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Skin Color, Scab Sensitivity and Field Performance of Lines Derived from Spontaneous Chimeras of Red Norland Potato

Doug Waterer · Hanny Elsadr · Mary-Lee McArthur

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Abstract On the Canadian prairies consumers favor red-skinned potatoes (*Solanum tuberosum*), with Red Norland representing the most widely grown red-skinned cultivar. However, the skin color of Red Norland is not as red as desired, particularly after extended storage. In 2004 three Red Norland tubers which appeared to have zones of darker skin color were discovered. Plants were grown from sprouts taken from both the light and dark colored zones of these tubers. The change in skin color was stable through several generations of vegetative propagation; otherwise the plants and tubers were comparable to Red Norland. This suggests that the color change was due to a chimeral mutation in the epidermis. In field trials conducted in 2005 and 2006 over 30 lines derived from the chimeral tubers were assessed for skin color, yields, tuber conformation and sensitivity to common (*Streptomyces scabies)* and powdery scab (*Spongospora subterranea*). Lines with acceptable yield and tuber configuration as well as enhanced scab resistance and/or superior red skin color were evaluated in replicated trials conducted from 2007 to 2009. Several lines were identified that had superior red skin color relative to Red Norland, while other lines appeared more resistant to common scab than Red Norland. Yield potential of the selected lines was comparable to Red Norland and when adjusted for grade out due to excessive common scab, yields of several of the chimeral lines were superior to Red Norland. This study suggests that chimeras may represent a method for rapid, low cost improvement of skin color and common scab resistance of potato, while maintaining desirable agronomic characteristics.

D. Waterer (✉) · H. Elsadr · M.-L. McArthur
Department of Plant Sciences, University of Saskatchewan,
51 Campus Rd,
Saskatoon, SK S7N-5A8, Canada
e-mail: doug.waterer@usask.ca

Resumen En las praderas canadienses, los consumidores favorecen las papas rojas (*Solanum tuberosum*), con Red Norland representando a la variedad de piel roja más ampliamente sembrada. No obstante, el color de la piel de Red Norland no es tan rojo como se quisiera, particularmente después de un almacenamiento prolongado. En 2004 se descubrieron tres tubérculos de Red Norland que parecían tener zonas de un color de piel más oscuro. Se cultivaron plantas desde brotes tomados de ambas zonas de estos tubérculos, la del color ligero y la del oscuro. El cambio en el color de la piel fue estable a lo largo de varias generaciones de propagación vegetativa; de manera que las plantas y los tubérculos fueron comparables a Red Norland. Esto sugiere que el cambio de color fue debido a una mutación quimérica en la epidermis. En ensayos de campo conducidos en 2005 y 2006 se evaluaron más de 30 líneas derivadas de los tubérculos quiméricos para color de piel, rendimiento, conformación de tubérculo y susceptibilidad a la roña común (*Streptomyces scabies*) y a la roña polvorienta (*Spongospora subterránea*). Se evaluaron líneas con rendimiento aceptable y configuración de tubérculo, así como con aumento en resistencia a la roña y/o con color de cáscara roja superior, en ensayos con repeticiones conducidos en 2007–2009. Se identificaron varias líneas que tuvieron color de piel roja superior en relación a Red Norland. Varias de estas nuevas líneas también parecieron más resistentes a la roña común que Red Norland. El potencial de rendimiento de las líneas selectas fue comparable al de Red Norland y cuando se ajustaron para la clasificación debido a la excesiva roña común, los rendimientos de varias de las líneas quimerales fueron superiores a Red Norland. Este estudio sugiere que las quimeras pudieran representar un método para el mejoramiento rápido, de bajo costo, del color de la piel y resistencia a la roña común de la papa, mientras que se mantienen las características agronómicas deseables.

