

Ornamental Cabbage and Kale Cultivar Comparison Study: Growth Characteristics and Response to Daminozide and Uniconazole Foliar Sprays

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ADDITIONAL INDEX WORDS. *Brassica oleracea* var. *acephala*, growth retardant, B-Nine, Sumagic

SUMMARY. Twenty-six ornamental cabbage and kale (*Brassica oleracea* var. *acephala*) cultivars were grown in 8-inch (20.8-cm) diameter pots during Fall 1998 to classify their foliage traits and determine their response to the plant growth regulator (PGR) daminozide. Cultivar vigor was classified by height. Foliage characteristics were described and cultivars of ornamental cabbage, notched ornamental kale, and curly ornamental kale were selected for retail or wholesale markets based on the shortest number of days until a significant center color change, the largest center color diameter, and attractive foliage characteristics. Two cultivars treated with 2,500 ppm (mg·L⁻¹) daminozide and eight cultivars treated with 5,000 ppm were significantly smaller in height compared to nontreated plants. Plants were treated 6 weeks after sowing, and the response to the PGRs may have been diminished by the age of the plant. Therefore, to further investigate PGR efficacy, seven outstanding cultivars selected in 1998 were treated with 5,000 ppm daminozide or 5 ppm uniconazole 14 days after potting (4 weeks after sowing) in Fall 1999. Greater control was observed with daminozide at 5,000 ppm in 1999 with a 13% smaller plant height as compared to 9% in 1998, when compared to the nontreated control. For greater height control, PGR applications to ornamental cabbage and kale should be applied 4 weeks after sowing.

Ornamental cabbage and kale are popular cool season crops which display attractive foliage with particularly brilliant plant centers. All cultivars of ornamental cabbage and kale are actually true kales, with the margins of the leaves determining the horticultural classification of the plant (Nau, 1998). Ornamental cabbage has smooth leaves, while ornamental kale leaves are curly or notched. Center color varies from red, pink, rose, or white. There are more than 25 cultivars on the market today, but a limited amount of descriptive literature or production information exists to assist growers in differentiating among the cultivars (Luczai, 1998; MacPhail and Best, 1996; Nau, 1998). Wholesale and retail growers should make selections based on noteworthy characteristics: growth habit, response to PGRs, days until a significant center color change, center color, foliage color, and foliage shape.

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Commercial production of ornamental cabbage and kale in the southeastern U.S. occurs during the late summer when warm temperatures promote extensive plant growth. Growers face the challenge of maintaining a short, yet robust plant, which looks proportional to pot size. Our study investigated the response of 26 cultivars of ornamental cabbage and kale treated with the industry standard PGR, daminozide (2,2-dimethylhydrazide) (B-Nine, Uniroyal Chemical, Middlebury, Conn.). The objective of this study was to evaluate cultivars grown in containers and make selections for the wholesale or retail markets from each type (ornamental cabbage, notched kale, and curly kale) and color (red, pink, rose, and white), based on plant characteristics and growth performance in a southern climate.

Materials and methods

EXPERIMENT 1. Cultivars of orna-

mental cabbage and kale (Table 1) were sown in 1.5 × 1.5 × 2.3 inch cells (3.8 × 3.8 × 5.7 cm) on 22 July 1998. Plugs were transplanted into 8-inch (20.8-cm) round plastic containers with a 0.78-gal (2.96-L) volume on 20 Aug. The root substrate used during germination and growing was Fafard 4-P (Fafard, Anderson, SC), which contained: 4 sphagnum peat : 2 pine bark : 2 vermiculite: 1 perlite (by volume). Plants were fertilized at each watering with nitrogen (N) at 200 ppm mixed from calcium nitrate (Ca(NO₃)₂•4 H₂O) (15.5N-0P-0K) and potassium nitrate (KNO₃) (13N-0P-36.5K). Once every 2 weeks, a supplemental application of magnesium sulfate (MgSO₄•7 H₂O) at the rate of 243 ppm magnesium (Mg) and Peters 20-10-20 (Scotts, Marysville, Ohio) (20N-4.4P-16.6K) at the rate of 200 ppm N were applied. The plants were grown under natural daylength.

