spreng.), *Hosta sieboldiana* Engl. (syn. *Hosta glauca* Stearn.), *Hosta fortunei* (Hort.) Engl., *Hosta undulata* (Hort.), *Hosta lancifolia* Engl. (syn. *Funkia japonica* Voss.), *Hosta albomarginata* Hook. (syn. *Hosta sieboldii* Aschers) (Toma, 2009). In Japan and China, new species and varieties are still undiscovered.

Hosta plants have a wide spread in parks and gardens, due to their preference for shade and semi-shade. This foliage plant can be grown for various purposes: for a position by itself, for edging, for borders, and for filling an entire flower bed (Noordhuis, 1995). *Hosta longipes* (Fr. et Sav.) *Matsumura* (*Liliaceae*), widely distributed throughout Korea, China, and Japan, is an edible vegetable in Korea. It has long been used as a traditional Korean medicine for treating cough, sputum, laryngopharyngitis, burns, swelling, snake bites and inflammation (Kim et al., 2014).

The plant grows in the form of leaf bushes with a height of about 60 cm and a diameter of 30

cm (Toma, 2009). It has rhizomes or stolons on the ground, lanceolate or ovate leaves (Toma, 2003). The colour of the leaves in the wild species is predominantly green, but there are species and cultivars with leaves having blue, yellow, gold and white colour. The leaves may have a single colour or may be variegated, with a white border or white streaks in the middle part of the leaf. The flowering takes place in the summertime, between June and July. The colour of the flowers is white, pink or lavender. The growth of the plant is relatively slow, especially for the dwarf varieties and for the varieties having foliage that is variegated or of a colour other than green (Șelaru, 2007).

Hosta is an unpretentious plant. It prefers loose, moist, humus-rich soils, sunny exposures, but it also grows in semi-shade and even shade (Băla, 2007).

In order to be adapted, all the wild species need the winter coldness, with temperatures below 4°C for several weeks in order to get an adequate rest (Greenfell, 2004).

Hosta species are vegetatively propagated by the division of the bush. The seed propagation is practiced more in the improvement work, for creating new varieties (Toma, 2009). The mother plants that undergo the division process must be at least four or five years from the last split. The optimum period for the division of the bush is autumn, in October, but the spring period (April) is not excluded, immediately after the plants start their vegetation (Toma, 2009). Sowing is less practiced. In vitro propagation is the most commonly used method for the production of planting material (Șelaru, 2007).

GROWTH, FLOWERING AND LEAF CHARACTER VARIATION OF HOSTA

The researches carried out by Mehraj & Shimasaki in 2017 use as a material and tracking method the following: 12 Hosta plant taxa, five plants from each one of those, studying their evolution of growth, flowering and variation of leaf characters during two years, 2015 and 2016. The 12 taxa are: *Hosta sieboldiana, Hosta alismifolia, Hosta sieboldii, Hosta longissima, Hosta tardiva, Hosta longipes* var. *gracillima, Hosta nakaiana, Hosta kikutii* var. *caput-avis, Hosta kikutii* var. *polyneuron, Hosta longipes* var. *expira, Hosta kiyosumiensis, Hosta montana,* marked as T1-T12 (Figure 1). The rhizomes were planted in pots and the culture substrate was enriched with 320 mg/L N; 210 mg/L P and 300 mg/L K, slightly acidic fertilizer. The observations made referred to the height of the plants, the number of leaves, the surface of the leaves, the chlorophyll content, the length of peduncle, the length of the inflorescence and the number of flowers in inflorescence. Chlorophyll was measured with the SPAD meter. Significant differences were determined using Tukey's HSD test ($P < 0.05$).

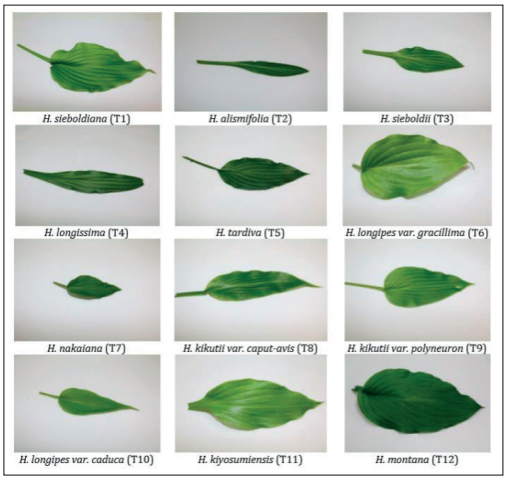

Figure 1. Pictorial presentation of leaves of the *Hosta taxa* (after Mehraj & Shimasaki)

After these researches carried out in 2015 and 2016, Mehraj and Shimasak obtained the following result and discussions: the highest plant was *H. montana* (year 2015: 73.17 cm and year 2016: 71.72 cm), and the smallest plant was *H. alismifolia* (year 2015: 22.93 cm and year 2016: 20.46 cm). The height of the plants decreased in the second year.

