

‘Frosty Morning’, ‘Patchwork Quilt’, ‘Irish Mist’, and ‘Pistachio Ice Cream’ Ornamental White Clover (*Trifolium repens* L.)

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White clover (*Trifolium repens* L.) is an annual or short-lived perennial found throughout temperate regions of the world (Gibson and Cope, 1985). Originally native to the Mediterranean (Ellison et al., 2006), white clover grows in a wide range of temperatures and in nearly any soil type provided there is enough moisture and sunlight (Gibson and Cope, 1985). In addition, white clover is a frost-tolerant species with little frost damage observed on leaves after exposure to mild frosts (up to -5°C) (Caradus, 1995; McCully et al., 2004). The plant has a prostrate growth habit (Leffel and Gibson, 1973) and spreads along the ground through stolons. White clover is primarily grown as forage for livestock (Van Keuren and Hoveland, 1985), but the plant has also been cultivated for ornamental use. Ornamental cultivar development in the species is possible primarily because of the many attractive leaf marks that are expressed. The attractive foliar marks, combined with its low, spreading growth habit and frost tolerance, makes white clover ideal for development as an ornamental bedding plant.

In addition to the attractiveness of white clover developed for ornamental use, there is also folklore associated with the plant that could make it more appealing to ornamental consumers. White clover might have been the “shamrock” plant used by St. Patrick to teach Christianity in Ireland (Kennedy, 1919). White clover also has a long history of being used as a token of good fortune. White clover

was believed to ward off evil spirits by the Celts (Taylor, 1985). Nearly 150 years ago, Masters (1869) described girls using four-leaf clovers as “a token of perfect happiness.” In the early 20th century, finding a four-leaf clover was a sign of good luck or a sign that a girl would soon meet her future husband (Beckwith, 1923). To this day, people search for four-leaf clovers to keep as a good luck charm.

In 2002, an ornamental white clover breeding program was initiated at The University of Georgia with the goal of developing cultivars with highly ornamental phenotypes and improved persistence in the Southeast. Four white clover cultivars, Frosty Morning (tested as genotype 04-O-2), Patchwork Quilt (tested as genotype 04-O-6), Irish Mist (tested as genotype 04-O-33), and Pistachio Ice Cream (tested as genotype 04-O-53), were developed at The University of Georgia. These cultivars have unique phenotypes that are distinct from other commercially available ornamental white clover cultivars. After 2 years of evaluation in the field, the four genotypes were found to be comparable or superior to two commercially available ornamental white clover cultivars, Dragon’s Blood and Dark Dancer, in terms of survival and stand quality in the southern United States (Tables 1–3). Thus, the four released cultivars were approved for release by The University of Georgia’s Ornamentals Release Committee in 2008 for use as ornamental annuals or short-lived perennials (Fig. 1).

Origin

The four released genotypes were developed from crossing four ornamental white clover genotypes: ‘Dragon’s Blood’, ‘Dark Dancer’, ‘DS’, and ‘RD’. ‘Dragon’s Blood’ and ‘Dark Dancer’ are two commercially available ornamental white clover cultivars.

‘DS’ and ‘RD’ are two genotypes developed at The University of Georgia for ornamental breeding purposes. ‘Dragon’s Blood’ has a combination of red midrib (Carnahan et al., 1955; Corkill, 1971), red fleck (Carnahan et al., 1955), and marginal mark (Lenoble and Papineau, 1970) leaf marks; trifoliolate leaves (Gibson and Cope, 1985); and blush flowers (Brewbaker, 1962). ‘Dark Dancer’ has the red leaf (Carnahan et al., 1955; Corkill, 1971) and white V (Brewbaker, 1955; Carnahan et al., 1955) traits, a low level of multifoliolate (greater than three leaflets per leaf) expression (Ford and Claydon, 1996), and blush flowers. This line is believed to be the same variety described by Parkinson (1640) as “fower leafed or purple grasse” (*Quadrifolium fuscum*). ‘DS’ was selected after two generations of recurrent selection from a cross of MSRLM, a redspot leaf mark (Hovin and Gibson, 1961) white clover germplasm release (Pederson, 1995), and a wild-type white clover genotype found in a lawn in Georgia with high multifoliolate expression. It is multifoliolate, has the redspot leaf mark (Hovin and Gibson, 1961), and blush flowers. ‘RD’ is an F_1 genotype resulting from the cross of ‘Dragon’s Blood’ \times ‘Dark Dancer’. It is trifoliolate, has the red leaf trait, and blush flowers. Genotypes 04-O-2 and 04-O-33 are BC_1 plants from the cross of ‘RD’ (‘Dragon’s Blood’ \times ‘Dark Dancer’) \times ‘Dragon’s Blood’. Genotypes 04-O-6 and 04-O-53 are F_1 plants derived from ‘Dragon’s Blood’ \times ‘DS’.