Two PGR foliar sprays were ap-

plied 12 d after potting (using a volume of 0.5 gal/100 ft² [204 mL·m⁻²]) with daminozide at 2,500 or 5,000 ppm, plus a nontreated control. The experiment was a randomized complete-block design with six, single-plant replications of the three treatments per cultivar. The number of days from potting until an initial center color change occurred was recorded. On 3 Nov., total plant height (measured from the pot rim to the top of the foliage), plant diameter, and color diameter (all diameters measured at the widest dimension and turned 90°, and averaged) were recorded. The number of d from transplanting until visible center color, plant height, diameter, and color diameter were tested by analysis of variance by general linear model (SAS Institute, Cary, N.C.) and means were separated by least significant differences (LSD) at *P* ≤ 0.05.

CLASSIFICATION AND GROWTH HABIT. Growers desire cultivars to be

Table 1. Classification of 26 untreated ornamental cabbage and kale cultivars by mean days until visible center color, color diameter, plant height, and plant diameter (Expt. 1).

Cultivar	Type ^z	Days until color	Color diam (cm) ^y	Plant ht (cm)	Growth habit ^x	Plant diam (cm)
Flamingo Plumes	NK	50.7	15.5	37.8	V	55.7
Peacock White	NK	58.7	15.4	35.7	V	51.7
Rose Bouquet	OC	45.8	12.1	32.1	T	37.1
Osaka Pink	OC	54.0	12.0	31.9	T	35.8
Coral Prince	NK	57.7	16.6	31.6	T	40.9
Osaka Red	OC	41.5	10.4	31.4	T	39.1
Color-up Pink	OC	53.7	12.3	30.4	T	33.2
Tokyo Red	OC	43.8	8.7	30.2	T	38.0
Snow Prince	NK	58.3	16.0	30.0	T	43.5
Coral Queen	NK	46.3	9.5	29.6	M	44.7
Pigeon Red	OC	47.0	12.0	27.8	M	36.1
Tokyo Pink	OC	56.8	7.5	27.3	M	39.7
Osaka White	OC	58.5	11.6	26.9	M	38.8
Color-up Red	OC	48.3	11.1	26.6	M	33.5
Pigeon White	OC	54.2	15.4	26.0	M	31.0
Tokyo White	OC	59.2	4.9	25.3	M	38.0
Color-up White	OC	54.2	15.7	25.3	M	30.8
Sparrow Red	CK	48.5	6.8	23.9	S	34.2
Chidori Red	CK	38.8	11.9	23.1	S	37.4
Nagoya Red	CK	44.0	7.3	22.3	S	36.0
Frizzy White	CK	62.5	8.6	22.0	S	36.3
Sparrow White	CK	62.2	8.6	21.7	S	39.2
Kamone White	CK	59.3	10.9	21.3	S	34.5
Chidori White	CK	62.0	7.4	21.2	S	36.2
Nagoya Rose	CK	48.5	9.1	18.8	D	31.6
Nagoya White	CK	62.3	7.1	18.2	D	35.9
Significance		***	***	***		***
LSD ($\alpha \leq 0.05$)		2.8	2.5	3.2		3.3

^zPlant type: OC = ornamental cabbage, NK = notched kale, CK = curly kale.

^y2.5 cm = 1.0 inch.

^xRange/LSD = 5, V = vigorous, T = tall, M = medium, S = short, D = dwarf.

***Significant at *P* ≤ 0.001, n = 6.

classified as to the type (ornamental cabbage, notched kale, or curly kale) and growth habit. Of the 26 cultivars included, 12 were ornamental cabbages, 9 were curly leaf kales, and 5 were notched leafkales (Table 1). Classifying ornamental cabbage and kale cultivars by growth habit assists growers in determining what type of fertilizer to use, the type and concentration of PGR, and wholesale shipping capacities (Whipker et al., 1998). The growth habit categories, which were based on mean heights of the nontreated controls, were separated into five groups using the range/LSD technique (Wehner and Shetty, 2000).

EXPERIMENT 2. The same procedures used in Expt. 1 were repeated, except as noted. Seven cultivars of ornamental cabbage and kale (Table 2), which were recommended for production from the 1998 trial, were sown in $1.2 \times 1.2 \times 1.8$ inch cells ($3.0 \times 3.0 \times 4.6$ cm) on 13 Aug. 1999. Plugs were transplanted on 29 Aug. Two PGR foliar sprays were applied 14 d after potting [using a volume of 0.5 gal/100 ft² (204 mL·m⁻²)] with daminozide at 5,000 ppm or uniconazole ((E)-1-(p-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl-1-penten-3-ol)) (Sumagic, Valent, USA, Marysville, Ohio) at 5 ppm, plus a nontreated control. The experiment was a randomized complete-block design with four, single-plant replications of the three treatments for each cultivar. On 7 Nov., total plant height, plant diameter, and color diameter were recorded.