The maximum number of leaves was at *H. kikutii* var. *caput-avis* (13.8/plant in 2015 and 12.8/plant in 2016), and the minimum number of leaves was recorded in *H. longipes* var. *gracillima* (3.78/plant in 2015 and 3.02/plant in 2016). The number of leaves decreased in the second year was higher in *H. longipes* var. *gracillima* (20.11%), *H. sieboldiana* (19.92%) and *H. montana* (16.95%).

The highest leaf area was recorded in *H. montana*, followed by *H. sieboldiana*, *H longipes* var. *gracillima* and *H. kiyosumiensis*, and the smallest leaf surface in *H. alismifolia*. The percentage reduction of leaf area in the two years was considered insignificant.

H. tardiva recorded the highest chlorophyll content (75.44% in 2015 and 74.14% in 2016) and the minimum chlorophyll content in the leaves was found in *H. longipes* var. *gracillima* both in 2015 (34.89%) and in 2016 (33.02%). The percentage reduction in chlorophyll content was considered insignificant.

H. montana had the longest petiole (81.10 cm in 2015 and 79.70 cm in 2016). The minimum length of the peduncle was found in *H. longissima* (71.90 cm and 70.30 cm in 2015, respectively 2016). The percentage reduction of the peduncle length was very small.

The maximum length of the inflorescence was found in *H. tardiva* and the minimum length in *H. kiyosumiensis,* both years. The percentage reduction was considerable in all taxa.

The highest number of inflorescences was in *H. sieboldiana*, and the least was found in *H. kiyosumiensis*. The percentage of inflorescence reduction was high.

The authors of the research also commented on the number of leaf nerves and the shape of the leaves.

ANTHOCYANINS OF THE GENUS OF HOSTA AND THEIR IMPACTS ON TEPAL COLORS

The researches made in 2012 by Liu et al., use the following as a material and method of tracking: the biological material was composed of 86 variants (six species and 80 cultivars). The flowers were harvested in the open flower stage in 2010 and then stored at - 40°C. The composition of anthocyanins was determined by high performance liquid chromatography coupled to diode array detection (HPLC-DAD) and high performance liquid chromatographyc with elecro spray ionization and mass spectrometry (HPLC-ESI-MS).

To measure the colour of the tepals, a colorimeter (NF333 spectrophotometer) was used. Anthocyanins were quantitatively determined by HPLC-DAD using a Dionex HPLC system (Dionex Corp., Sunnyvale, CA, USA) equipped with a P680 pump, an UltiMate 3000 autosampler, a TCC100 thermostated column compartment and a Dionex PDA-100 detector.

Following these researches conducted between 2010-2012, Liu et al. obtained the following results and discussions: initially, the researchers identified 9 anthocyanins in a purple cultivar, *Hosta nakaimo,* and in a species of white flowers, *Hosta montana*. Nina Liua et al. found the following anthocyanins: delphinidin 3,5-O-diglucoside (Dp3G5G), cyanidin 3,5-O-diglucoside (Cy3G5G), petunidin 3,5-O-diglucoside (Pt3G5G), peonidin 3-O-rutinoside-5-O-glucoside (Pn3Ru5G), malvidin 3-O-rutinoside-5-0-glucoside (Mv3Ru5G) malvidin 3,5-O-diglucoside (Mv3G5G), petunidin 3-O-rutinoside (Pt3Ru), peonidin 3-O-rutinoside (Pn3Ru), malvidin 3-O-rutinoside (Mv3Ru).

The violet variants had a higher level of anthocyanins and correlated with the pigments Mv3Ru5G, Mv3G5G, Pt3G5G and Dp3G5G, and the variants with white flowers had a lower level of anthocyanins and correlated with the pigments Pt3Ru, Pn3Ru, and M Pn3Ru5G. Mv3G5G and Mv3Ru5G dominated the purple flowers.

Nina Liu et al., find that anthocyanin contents were different among the selected 86 hostas. There were discovered nine anthocyanins in *Hosta* "Grand Master", a cultivar with purple flowers, three anthocyanins in the species with white flowers *Hosta montana* and three anthocyanins in *H. montana*. They identified four anthocyanins (delfinidin, cyanidin, petunidin and malvidin) of 3,5-O-diglucoside, 2 anthocyanins (peonidin and malvidin) of 3-O-rutinoside-5-O-glucoside and 3 anthocyanins (petunidin, peonidin and malvidin) of 3-O-rutinozide.