Description

To accurately measure the vegetative and floral color traits of the four released genotypes, each trait was compared with the Royal Horticulture Society’s Color Chart [Royal Horticultural Society (Great Britain), 1995]. ‘Frosty Morning’ (04-O-2) is trifoliolate, has leaves borne alternately along the stolon, obovate in shape, with serrulate margins, a retuse tip, and rounded base that range in width from 2.5 to 3.6 cm when mature. Individual leaflets range in width from 1.2 to 1.9 cm. The leaflets contain the marginal and redspot leaf marks. The marginal mark is characterized by a light green crescent mark that corresponds to grayed-green 191-A. The redspot leaf mark is characterized by a grayed-purple 187-A-colored V-shape basal to the marginal mark that extends to the petiolule as the leaflet matures. The inner leaflet color is green 137-B basal to the red leaf mark. The stolon color initially corresponds to yellow-green 147-C and then changes to grayed-purple 187-C when exposed to direct sunlight. The flowers are a deep blush color, which corresponds to red-purple 73-C.

‘Patchwork Quilt’ (04-O-6) is mostly trifoliolate, but also expresses a low level ($\approx 12\%$) of multifoliolate leaves in the summer. The leaves are borne alternately along the stolon, obovate in shape, have an entire margin, retuse tip, and rounded base that range in width from 2.0 to 3.6 cm. Individual

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Table 1. Measurements comparing the performance of the four released ornamental white clover genotypes with two commercially available cultivars at the Georgia field location during the 2006–2007 growing season.

Genotype	Survival (%)	Spread (cm)	Ht (cm)	Canopy density ^z	Disease incidence ^y
04-O-2	100 a ^x	40.5 ab	4.2 b	4.1 a	1.8 ab
04-O-6	100 a	47.4 a	5.4 ab	2.8 bc	2.6 a
04-O-33	100 a	35.1 b	4.4 b	3.8 ab	1.7 ab
04-O-53	92 ab	31.9 b	6.8 a	3.3 abc	2.4 ab
Dragon's Blood	17 c	3.1 d	0.4 c	0.4 d	1.0 b
Dark Dancer	75 b	14.4 c	1.8 c	2.5 c	2.0 ab

^zCanopy density was scored on a scale of 0 to 5: 0 = no canopy, 5 = dense canopy.

^yDisease incidence was scored on a scale of 0 to 5: 0 = no disease symptoms to 5 = strong disease symptoms.

^xMeans followed by the same letter are not significantly different at $\alpha = 0.05$ ($P < 0.05$).

Table 2. Measurements comparing the performance of the four released ornamental white clover genotypes with two commercially available cultivars at the Georgia field location during the 2007–2008 growing season.

Genotype	Survival (%)	Spread (cm)	Ht (cm)	Canopy density ^z	Disease incidence ^y
04-O-2	100 a ^x	46.4 a	7.5 b	4.7 a	1.4 b
04-O-6	100 a	42.7 a	5.7 b	4.3 a	1.7 b
04-O-33	100 a	37.6 a	7.7 b	4.4 a	1.8 b
04-O-53	100 a	46.6 a	10.6 a	4.8 a	1.8 b
Dragon's Blood	25 c	1.8 b	0.3 c	0.3 c	4.7 a
Dark Dancer	58 b	9.2 b	2.1 c	2.3 b	2.0 b

^zCanopy density was scored on a scale of 0 to 5: 0 = no canopy, 5 = dense canopy.

^yDisease incidence was scored on a scale of 0 to 5: 0 = no disease symptoms to 5 = strong disease symptoms.

^xMeans followed by the same letter are not significantly different at $\alpha = 0.05$ ($P < 0.05$).

Table 3. Measurements comparing the performance of the four released ornamental white clover genotypes with two commercially available cultivars at the Oklahoma field location during the 2006 growing season.