Keywords *Solanum tuberosum* · *Streptomyces scabies* · *Spongospora subterranea*

Introduction

Skin color is important in consumer acceptance of fresh market potatoes. Potatoes are available in a wide range of skin colors, with white, red and buff being predominant in different areas of North America. On the Canadian prairies, consumers favor red-skinned potatoes and growers consequently strive to create and maintain red skin color during production, storage and marketing.

'Red Norland' is the dominant red-skinned cultivar grown on the Canadian prairies. Red Norland is early maturing and produces moderately high yields of tubers with an acceptable red skin color. However, the skin color of Red Norland tends to fade during storage (CFIA 2010). Red Norland originated as a darker red line selection from Norland (CFIA 2010). Subsequent line selections have been developed from Red Norland that purport to have still better skin color (Dark Red Norland, New Red Norland, Super Red Norland, Red Norland Strain 72) (CFIA 2010) however, their color, yields or tuber configuration tend to vary with the year and production practices (Waterer 2009a). For example, in 15 years of demonstration trials conducted by the University of Saskatchewan, Dark Red (DR) Norland had a darker skin color than Red Norland in most years, but its color seemed more variable both from tuber to tuber and across the surface of each tuber (Waterer unpublished). Red Norland is only moderately resistant to common scab (*Streptomyces scabies*) or powdery scab (*Spongospora subterranea*) (CFIA 2010; Waterer 2009b). While crop growth and yields are generally unaffected by either type of scab, the presence of scab lesions on the surface of potatoes reduces market acceptance. Once either type of scab has been introduced into a field there are no practical means to rid the area of the problem.

Chimeras are genetic mosaics, with a single organism or parts of the organism containing two or more genetically different types of tissues (Norris et al. 1983). In plants, chimeras commonly form as a result of naturally occurring or induced mutations in the meristems (Klekowski et al. 1985; Marcotrigiano and Gradziel 1997). The chimeral meristematic cells multiply forming layers or sections of genotypically variable tissue. The most easily detected chimeras are those that cause an obvious change in the phenotype such as variegation in plant organs (Tilney-Basset 1986) or loss of thorns (Canli 2003). More difficult to detect are chimeras that lead to physiological changes such as altered biochemical composition (Dermen 1948). By employing vegetative propagation techniques, tissues isolated from chimeral sections of a plant can be used to generate new plants that are genotypically uniform and identical to the initially mutated cells (Howard 1970). If the chimera confers some advantage, this may represent an efficient avenue for plant improvement, particularly when the beneficial change occurs within an already adapted and established cultivar (Miller 1954).

In 2004, three Red Norland potatoes, chimeral for skin color, were discovered in research plots managed by the University of Saskatchewan (Fig. 1). These potatoes contained sections of dark skin and lighter skin; a characteristic indicative of a mericlinal or sectoral chimera. The darker areas of the chimera tubers appeared to be redder than Red Norland and these zones also appeared to have fewer scab lesions compared to the lighter areas or standard Red Norland tubers.

This study sought to determine if lines comparable to Red Norland in field performance and quality but with superior red skin color and enhanced scab resistance could be developed from these chimeras.

Materials and Methods

Line Development

Sprouts developing from buds located in the dark (D) and light (L) sections of the three original chimeral potatoes were excised and grown out in pots in a greenhouse during the winter of 2005/2006. While the differences in skin color were still apparent in most the resulting lines, many were low yielding or produced a high incidence of off-shaped tubers and/or skin color chimeras. These lines were discarded. In non-replicated field trials conducted in 2005 and 2006, the remaining lines were again evaluated for skin

Fig. 1 Chimera for skin color in Red Norland

color, tuber conformation, yield potential and scab reaction, with further selection occurring in each year.

Field Assessment

In 2007, 2008 and 2009 the selected lines were grown out in field trials that also included standard Red Norland and Dark Red (DR) Norland for comparison purposes (Rockyview Elite Tuber Ltd., Keoma, AB). The trials were conducted at two field sites managed by the Potato Research Program of the University of Saskatchewan in Saskatoon Saskatchewan.