ANALYSIS OF THE VARIATION IN SCENT COMPONENTS OF HOSTA FLOWER BY HS-SPME AND GC-MS

During this research made in 2014 by Liu et al., the following material and method were used: as a plant material, they used six species and 40 Hosta cultivars and determined the composition and content of volatile floral compounds by

headspace solid-phase microextraction (HS-SPME) and gas chromatography-mass spectrometry (GC-MS). Volatile compounds in different stages of development and different floral organs were analyzed. HS-SPME analysis was performed with SPME fiber 85 carboxen polydimethylsiloxane (CAR-PDMS), equipped with a manual SPME support.
After this research, Liu et al., obtained the following result and discussions: they identified over 70 volatile compounds. The predominant components were terpenoids, mainly myrcene, limonene and linalool. Linalool has emerged from these researches as being the component with character impact of Hosta flowers. Among these volatiles, 48 fragrance compounds, of which 2-ethenyl-1,1-dimethyl-3-methylenecyclohexane and 1,3,5,5-tetramethyl-1,3-cyclohexadiene were identified and have not been previously reported.
Among the fragrant varieties there were slight differences in perfume detected by the human sensory evaluation. In *Hosta plantaginea* and *Hosta* "Summer Fragrance" predominated linalool. *Hosta* "Royal Standard", *Hosta* "Tortilla Chip" and *Hosta* "So Sweet" had high levels of myrcene, lemonene and linalool, and in *Hosta* "Diana Remembered" and *Hosta* "Moonlight Sonata", ocimene and linalool.

NECTAR AND POLEN PRODUCTION AND INSECT VISITATION ON ORNAMENTALS FROM THE GENUS HOSTA TRATT. (ASPARAGACEAE)

The researches made between 2012-2014 by Bożek et al. use as material the following Hosta species and cultivars: *H. sieboldiana* Engler, *H. capitata* Nakai, *H. crispula* Maekawa, *H. fluctuans* Maekawa, syn. *H. sieboldiana* var. *fluctuans* hort., *H. undulata* var. *univittata* Miquel (Hylander), syn. *H. univittata*.
The phenology of flowering, the production of pollen and nectar were studied, observing the biology of flowering, the nectar secretion, the pollen production, the shape and size of pollen grains (Figure 2) and the groups of visiting insects. The phenology of flowering was documented for two years, using the method described by Denisow, establishing the flowering time and the duration of the flowering period. The number of inflorescences on the flower stems and the number of flowers on the plant was determined.
The nectar production was determined over two years, by collecting it using the pipette method (Jabłoński, 2002). The nectar harvesting was repeated three, five times, during the blooming period, collecting four – six samples each time. The total sugar concentration was measured with an Abbe refractometer. The amount of sugars produced per 10 flowers (in mg) and per 10 m^2 (in g) was determined.
Pollen production was determined using the ether-ethanol method described in detail by Denisow (2011). The mass of pollen produced was calculated for 10 flowers (in mg) and for 10 m^2 (in g). Observations on the dimensions of the pollen grains were performed using a Nikon Eclipse 200 microscope.

Figure 2. Light micrographs of the pollen grains of *Hosta capitata* in a. equatorial view b. distal polar view and c. proximal polar view; insect visitors d. *Apis mellifera*, e. *Halictus* sp. (after Małgorzata Bożek)

Insects visits were recorded between 7:00 and 18:00, at intervals of two, three hours on random plots, for three consecutive days, during the full flowering phase of the species. During each observation census (three to six min), the total number of visiting insects was recorded.
After this researches, Bożek et al. obtained the following result and discussions: *Hosta sieboldiana* was the first to flower, followed by *H. fluctuans*, *H. capitata*, *H. crispula* and *H. undulata* var. *univittata*.

The flowering lasted the least time in *Hosta crispula* (16-20 days) and the longest time in *H. capitata* (25-36 days). In 2014, compared to 2012 and 2013, the flowering period was advanced by 10-14 days.

H. undulata var. *univittata* and *H. crispula* recorded the smallest number of flowers in inflorescences and *H. sieboldiana* the highest number.

Hosta flowers have been observed to attract insects. The pollen is released from anthers in the first hours of the flower life cycle. The highest amount of pollen was recorded in *H. capitata*, and the smallest in *H. undulata* var. *univittata*. The average pollen production per 10 m^2 was 0.24 g (*H. undulata* var. *univittata*) and 9.53 g (*H. capitata*). The pollen granules of the Hosta species were bilaterally symmetrical.