Genotype	Survival (%)	Spread (cm)	Ht (cm)
04-O-2	100 a ^z	68.0 a	8.8 bc
04-O-6	100 a	60.4 ab	8.0 c
04-O-33	100 a	70.0 a	11.0 b
04-O-53	100 a	63.8 a	13.6 a
Dragon's Blood	100 a	57.3 ab	6.6 cd
Dark Dancer	100 a	50.3 b	4.9 d

^zMeans followed by the same letter are not significantly different at $\alpha = 0.05$ ($P < 0.05$).

leaflets range in width from 0.9 to 1.9 cm. The leaflets contain the marginal, red fleck, redspot, and red midrib leaf marks. The marginal mark is characterized by a light green crescent mark that corresponds to grayed-green 191-A. The red fleck is characterized by grayed-purple 187-A spots of pigmentation appearing randomly along the blade. The redspot leaf mark is characterized by a purple 79-A-colored V-shape basal to the moon mark that extends to the petiole as the leaflet matures. The red midrib is characterized by a grayed-purple 187-A colored herringbone pattern from the base of the blade to the tip. The stolon color initially corresponds to yellow-green 147-C and then changes to grayed-purple 187-A when exposed to direct sunlight. The flower color is pale blush, which corresponds to red-purple 75-C.

'Irish Mist' (04-O-33) is trifoliolate, has obovate leaves borne alternately along the stolon with a serrulate margin, retuse tip, and rounded base that range in width from 1.7 to

3.0 cm when mature. Individual leaflets range in width from 0.9 to 1.9 cm. The leaflets contain the marginal mark, redspot, and red leaf traits. The marginal mark is characterized by a light green crescent mark that corresponds to grayed-green 189-A. The redspot leaf mark is characterized by a V-shape basal to the marginal mark that extends to the petiole as the leaflet matures. This leaf mark is most similar to grayed-purple 187-A but is darker in color. The red leaf mark is characterized by a grayed-purple 187-A color covering the center of the blade to the petiole and edge as the leaflet matures. The immature leaflet color is green 138-A basal to the marginal mark, which darkens to purple 79-A as the red leaf trait expands. The stolon color initially corresponds to yellow-green 143-C and then changes to grayed-purple 187-C when exposed to direct sunlight. The flowers are pale blush-colored, which corresponds to red-purple 75-C.

'Pistachio Ice Cream' (04-O-53) is mostly trifoliolate, but also expresses a moderate level ($\approx 33\%$) of multifoliolate leaves in the summer. The leaves are obovate, borne alternately along the stolon, have a serrulate margin, retuse tip and rounded base that range in width from 4.6 cm to 6.7 cm. Individual leaflets range in width from 2.5 to 3.6 cm. The leaflets express the marginal and redspot leaf marks. The marginal mark is characterized by a light green crescent mark that corresponds to grayed-green 191-A. The redspot leaf mark is characterized by a grayed-purple 187-A-colored V-shape basal to the marginal mark that extends to the petiole as the leaflet matures. The stolon color initially corresponds to yellow-green 146-D and then changes to grayed-purple

187-C when exposed to direct sunlight. The flower color is pale blush, which corresponds to red-purple 73-B.

Evaluation

The four genotypes were selected for release after 1 year of greenhouse evaluation and 2 years of replicated field trials. In 2004, 22 reciprocal crosses were made with nine different genotypes selected as parents for ornamental traits or stand performance in the southeast United States. The crosses were done by hand pollination in the greenhouse at The University of Georgia. Seed was harvested by hand 3 to 4 weeks later and stored at -20°C to help break dormancy until planted. In 2005, 950 seeds resulting from the crosses were planted in the greenhouse and evaluated for ornamental potential. The seed were germinated by first scarifying them between two pieces of 100-C sandpaper and then placing them in 96-cell tray liners containing a potting mix made up of equal parts Fafard #3 potting soil (Conrad Fafard, Inc., Agawam, MA), river sand, and farm soil [Cecil sandy clay loam (clayey, kaolinitic, thermic, Typic Kanhapludults)]. The seed was then covered in a fine layer of inoculant (Nitragin, Inc., Milwaukee, WI) containing *Rhizobium meliloti* and *R. leguminosarum* biovar *trifolii*. A thin layer of potting soil was put over the inoculant, and the tray was placed under a misting station for 3 to 4 weeks. After removal from the misting station, the plants were placed on a greenhouse bench with 14-h supplemental lighting. The seedlings were grown in the greenhouse for an additional 4 to 8 weeks and then evaluated for ornamental potential. The seedlings were evaluated twice in the greenhouse, once for phenotype and once for growth habit. The phenotype evaluation occurred while the plants were in the 96-cell tray liners. Plants that were found to have an ornamental phenotype were potted into 15-cm pots with the same potting soil and evaluated for growth habit 4 to 6 weeks later. Plants that passed the growth habit evaluation were propagated for replicated field trials.