Field #1 featured a sandy loam soil, pH 7.2, EC<1 dS, with 4% organic matter. This site is relatively free of both common and powdery scab and was therefore suited for unbiased evaluation of skin color. Nitrogen, as 46-0-0, was broadcast prior to planting to bring the total soil nitrogen level (residual + applied) to 175 kg/ha. Potatoes were planted in mid-May with 25 cm between seed pieces within the row and 1 m between rows. Each line was planted in a single 4 m long row. Sufficient phosphorus (11-55-0) was applied in a band adjacent to the seed to raise soil P_2O_5 levels to 120 kg/ha. Weed control was achieved utilizing pre-plant application of the herbicide EPTC and post-plant application of linuron. A rolling cultivator was used after ground crack and again 2 weeks later to form hills. Soil moisture levels were monitored in the plots using electric resistance meters. The plots were irrigated whenever soil water potentials at 20 cm depth fell below −60 kPa. No significant problems with insects or disease were observed and the plots received no pesticides beyond those already described. In late August the vines were flailed and then desiccated with diquat. The crop was harvested 3 weeks later. The harvested tubers were cured in a dark 15°C storage for 2 weeks and then shifted to a 4°C storage.

Six weeks after harvest 20 tubers randomly selected from each line grown in Field #1 were washed and then evaluated for skin color using a Hunter Lab colorimeter. The colorimeter was used to measure the CIE **L**, **a**, **b** and **a/b** (hue angle) values at two locations on for each tuber. The **L*a*b** space describes colors by their position along three axes in 3D color space. The **L** axis represents the lightness or brightness of the image and is a measurement of the white-to-black content of any color. **L** values run from 0 (all black) to 100 (all white). The **a** axis runs from red to green with a range from −128 (green) to 127 (red). The **b** axis runs from yellow to blue with a range from −128 (blue) to 127 (yellow). **Hue angle** values measure the ratio of red-green hues against yellow-blue hues. The potatoes were also visually evaluated by a panel of trained observers who rated the tuber skin color as 'superior', 'equal' or 'inferior' to Red Norland and Dark Red Norland grown in the same plot.

Field #2 featured a sandy loam soil, pH 7.6, EC<1.1 dS, with 6% organic matter. However, Field #2 has a long history of potato production and harbors high levels of both common and powdery scab. The plots in Field #2 were mechanically planted in early May in a randomized compete block design with three replicates in 2007 and four replicates in 2008 and 2009. Each row was 8 m long. All other aspects of the plot and crop management practices were identical to those presented for Field #1. Potatoes harvested from Field #2 were used for scab and yield analyses. After curing, the crop was graded according to size, counted and weighed. Specific gravities were determined using the weight in air/weight in water method.

Six weeks after harvest, 15 tubers randomly selected from each replicate of each line were washed and then visually rated for scab. Detection of spore balls was used to differentiate lesions caused by powdery scab from similar appearing lesions caused by common scab. Some lines produced a significant number of tubers with light and dark areas of skin. Although these lines would have limited market potential they did provide an opportunity to study the relationship between skin color and scab sensitivity Separate scab readings were taken on the darker and lighter sections of the skin on these tubers. For the purpose of calculating marketable yields, tubers were considered to be unmarketable if the skin color was non-uniform or if >5% of the tuber surface was affected by either type of scab (USDA 2010).

Yield, color and disease data were analyzed using PROC MIXED of the Statistical Analysis System (SAS 2003) with years and lines as fixed effects and replicates as random effects. Single degree of freedom contrasts were used to compare the new lines against Red Norland. All percentage data were normalized by arcsine square root transformation and then back-transformed for presentation. Kruskal-Wallis tests were used to analyze ranked data.

