

‘Eight Ball^{Plus}’, ‘Six Ball’, ‘Cue Ball^{Plus}’, and ‘One Ball^{Plus}’: New Ball Summer Squash Cultivars

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Summer squash are generally regarded as any variety of *Cucurbita* used immature as a table vegetable, but more commonly refer to any cultivated type of *Cucurbita pepo* that produces immature fruit for consumption (Herrington and Persley, 2002; Lu, 1979; Paris, 1996; Whitaker and Robison, 1986; Zhang, 2012). The summer squash, in the more narrow sense, have an erect or semierect plant and various fruit types differentiated by a fruit color and shape, such as the cylindrical black zucchini ‘Jack Pot’, tapered pale courgette ‘Basima’, yellow crook neck ‘Delta’, scallop zucchini ‘Peter Pan’, and cylindrical pale xihulou ‘Alexandria’ (Hollar Seeds, 2015; Loy, 2004; Schultheis and Walters, 1998; Whitaker and Davis, 1962). Since the black-round zucchini ‘Eight Ball’ (after its namesake billiard ball) was created by Hollar Seeds in the 1990s, more ball summer squashes have been developed and become important novel products in the world market. Such ball summer squashes include the gray ‘Ronde De Nice’ courgette (Burpee Seeds, 2015), golden ball zucchini ‘One Ball’, and pale ball zucchini ‘Cue Ball’ (Hollar Seeds, 2015; Zhang, 2002). However, some ball squash cultivars have fallen from favor because they are susceptible to powdery mildew (PM) and/or viruses, or they have a fruit with a large blossom scar which is subject to tip rot during transportation and/or storage, or they fail to satisfy commercial production standards in productivity, fruit color uniformity, and harvest convenience. In an effort to enhance the existing cultivars, we developed the new ball summer squash series ‘One Ball^{Plus}’, ‘Six Ball’, ‘Eight Ball^{Plus}’, and ‘Cue Ball^{Plus}’ that combines all of the desirable characteristics of the existing ball squashes, plus powdery mildew (*Sphaerotheca fuliginea*; *Erysiphe cichoraceaeum*) resistance (PMR), a small blossom scar, and one or two other important traits such as *Zucchini yellow mosaic virus* (ZYMV) resistance, *Watermelon mosaic virus* (WMV) resistance, prolificacy, a long peduncle, and a consumer-preferred color.

Origin

The development of the new ball summer squash series started with transferring virus and PM resistance to the selected parent lines of ‘One Ball’, ‘Eight Ball’, and ‘Cue Ball’ from the Hollar summer squash germplasm ‘PMR3112’ in 2008, which is a middle eastern pale summer squash with ZYMV, WMV, and PM resistance. At the same time, a gray color was transferred to the existing ball lines from the gray zucchini ‘Orion’ for the development of a gray ball as the fourth new cultivar in the Hollar ball summer squash novelties. During the breeding process, three conventional breeding methods, pedigree, backcross, and half-sib selection, were adopted. With the aforesaid three breeding methods, prolificacy, a long peduncle, and a small blossom scar were recombined into the new breeding families and lines as the disease-resistance screenings were performed. The germplasm used for the targeted traits was the Hollar breeding line ‘Prolific Gold’. Fruit colors were also readjusted through the genetic recombination and plant selections based on the degree of their expression in hybrids. Selection proceeded three generations per year and continued for eight generations until the two best lines in each of the four color categories were selected, alternating between the greenhouse and field of Hollar Seeds. Among the selected lines, six of them, (3112PMRxCueBallFxGold)BC₁F₂₂-1-2-1-1, (3112PMRxCueBallMxGold)BC₁₄F₃₂-1-1-1, (3112PMRxOneBall)BC₁₁Sib₁-4-1-1-1, (Gryx3112PMRxGoldBall)F₄₄-3-3-1-1, (3112PMRxStrpGBallxGoldBall)BC₁₄Sib₂-2-1-1-1, and (3112PMRxStrpGBallxGoldBall)BC₁₁-3-1-2-1-1, performed the best on their overall expression in early-generation crosses which were tested by early generation evaluation trials with an augmented completely randomized design in the summers of 2011 and 2012. During the early generation evaluations, two promising crosses in each color category were picked out as future cultivar candidates, which derived from the inbreds based on a dominant/recessive relationship between certain fruit colors. At the same time, the selected crosses were also sent to Hollar’s distributors in France, Italy, and Mexico for commercial tests. With the existing cultivars as comparisons, the newly selected F₁ candidates were further tested with a completely randomized block design with two blocks and two replications, each of which consisted of