Results and discussion

The PGR \times cultivar interaction was significant for plant height, plant color diameter, and days until color in Expt. 1 (data not shown), because there was widespread variability among cultivars treated with daminozide. The plants were treated 6 weeks after sowing and the age of the plant may have diminished the response to the PGRs. Due to the variability, only the main effects within the 26 cultivars were reported in order to classify plants by growth habits and foliar characteristics.

DAYS TO COLOR. Growers require short production times for ornamental cabbage and kale to achieve early sales that can complement garden chrysanthemums (*Dendranthema \times grandiflorum*) and pansies (*Viola \times wittrockiana*). Color initia-

tion is inhibited by night temperatures ≥ 55 °F (12.8 °C) (Galinat, 1995) in the early fall, therefore selecting cultivars with the shortest amount of time to color is crucial for early sales. The red curly kale-type cultivar 'Chidori Red' (38.8 d) and the red cabbage-type cultivars 'Osaka Red' (41.5 d) or 'Tokyo Red' (43.8 d) were the earliest to color and would be the cultivars of choice for growers who want the shortest production time (Table 1). Among the white cabbage cultivars, 'Pigeon White' and 'Color-up White' were the earliest to color at 54.2 d. As a group, all the white cultivars of curly kale took the longest time to color (>59.0 d). The notched kale cultivars were also slow to develop color (>50.0 d), except for the rose colored cultivar, 'Coral Queen', which showed color after 46.3 d. Even though the coloration time for some cultivars like 'Peacock White' with its finely textured leaves, or 'Snow Prince' with its tinges of blush pink in a cream-white center, can be up to 20.0 d longer than the shortest cultivars to show color, their unique leaf type and color characteristics may make them desirable.

The PGR \times cultivar interaction was significant for days until color. Daminozide sprays of 5,000 ppm shortened the coloration time for 'Tokyo Pink' and 'Sparrow Red' by 3.5 d (data not shown). Even though the rate of coloration was quicker and statistically significant with the use of PGRs, the differences would not be commercially important.

COLOR DIAMETER. Not only does the number of days to color affect

cultivar selection, the expansiveness of the center color can be a major marketing feature. Excluding 'Coral Queen', the notched kale cultivars, with their vigorous growth habits, had the largest color diameters [>6.1 inches (15.4 cm)] (Table 1). Of the white cabbage cultivars, 'Pigeon White' and 'Color-up White' had the largest center color diameters [>5.9 inches (15 cm)], while 'Tokyo White' had the smallest color diameter of 1.9 inches (4.9 cm). The 'Tokyo' cultivar series had smaller diameters than either the 'Pigeon' or 'Color-up' cultivar series. 'Chidori Red' had the largest color diameter of 4.7 inches (11.9 cm) among the red curly kales, while the white curly kale 'Kamone White' had a 36% larger color diameter than 'Chidori White' or 'Nagoya White'.

Color diameter was significant for the cultivar \times PGR interaction because there was a great deal of variability in color response to PGRs among the cultivars (data not shown). Fewer than half of the cultivars treated with 2,500 or 5,000 ppm daminozide had significantly smaller color diameters, when compared to the nontreated control.

Plant height

EXPERIMENT 1. Plant height varied by cultivar, with the height of the plants increasing (shortest to tallest) from the curly leaf kale cultivars to the ornamental cabbage and notched kale cultivars (Table 1). Using the range/LSD technique (Wehner and Shetty, 2000), cultivars were classified into groups which characterized their growth habit by the mean height.

Table 2. Mean height, plant diameter, and center color diameter of seven cultivars of ornamental cabbage and kale (Expt. 2).