Ninety plants (clonal genotypes) that were selected for field trials and six of the parental genotypes were grown in 12-cm pots and planted in full sun in two locations in 2006 (Watkinsville, GA, and Ardmore, OK) in a randomized complete block experimental design with four clonal replications (blocks) of each genotype at each location. Each genotype was planted on 75-cm centers. The Georgia field test was established in Mar. 2006 in a Cecil sandy clay loam (clayey, kaolinitic, thermic, Typic Kanhapludults) soil with a pH of 6.5. At the Georgia location, the plants were evaluated three times for quality traits: 3 July 2006, 10 Oct. 2006, and 6 Apr. 2007. The ornamental traits measured were survival, spread, height, canopy density, flower color, flowering amount, leaflet number, and disease symptoms. The experiment was repeated at the Georgia location in 2007. The second-year Georgia



Fig. 1. Images of the four ornamental white clover genotypes selected for cultivar release after 2 years of field evaluations showing superior performance of the genotypes when compared with two commercially available cultivars: 'Frosty Morning' (A), 'Patchwork Quilt' (B), 'Irish Mist' (C), and 'Pistachio Ice Cream' (D).

field test plot was as described previously, except the establishment date was Oct. 2007 and the soil pH was 6.1. Second-year ornamental quality measurements were taken three times: 20 Nov. 2007, 6 Apr. 2008, and 14 July 2008, as described previously. The Oklahoma field test was planted in a Normangee clay loam (fine, smectitic, thermic Udic Haplustalfs) soil with a pH of 6.7. At the Oklahoma location, the plants were established as described previously in Oct. 2005 and were evaluated only once in June 2006. The quality traits measured in Oklahoma were survival, spread, height, flowering amount, and seed count.

Spread was measured by taking the average of two perpendicular measurements of the stand diameter. Height was measured at the center of the stand from the soil line to the top of the canopy. Canopy density was measured by a 0 to 5 rating system based on the amount of soil visible through the stand. A zero value indicated that no leaves were on the plant. A score of three indicated that 10 to 15 cm² of soil was visible through the canopy. A score of 5 indicated that the canopy was so dense that no soil was visible. Whenever possible, flower color was defined based on descriptions by Brewbaker (1962) of white clover flower pigmentation, although additional color variations were found within the breeding population at The University of Georgia. Flowering amount was measured

by a 0 to 3 rating system based on the number of flowers, living or dead, present on the stand at the time of evaluation. A zero score indicated that the plant did not flower. A score of 1 indicated that there were up to 10 flowers on the plant. A score of 3 indicated that the plant had over 30 flowers. Leaflet number was tabulated as either trifoliolate or multifoliolate. Plants with at least one multifoliolate leaf were scored as multifoliolate plants. Disease incidence was scored on a 0 to 5 rating system based on the symptoms of the leaves in the stand. A score of zero indicated that no disease symptoms were found on any leaves at the time of evaluation. A score of 3 indicated that many leaves had necrotic spots and some leaves were showing symptoms of chlorosis. A score of 5 indicated that many leaves were dead and all remaining leaves were chlorotic.

The data from each location were combined by year and analyzed to determine which genotype means were statistically different for each ornamental quality trait when compared with the means of two commercialized ornamental white clover cultivars, Dragon's Blood and Dark Dancer, by Duncan's multiple range test ($P = 0.05$) using SAS 9.1 (SAS Institute, Inc., Cary, NC). Genotypes were selected for cultivar release based on superior survival, spread, height, canopy density, and disease symptom scores when compared with the two commercial checks.

At the Georgia location, the first year of field evaluations occurred in atmospheric temperatures that were warmer and drier than the 30-year average. According to the Georgia Automated Environmental Monitoring Network, the average daily maximum air temperature from 1 June to 30 Sept. 2006 was 30.82 °C, which was 0.8 °C higher than the previous year and 0.7 °C higher than the 30-year average (1971 to 2000). During the same period, 310 mm of precipitation fell, which was 267 mm less than the previous year and 76 mm less than the 30-year average (1971 to 2000). The second year of field evaluations was even warmer and drier than 2006. The average daily maximum air temperature from 1 June to 30 Sept. 2007 was 32.02 °C, which was 1.2 °C higher than the previous year and 1.9 °C higher than the 30-year average (1971 to 2000). During the same period, only 222 mm of precipitation fell, which was 88 mm less than the previous year and 164 mm less than the 30 year average (1971 to 2000).