Results and Discussion

Color Analysis

Based on visual assessments, many of the lines derived from the chimeras tended to produce tubers that were also chimeral for skin color (Fig. 2). As uniformity of skin color is expected in the marketplace these lines were dropped. However, the uniformity of skin color of four of the lines derived from the chimeras (1–9D, 2–9D, 2–11D and 3–8D) was rated as equal or superior to Red Norland (Fig. 2). It is noteworthy that in both Red Norland (8%) and Dark Red Norland (18%), a significant proportion of the tubers showed enough color variability to merit those tubers being graded out. The higher level of grade out to color instability

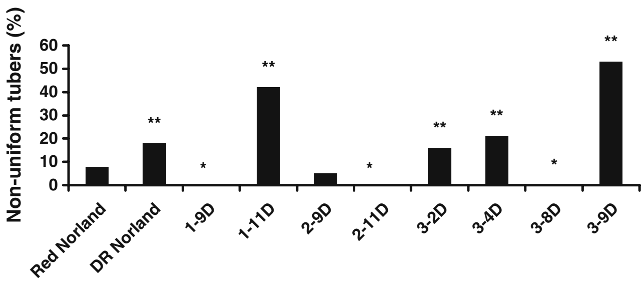

Fig. 2 Proportion of the tubers showing non-uniform skin color for established Red Norland lines and news lines derived from chimeras of Red Norland—2007 trial. *, ** indicate that the value is significantly different from Red Norland at $P=0.05$ or 0.01, respectively

in Dark Red Norland corresponds with previous experience with this line selection.

Based on the opinions of the trained observers, the skin color of several of the new lines derived from the dark-skinned areas of chimeral Red Norland potatoes was rated as 'superior' to the tubers from standard Red Norland tubers (data not shown). The skin color of the lines derived from the light zones of the chimeras was rated as either 'equal' to or 'inferior' to standard Red Norland.

As this type of color assessment is quite subjective, a colorimeter was also used to provide an objective measurement of skin color. The CIE **L** values were significantly influenced by the year, the line and the interaction between year and line. The **L** values in 2007 were significantly higher (lighter) on average than in 2008 or 2009 (Fig. 3a). In the 2007 and 2008 trials, the **L** values for the selected new lines were lower (darker) than standard Red Norland, but comparable to Dark Red Norland. In the 2009 trial the **L** values for line 1–9D were significantly lower than for all other lines and was also lower than for that line in previous years.

The CIE **a** values, which reflect the relative amount of red-green in the skin, were influenced by the year but not by the line tested (Fig. 3b). This was unexpected, given the apparent difference in the depth of red color in the skin of the various lines. The **a** values in 2009 were lower than in previous years. Low **a** values suggest a greater preponderance of green relative to red in the skin color in 2009.

The CIE **b** values, which reflect the relative amount of blue:yellow were influenced by the year, the line and the interaction between year and line (Fig. 3c). The **b** values in 2007 were much higher (more yellow) than in 2008 or 2009. In all 3 years of testing the new dark skinned chimeral lines had lower **b** values (more blue) than standard Red Norland, but were comparable to Dark Red Norland. In the 2009 trial, line 1–9D had much lower **b** values than in previous years.

In all 3 years the new dark skinned lines tended to have a lower **hue angle** ratio than standard Red Norland, but were usually comparable to Dark Red Norland (Fig. 3d). A low hue angle indicates a greater preponderance of red and blue in the chroma rather than greens and yellows. As a mixture of red and blue pigments appear purple, it is possible that the 'superior' color rating for the new lines in the visual assessments is due to these lines appearing more purple, rather than red. This is consistent with other studies of the