Cultivar	Type ^z	Plant ht (cm) ^y	Plant diam (cm)	Color diam (cm)
Flamingo Plumes	NK	27.0	54.4	11.9
Peacock White	NK	24.3	47.5	13.9
Osaka Pink	OC	20.5	37.4	11.3
Snow Prince	NK	20.3	44.3	12.6
Rose Bouquet	OC	17.9	34.7	14.3
Chidori Red	CK	17.3	38.7	13.7
Kamone White				
Significance	CK	14.7	***	
		34.3	***	
		1.9	13.1	
		***	1.5	
LSD ($\alpha \leq 0.05$)		1.7		

^zPlant type: OC = ornamental cabbage, NK = notched kale, CK = curly kale.

^y2.5 cm = 1.0 inch.

***Significant at $P \leq 0.001$, $n = 28$.

Table 3. Effect of plant growth regulator (PGR) application on growth of ornamental cabbage and kale (Expt. 2).

PGR treatment	Plant ht (cm) ^z	Plant diam (cm)	Percent of control
Control	21.8	---	42.2
5,000 ppm (mg·L ⁻¹) daminozide	18.8	87.0	39.8
5 ppm uniconazole	20.2	94.0	42.9
Significance ²	***	***	***
LSD ($\alpha \leq 0.05$)	1.1	7.2	1.2

^z2.5 cm = 1.0 inch.

***Significant at $P \leq 0.001$, $n = 12$.

Cultivars with mean heights 13.8 inches (35.0 cm) or higher were classified as vigorous growers, ≥ 11.8 to < 13.8 inches (30.0 to 35.0 cm) as tall, ≥ 9.8 to < 11.8 inches (25 to 30.0 cm) as medium, ≥ 7.9 to < 9.8 inches (20 to 25.0 cm) as short, and < 7.9 inches (20.0 cm) as dwarf (Table 1). The notched kales were either classified as vigorous or tall with mean heights greater than 11.4 inches (29.0 cm). This tall habit suits them for both retail production and most garden settings as background or specimen plants. Ornamental cabbage plants were classified as either medium or tall, with the tall cultivars being more suitable for the retail grower, and medium size cultivars desired by wholesale growers. Ornamental curly kale cultivars were classified as short or dwarf in growth habit, and all would be considered suitable for both retail or wholesale production, and would make excellent border plants in garden settings.

Total plant height and the percentage reduction in plant height from the nontreated control was significant for the PGR \times cultivar interaction, but there were inconsistent variabilities, therefore data are not shown. The variability in height control to daminozide demonstrated the importance of an additional PGR study.

EXPERIMENT 2. Plant height was significant for the cultivar or PGR treatment, but the interaction was not significant. Cultivars were much shorter in Fall 1999 because the plants were transplanted into the final container when they were 2 weeks old as compared to 4 weeks old in Expt. 1. Although the cultivars were much shorter in Expt. 2, the trend of notched kales and ornamental cabbages being taller than curly kales was still observed (Table 2). A greater control of plant height was observed with daminozide at 5,000 ppm (13% shorter), than with uniconazole at 5 ppm (6% shorter),

when compared to the nontreated control (Table 3).

Plant diameter

EXPERIMENT 1. Plant diameter of an ornamental cabbage or kale plant is very important to all growers. Large expansive diameters are demanded by retail growers who wish the grandest display for consumers. Filling production areas or shipping carts with as many plants as possible is a concern of wholesale growers, and can be achieved by growing smaller diameter plants. Small diameter ornamental cabbage cultivars such as the 'Pigeon' or 'Color-up' series, are suitable for the wholesale grower (Table 1). The notched white kale 'Peacock White', and the magenta colored notched kale 'Flamingo Plumes' had the largest diameters. Both cultivars have a unique foliage texture, but because of their vigorous growth habit they would be recommended for retail production. A wholesale grower may want to produce these cultivars, but should be willing to accept lower plant density during production and shipping. Opposite of what was observed for center color diameter, the ornamental cabbage cultivars of the 'Tokyo' series were larger in diameter than the 'Color-up' series cabbage cultivars. All curly red and white kales had plant diameters greater than 13.5 inches (34.2 cm) and less than 15.4 inches (39.2 cm). Although there were statistically significant differences within plant type, 'Sparrow White' was larger than 'Kamone White' or 'Sparrow Red', the 2 inches (5 cm) difference would not be commercially significant for growers.

Although the plant diameter was significantly affected by PGR treatment, there was a wide variability between cultivars treated with daminozide at 2,500 or 5,000 ppm (data not shown). Ornamental cab-

bage and kale cultivars were 6 weeks old when treated with daminozide and this age may have diminished the response to daminozide. These results were in agreement with Barrett (1992) in which older plants were less responsive to PGRs than younger plants.