30 plants in a small plot (15.00 m × 1.15 m). The trials were conducted on the Hollar trial ground in southern Colorado in the 2013–15 growing seasons. The first picking started around 35 d after planting when more than 80% of the cultivars were bearing marketable fruit. The first five harvests were recorded for yield evaluation. The virus resistance was tested by inoculating the seedlings at a cotyledon stage in greenhouses and PMR was evaluated after midseason when PM occurred in both the greenhouses and fields. An evaluation system that awards a higher score for a higher resistance was adopted for commercial convenience, in contrast with the system that awards a higher score for a lower resistance (Cavatorta et al., 2012; Zhang, 2013). The PM and virus resistance were divided into six scores or levels thereof comprised of 0, 1, 2, 3, 4, 5, in which 0 indicates that the plants were 100% infected and susceptible, and 5 indicates that the plants were highly resistant and had no symptoms of the diseases on them. One score increase is equivalent to an increase of 20% uninfected area on a leaf and a stem. According to the results of the 3-year tests and commercial feedback, four crosses superior to the existing cultivars were selected and first assigned the Hollar research numbers ‘HSR4750’, ‘HSR4765’, ‘HSR4760’, and ‘HSR4767’, then named and released as F₁ hybrids ‘Eight Ball^{Plus}’, ‘Six Ball’, ‘Cue Ball^{Plus}’, and ‘One Ball^{Plus}’ (Figs. 1A–4A), respectively.

Description and Performance

‘Eight Ball^{Plus}’, ‘Six Ball’, ‘Cue Ball^{Plus}’, and ‘One Ball^{Plus}’ have vigorous bush plants with a single central stem, an erect and open habit that is identified by the average degree of an upward angle (>45° and ≤90°) between a petiole and the stem bearing it, measured at an adult leaf stage of 10–15 d. This particular feature allows for easy picking and convenient control of pests and diseases. Another striking feature of the cultivars is their continuous and concentrated fruit setting, with three to five fruits per harvest date. The fruit are usually harvested at an immature stage of 3–5 d after blooming, which starts in ≈30–35 d after sowing. Each weighs around 150 to 200 g and has a diameter of ≈5–10 cm, depending on locally preferred fruit sizes for consumption. When the fruit of ‘Eight Ball^{Plus}’, ‘Six Ball’, ‘Cue Ball^{Plus}’, and ‘One Ball^{Plus}’ are harvested in their marketable sizes, the colors are dark green, gray, pale green, and gold, respectively, which correspond with each of their namesake billiard balls, as set forth below in comparison with the Royal Horticultural Society Color Chart [Royal Horticultural Society (RHS), 1986] (Figs. 1–4; Table 1). The cultivars are suitable for planting inside and outside with the routine growing practice typically used for a common zucchini. The first picking is in ≈30–40 d after sowing, in accordance with growing conditions where the cultivars are planted. With the erect and open plant structure, a continuous and concentrative

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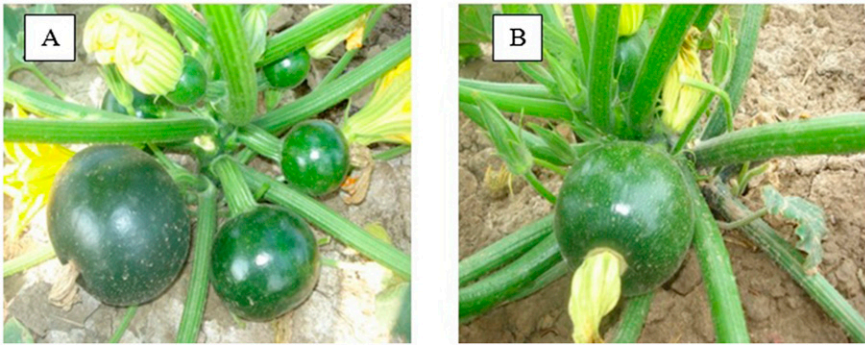


Fig. 1. Dark green ball squashes. (A) 'Eight Ball^{Plus}' plant with prolificacy and fruits with long peduncles and small scars and (B) plant and fruits of 'Eight Ball' as a comparison.