ANALYSIS OF ESSENTIAL MACRO-MICRO MINERAL CONTENT OF TWELVE *HOSTA TAXA*

During this research made in 2017, Mehraj et al. use as material and method the following: as biological material, the leaves of 12 taxa of Hosta namely *Hosta sieboldiana, H. alismifolia, H. sieboldii, H.longissima, H. tardiva, H. longipes* var. *gracillima, H. nakaiana, H. kikutii* var. *caput-avis, H. kikutii* var. *polyneuron, H. longipes* var. *caduca, H. kiyosumiensis* and *H. montana*. The rhizomes of the 12 *Hosta taxa* were planted in the field for 1 year, then they were transferred into pots, four plants for each cultivar/variety, with a total of 48 plants. The culture substrate was supplemented with 320 mg/L N, 210 mg/L P and 300 mg/L K, without using any additional fertilizer. Leaves were collected, washed with tap water, rinsed with distilled water, dried in an oven, powdered and placed for six hours in the desiccators to remove moisture.

Then the procedures described by Ikeda (1980) for sample preparation and acid dissolution were followed. The mineral content of the samples was determined using Induced Coupled Plasma Spectroscopy (Japan), Plasma spectroscopy equipped with an automatic module for macro minerals (K, P, Ca and Mg) and micro minerals (Fe, Zn, Mn and Cu).

After this researches made in 2017, Mehraj obtained the following result and discussions: K content was 4.05% in *H. alismifolia*, 3.87% in *H. montana* and 3.23% in *H. sieboldii*. The highest P content, 0.34%, was recorded in *H. nakaiana*, followed by *H. tarvida* with 0.29%, *H. montana* with 0.23% and *H. sieboldii* with 0.21% P. The Ca content, significantly higher was observed in *H. sieboldii* (1.15%), and the lowest in *H. montana* (0.17%). The highest Mg content was recorded on the leaves of *H. nakaiana* (794.12 ppm), followed by *H. alismifolia* (767.37 ppm), *H. montana* (606.68 ppm) and *H. sieboldii* (603.95 ppm).The highest content in Mn was observed in the leaves of *H. longissima* (133.77 ppm). Zn content was highest in the leaves of *H. nakaiana* (334.52 ppm), followed by *H. longissima* (322.08 ppm), *H. montana* (294.92 ppm) and *H. alismifolia* (284.78 ppm). In terms of Cu content, the leaves of *H. longissima* (5.95 ppm), *H. nakaiana* (5.62 ppm) and *H. montana* (5.52 ppm) were noted. Fe content was highlighted in the taxa of *H. sieboldii* (251.95 ppm) and *H. alismifolia* (206.41 ppm).

Leafy vegetables from spontaneous flora have a higher content in macro and micro minerals compared to growing vegetables (Pradeepkumar et al., 2013). *H. montana* and *H. sieboldii* are plants whose leaves are commonly consumed in Japan.

SEED STORAGE LONGEVITY OF *HOSTA SIEBOLDIANA* (ASPARAGACEAE)

During this research made in 2015, Kanazawa et al., used as material and method the following: mature and immature seeds by *H. sieboldiana* were harvested from two areas of Japan. The first area, where the seeds were ripe, was noted with YA, and the second area, with immature seeds, was noted AS. Immediately after the harvesting, the seeds were stored at temperatures of - 20°C and 5°C, at a humidity of about 65%. The seeds were also dried to about 10% or 5% of the moisture content (MC). The study was conducted for more -than four years and tracked the maturity and the effects of seed storage, the moisture value and the temperature during storage. The

storage was done in three variants: ~ 65% (the initial MC of seeds on collection), ~ 10% (dry) and ~ 5% (very dry). The seeds were divided into three groups: the first group was sealed in polyethylene bags immediately after collection and then stored at 5°C and - 20°C, with a content of 64% to 66% MC (moisture content). In the other two groups, the seeds were first dried for 9 to 18 days and then stored at both 5°C and - 20°C. During storage, germination tests were performed every three months. The moisture content of 180 seeds was evaluated gravimetrically, by drying the seeds for 16 hours at 105°C.

After this researches, Kanazawa et al., obtained the following result and discussions: the mature seeds of YA had an initial germination of 82%; the immature seeds from AS had an initial germination of only 18%. During storage, YA seed viability decreased significantly.

Seeds with a high MC of 65.7% died rapidly at both 5°C and - 20°C.