EXPERIMENT 2. Plant diameter was significant by PGR treatment. Plant diameters were 6% smaller when treated with daminozide, when compared to the nontreated control (Table 3). A 5 ppm application of uniconazole had no effect, when compared to the nontreated control.

Conclusion

Under central North Carolina climate conditions, the foliar characteristics, number of days until center color, center color diameter, and the plant diameters of ornamental cabbage and kale evaluated in Expt. 1 aided in selecting cultivars of different plant types and colors for retail and wholesale markets. For a detailed description of all cultivars evaluated in Expt. 1, see Whipker et al. (1998).

The retail selection for a red ornamental cabbage would be 'Osaka Red'; preferred over 'Pigeon Red' and 'Color-up Red' because it was 5 d quicker in developing color. 'Rose Bouquet', with its rose colored center and undulating leaf margins, is a tall cultivar that is best suited for retail production. 'Pigeon Red' and 'Color-up Red' had similar foliage, growth characteristics, and coloration time. 'Pigeon Red' and 'Color-up Red' are suited for wholesale production because they are smaller in diameter than 'Rose Bouquet' or 'Osaka Red'. The 'Tokyo' series cultivars were not selected for either retail or wholesale production because of their small color diameter. 'Pigeon White', 'Osaka White', and 'Color-up White' were similar in color diameter and days until color, but 'Osaka White' would be more suitable for retail sales because it had a more attractive center color, a larger plant diameter, and the leaf margins were slightly serrated, giving this cultivar a unique textural quality. 'Color-up White' and 'Pigeon White' were preferred cultivars for wholesale production because of their medium plant heights, small diameters, and their 5.9 inches (15.0 cm) color diameters. Both 'Osaka Pink' and 'Color-up Pink' ornamental cabbages were similar in growth habit, plant diam-

eter, color diameter, and days until color, making both suitable for retail and wholesale markets. However, 'Osaka Pink' had a very bright pink to fuchsia center color which may be attractive to retail customers.

The retail or wholesale selection for a red curly kale with purple foliage was 'Chidori Red'. The preferred red curly kale with green foliage for the wholesale or retail market was 'Nagoya Red' because of its shorter time (4.5 d) until coloration, when compared to 'Sparrow Red'. The white curly kale 'Kamome White' was selected based on its smaller diameter for the wholesale market, and the retail selection was 'Sparrow White'. Both of these cultivars had a deeper green foliage color, making it more attractive than 'Chidori White', 'Frizzy White' or 'Nagoya White' because these cultivars had a pale green appearance typical of nitrogen deficiency.

The selections for the white notched kale with shallowly notched leaves were either 'Coral Prince' or 'Snow Prince'. Both cultivars were similar in growth habit and foliage characteristics. 'Peacock White', a deeply notched white kale, and 'Flamingo Plumes', the medium notched magenta-rose colored kale, were selected as cultivars for the retail market, but because of their unique leaf type a wholesaler may be willing to produce these vigorous cultivars if they are willing to accept a lower plant density during production and shipping. 'Coral

Queen', the only rose colored shallowly notched kale was selected as both a retail or wholesale product.

Classifying cultivars based on the shortest number of days until a significant center color change, the largest center color diameter, and attractive foliage characteristics of the nontreated plants was conducted because of the widespread variability in PGR effects. Therefore to further investigate PGR efficacy, seven selected cultivars from Expt. 1 were treated with 5,000 ppm daminozide or 5 ppm uniconazole in Expt. 2. Cultivars responded similarly to each PGR treatment with greater control being observed with daminozide with a 13% smaller plant height as compared to 6% for uniconazole, when compared to the untreated control. Based on the significance at the PGR level, greater control of plant height of the seven selected cultivars in Expt. 2 was observed with daminozide at 5,000 ppm with a 13% smaller plant height as compared to 9% in Expt. 1, when compared to the untreated control. During Expt. 2 the plants were sprayed two weeks earlier than in Expt. 1. Ornamental cabbage and kale should be treated 4 weeks after sowing with daminozide in order to control stem elongation.

By classifying the heights, addressing the coloration times, and comparing diameters and color diameters within plant types and colors, growers will be able to produce plants which

will be directed towards specific markets and can suggest cultivars for placement in garden settings.

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