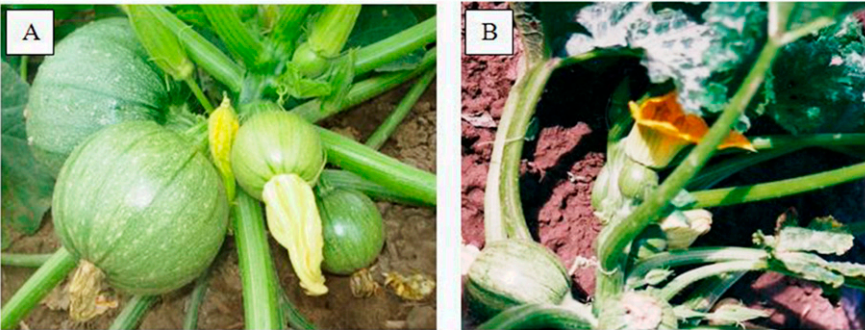


Fig. 2. Gray ball squashes. (A) 'Six Ball' plant with prolificacy and fruits with a gray color and medium-sized scar and (B) plant of 'Ronde De Nice' with green-mottled gray fruits as a comparison.

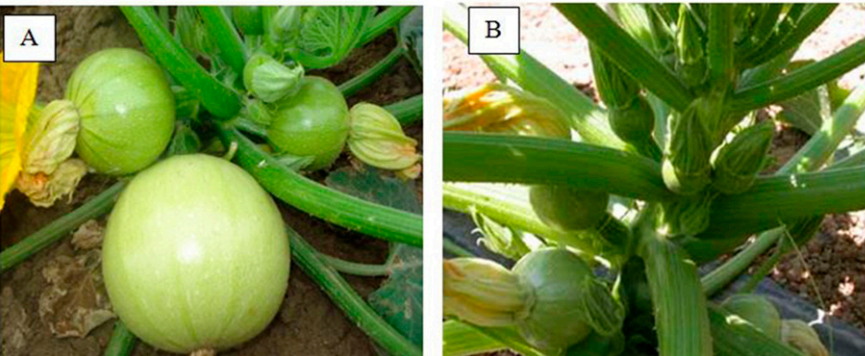


Fig. 3. Pale-green ball squashes. (A) 'Cue Ball^{Plus}' plant with prolificacy and fruits with a pale-green color and small scar and (B) plant and fruits of 'Cue Ball' with a pale color and medium-large scar as a comparison.



Fig. 4. Golden ball squashes. (A) 'One Ball^{Plus}' plant with prolificacy and fruits with a uniform golden color and small scar and (B) plant and fruits of 'One Ball' with a green tip and medium-sized blossom scar as a comparison.

fruit setting, and colorful fruits, the four cultivars as a group are unique summer squashes for the vegetable industry and exceptional as ornamentals for gardening.

'Eight Ball^{Plus}'. This cultivar has the fruit color of dark green (RHS Green141B) (Fig. 1A; Table 1). The fruit have a peduncle that is 5 to 8 cm long, which not only makes fruit picking convenient, but also reduces the possibility of scratching fruit damage during harvests (Fig. 1A). 'Eight Ball^{Plus}' highly resists ZYMV, WMV, and PM diseases. The aforementioned highly advantageous resistance on the part of 'Eight Ball^{Plus}' are absent from 'Eight Ball' and 'Ronde De Nice' (Table 1). Experiments in Colorado, United States, indicated that 'Eight Ball^{Plus}' had a significantly greater yield, up to 49% higher, and a significantly smaller blossom scar, up to 88% smaller, than 'Eight Ball' (Fig. 1; Table 1). The 'Eight Ball^{Plus}' fruit are edible in ≈ 30 d after sowing, which are 5 to 10 d earlier than 'Eight Ball'.

'Six Ball'. The primary difference between 'Six Ball' and the commercial gray 'Ronde De Nice' is its plant habit (Fig. 2A and B). 'Six Ball' has a strong single central stem with upright-open habit, and 'Ronde De Nice' has multiple branches with a close habit that has the degree of an upward angle ($<30^\circ$) between a petiole and the stem bearing it, which causes more scratch damage on fruit, uneasy picking, and inconvenient control of pests and diseases. 'Six Ball' has PMR, and highly resists ZYMV and WMV. Six Ball produced a significantly larger tonnage of fruit than 'Ronde De Nice' in successive experiments at Hollar (Table 1). The fruit of 'Six Ball' are round in shape with a medium-long peduncle and medium-sized blossom scar, which is significantly smaller than all of the existing cultivars. The fruit color of 'Six Ball' is gray (RHS Grayed-Green192A) (Fig. 2; Table 1). Like Eight Ball^{Plus}, Six Ball is also an early cultivar that is ≈ 10 d earlier than 'Ronde De Nice'.