Seeds with 9.6% MC, stored at - 20°C, lost their viability much faster than seeds with 9.6% MC and 4.5% MC kept at 5°C.

The viability of the stored seeds with 7.7% humidity (MC) increased both at 5°C and at - 20°C and decreased faster than that of the stored seeds with 5% MC.

At the same humidity (MC 5% or 7.7%), the viability increased in equal percentages for the two temperatures, but decreased much faster at - 20°C than at 5°C.

Seeds of *H. sieboldiana* survived at the 5% moisture content and the temperature of - 20°C. For both mature and immature seeds, decreasing the moisture content increased the longevity of the seeds.

With a high moisture content (MC) of ~ 65%, the seeds of *H. sieboldiana* have lost all viability within five months.

The dried seeds of *H. sieboldiana* (~ 5% to ~ 10% MC) lost their viability faster at - 20°C than at 5°C.

During storage, immature seeds (AS) of *H. sieboldiana* continued their maturation. When maturation was completed, the germination rates decreased faster at higher MC and at lower temperatures.

CONCLUSIONS

As a result of their researches made in 2017, Mehraj and Shimasaki reached the following conclusions: over the course of two years, it is noted that the 12 varieties and cultivars of Hosta behaved well as perennial plants, even though some traits diminished in the second year, such as the number of leaves and the flowering of the plants.

Mehraj and Shimasaki's conclusion was that the division of the bushes at Hosta improves the plant's appearance, but repeated division leads to a decrease in the size of the leaves and of the flowers and it is recommended that the separation of the plants must be done only at the maturity of the plants.

As a result of their researches made in 2012, Liu et al., reached the following conclusions: the tepals of the Hosta genus present colour variations, but these are insignificant. There were differences between the purple flowers and the white flower variants. In terms of anthocyanin content, the highest values were obtained for *Hosta longipes* (purple species). Hosta varietes with purple flowers, *Hosta* "Kabitan", *Hosta* "Spritzer", *Hosta lancifolia, Hosta* "Grand master" and *Hosta* Antioch contain all 10 anthocyanins identified.

The results concured the hypothesis according to which the dominant positions of Mv3G5G and Mv3Ru5G in the synthesis of anthocyanidin glycosides were responsible for the purple color in the Hosta flowers.

As a result of their researches made in 2014, Liu et al. reached the following conclusions: the fragrant components were noticeable in the open flower stage, but decreased greatly after complete flowering. 39 of the 40 Hosta plants analyzed have no distinct perfume. Part of the 39 varieties emitted a light scent that can only be felt in the proximity of the flowers.

Regarding the presence of the perfume in different stages of the flowering and in different floral organs, the strong emission of the perfume took place in the open flower stage and decreased after flowering. Regarding the differences in perfume between tepals, stamens and pistil, there were not significant variations found.

As a result of their researches made in 2012-2014, Bożek et al. reached the following conclusions: the Hosta species taken into study continue to bloom continuously starting from the second decade of June until the first week of August. The flowers of the inflorescences had a longevity of 20-38 hours. The number of flowers in inflorescence did not change during the study years.
H. sieboldiana, H. fluctuans, H. crispula and *H. undulata* var. *univittata* were sought mostly by bumblebees, and the flowers of *H. capitata* were visited mostly by bees.
The phenotypic features of the flowers prevent access to the nectar and restrict the visit of insects. Although total sugar mass and pollen production are low in Hosta species, the flowers can complement summer pastures, especially for bumblebee.

As a result of their researches made in 2017, Hasan Mehraj et al. reached the following conclusions: -the leaves of *H. sieboldii* have a content of 1.15% Ca, higher than STFC-2015 (The Standard tables of food composition in Japan - 2015) and higher than the studies made in different countries for various wild edible plants. Hosta is asparagus-like; the young leaves, the petiole and the sprouts are edible. *H. sieboldii* and *H. alismifolia* are good sources of Fe, *H. nakaiana* and *H. longissima* of Zn. The results of Hasan Mehraj et al.'s research showed that Hosta leaves have a higher mineral content than asparagus and that they represent a very good source of minerals. *H. alismifolia, H. sieboldii, H. nakaiana, H. longissima, H. montana* may be recommended for their K, Ca, Fe, P, Mg and Zn content.

As a result of their researches made in 2017, Yumiko Kanazawa et al. reached the following conclusions: on a short term, the storage of *H. sieboldiana* seed may be feasible, but the cryogenic storage would be considered a more efficient method for the long-term storage of these seeds. The state of maturity had significant effects on the longevity of the seed storage. The longevity of the immature seeds was shorter than that of the mature seeds stored under the same storage conditions.

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