'Frosty Morning' (04-O-2) had 100% survival for both years of evaluation at the Georgia location (Tables 1 and 2), which was statistically higher than the survival rate of both commercial checks. This genotype also had 100% survival at the Oklahoma location (Table 3), similar to both commercial checks. The average spread and height of 04-O-2 was significantly larger than 'Dark Dancer' at each evaluation location (Tables 1–3). Genotype 04-O-2 had a significantly larger spread and height than 'Dragon's Blood' at the Georgia location over both years of evaluation (Tables 1 and 2) and similar spread and height to 'Dragon's Blood' at the Oklahoma location (Table 3). The canopy density of 04-O-2 was significantly denser than both commercial checks over both years of evaluation at the Georgia location (Tables 1 and 2). The disease incidence of this genotype was similar to 'Dark Dancer' for both years of evaluation at the Georgia location (Tables 1 and 2). When compared with 'Dragon's Blood,' the disease incidence of 04-O-2 was similar during the first year of evaluation but significantly less than 'Dragon's Blood' during the second year of evaluation at the Georgia location.

'Patchwork Quilt' (04-O-6) had 100% survival for both years of evaluation at the Georgia location (Tables 1 and 2), which was statistically higher than the survival rate of both commercial checks. This genotype also had 100% survival at the Oklahoma location (Table 3), similar to both commercial checks. The average spread and height of the genotype were significantly greater than both commercial checks at the Georgia location for the 2 years of evaluation. At the Oklahoma location, 04-O-6 had similar spread and height measurements to 'Dragon's Blood'. When compared with 'Dark Dancer,' 04-O-6 had similar spread measurements but was significantly taller. The canopy density and disease incidence of 04-O-6 was similar to 'Dark Dancer' and superior to 'Dragon's Blood' for the first year of the Georgia

evaluation. For the second year of Georgia evaluations, 04-O-6 had superior canopy density and disease incidence values when compared with 'Dragon's Blood'. When compared with 'Dark Dancer' during the second year of evaluations, 04-O-6 had a denser canopy value and a similar disease incidence value.

'Irish Mist' (04-O-33) had 100% survival for both years of evaluation at the Georgia location (Tables 1 and 2), which was statistically higher than the survival rate of both commercial checks. This genotype also had 100% survival at the Oklahoma location (Table 3), similar to both commercial checks. The average spread and height of the genotype were significantly greater than both commercial checks at the Georgia location for the 2 years of evaluation. At the Oklahoma location, the average spread of 04-O-33 was similar to both commercial checks (Table 3). Genotype 04-O-33 was significantly taller than both commercial checks at the Oklahoma location (Table 3). The canopy density of 04-O-33 was significantly denser than both commercial checks over both years of evaluation at the Georgia location. The average disease incidence value of 04-O-33 was similar to both checks during the first year of evaluation at the Georgia location. During the second year of evaluation at the Georgia location, 04-O-33 had an average disease incidence value similar to 'Dark Dancer' but superior to 'Dragon's Blood'.

'Pistachio Ice Cream' (04-O-53) had 92% survival during the first year Georgia evaluation (Table 1), which was statistically similar to 'Dark Dancer' but superior to 'Dragon's Blood'. During the second year of evaluation at the Georgia location, 04-O-53 had 100% survival, which was higher than the survival rate of both commercial checks (Table 2). At the Oklahoma location, 04-O-53 had 100% survival (Table 3), which is similar to both commercial checks. This genotype had spread and height measurements significantly greater than both commercial checks at both locations and for both years of evaluation at the Georgia location (Tables 1–3). During the first year of evaluation

at the Georgia location, 04-O-53 had canopy density and disease incidence values similar to 'Dark Dancer'. When compared with 'Dragon's Blood', 04-O-53 had a significantly denser canopy and a similar disease incidence value during the first year of evaluation at the Georgia location. During the second-year Georgia evaluation, the canopy density value of 04-O-53 was superior to both commercial checks. The disease incidence value of 04-O-53 was similar to 'Dark Dancer' but significantly lower than the disease incidence value of 'Dragon's Blood' during the second year of evaluation at the Georgia location.

Recommendation

The four ornamental white clover cultivars, Frosty Morning, Patchwork Quilt, Irish Mist, and Pistachio Ice Cream, are intended for use as annuals or short-lived perennials in gardens and containers. The plants grow in full sun to partial shade and have the most attractive foliage during the cooler winter months. Therefore, these genotypes are recommended to be grown as cool-season plants.

Availability

Cuttings of 04-O-2, 04-O-6, 04-O-33, and 04-O-53 will be maintained by The University of Georgia, Athens, GA. Plant patents for each genotype are being applied for.

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