'Cue Ball^{Plus}'. 'Cue Ball^{Plus}' (Fig. 3A) is identified by its pale-green fruit color (RHS Grayed-Green193B) in comparison with 'Cue Ball' (RHS Grayed-Green193D) (Fig. 3B). The fruit of 'Cue Ball^{Plus}' have a medium-long peduncle and round shape. Although the yield of 'Cue Ball^{Plus}' is not different from 'Cue Ball', the PM, ZYMV, and WMV resistance are significantly higher, and the blossom scar size is significantly smaller. In observing the plant structure, 'Cue Ball^{Plus}' has a stronger bush than 'Cue Ball' (Fig. 3; Table 1). Both bloom in ≈ 30 –35 d from a planting date.

'One Ball^{Plus}'. This cultivar has novel fruit with a uniform golden color (RHS Yellow-Orange 17B) (Fig. 4A), as differentiated from 'One Ball' that occasionally has undesirable green tips (RSH Green141B) (Fig. 4B). Three years of replicated trials found no differences in yield, or ZYMV and WMV resistance between 'One Ball^{Plus}' and 'One Ball'. Nevertheless, the moderate PM resistance and significant smaller blossom scars of 'One Ball^{Plus}' are great advantages over 'One Ball' (Fig. 4; Table 1). As far as earliness is concerned, both One Ball^{Plus} and

Table 1. Plant and fruit characteristics for ‘Eight Ball^{Plus}’, ‘Six Ball’, ‘Cue Ball^{Plus}’, ‘One Ball^{Plus}’ and the existing ball squashes compared over the years 2013–15.

Cultivar	Fruit color ^z	Scar size ^y (cm ²)	Yield ^x (t ha ⁻¹)	PMR level ^w	ZYMV/WMV resistance ^v
Eight Ball ^{Plus}	Dark Green (Green141B)	0.82 d ^u	32.00 a	4.78 a	5.0
Eight Ball	Dark Green (Green139B)	6.65 a	16.43 c	0.00 d	0.0
Six Ball	Gray (Grayed-Green192A)	1.58 c	28.86 ab	3.96 b	4.0
Ronde De Nice	Gray (Grayed-Green192C)	6.71 a	15.96 c	0.00 d	0.0
One Ball ^{Plus}	Gold (Yellow-Orange17B)	1.13 d	28.71 ab	3.73 c	5.0
One Ball	Gold (Yellow-Orange17B)/Green (Green141B) ^t	2.60 b	27.16 b	0.00 d	4.0
Cue Ball ^{Plus}	Pale Green (Grayed-Green193B)	1.00 d	26.69 b	3.80 bc	5.0
Cue Ball	Pale Green (Grayed-Green193D)	2.75 b	26.39 b	0.00 d	3.0

^zFruit color is distinguished by the Royal Horticultural Society (RHS) Color Chart (1986).

^yBlossom scar size is the mean of the scar area of 30 fruits from each of two replications over 3 years.

^xYield is the average yield/hectare of marketable-sized fruits of the first five pickings from each of two replications over 3 years, which was calculated from conversion of yield per plot = 0.17/100 yield per hectare base.

^wPMR (powdery mildew resistance) level is the mean of PMR scores of 30 plants from each of two replications over 3 years. PMR was scored in six levels, in which per score increase is equivalent to the incremental value of 20% uninfected area on a leaf and a stem, and 0 = susceptible, 1–3 = moderately resistant, and 4–5 = highly resistant.

^vZYMV (*Zucchini yellow mosaic virus*)/WMV (*Watermelon mosaic virus*) resistance were scored in 6 levels, in which 0 = susceptible, 1, 2, 3 = moderately resistant, and 4, 5 = highly resistant.

^uMeans in a column not followed by the same letter are significantly different at $P \leq 0.05$ by Duncan’s multiple range test.

^tGolden fruit with a green tip.

One Ball are early cultivars that have the first picking in ≈ 30 d after sowing.

Availability

‘Eight Ball^{Plus}’, ‘Six Ball’, ‘Cue Ball^{Plus}’, and ‘One Ball^{Plus}’ are being offered by Hollar Seeds to commercial distributors. For requests of a small sample of seed, the seed is available

from Hollar Seeds, P.O. Box 106, Rocky Ford, CO 81067 (<http://www.hollarseeds.com/>).

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