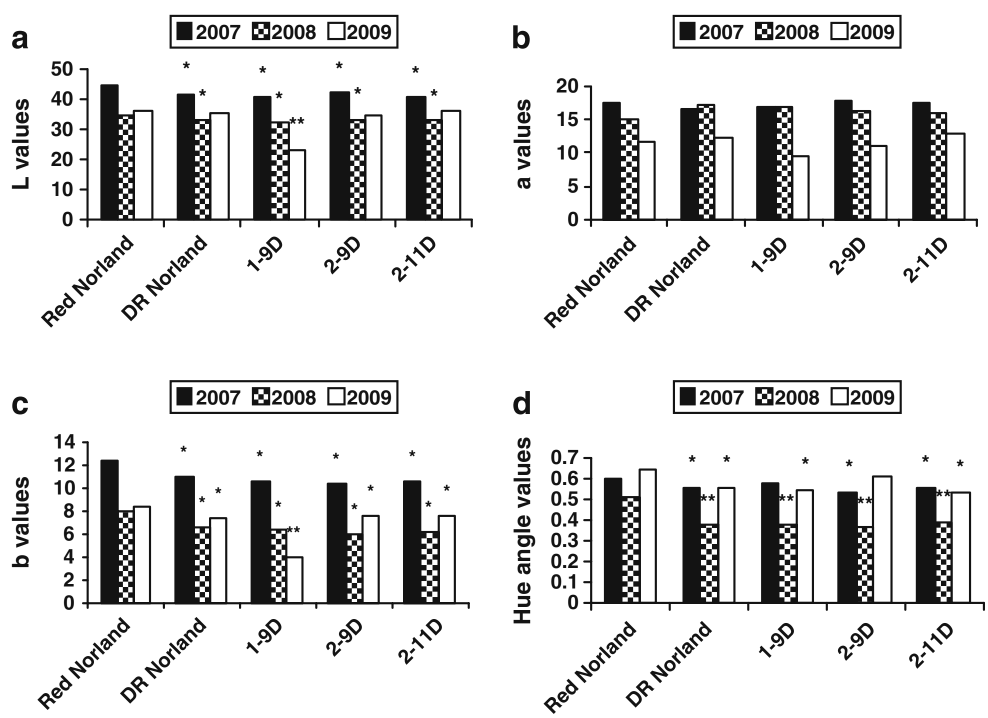

Fig. 3 CIE L, a, b and hue angle values (arctan b/a) in 2007, 2008 and 2009 for established Red Norland lines and for new lines derived from chimeras of Red Norland . *, ** indicate that the value is significantly different from Red Norland at $P=0.05$ or 0.01, respectively

skin color in Red Norland which indicate that this cultivar tends to accumulate purple anthocyanins such as peonidin glycosides when under stress (Rosen et al. 2009).

Scab Analysis

2007 trial As the period of tuber set and early development in 2007 was unusually warm, common scab was far more prevalent than powdery scab and all scab ratings in the 2007 trial refer to common scab. Many of the lines tested in 2007 produced a significant number of tubers that were chimeral for skin color (ie; both light and dark red areas). Tubers that were non-uniform for skin color had differing scab ratings depending on the area of the skin surface being observed. In some, but not all cases, less common scab was found on the darker red-skinned areas compared to the lighter colored areas (Fig. 4).

Based on scab ratings taken from tubers with uniform color in the 2007 trial, several of the lines derived from dark areas on the original chimeral tubers appeared to be more tolerant of common scab than standard Red Norland (Fig. 5).

2008 and 2009 trials Only lines that had shown good yield potential and a high proportion of tubers expressing superior red skin color in the 2007 trial were tested in 2008 and 2009. Cool conditions in 2008 and 2009 meant that there was a more even balance between common and powdery scab on the infected tubers. Intensity of infection by both types of scab was exceptionally high in 2009.

Based on the data from the 2008 and 2009 trials, there again appeared to be significant variability between the various Norland lines in terms of their scab sensitivity (Fig. 6). The chimeral lines 2–11D, and to lesser extent line 1–9D, appeared to be less susceptible to common scab than standard Red Norland. Susceptibility of the new lines to powdery scab was not consistently different from standard Red Norland.

The data suggests a potential relationship between the intensity of skin color and resistance to common scab. This concept is supported by our findings that application of low dosages of the plant growth regulator 2,4-D to both Red Norland and Peregrine Red plants at tuber set appeared to intensify the red skin color, while also reducing grade-out due to common scab (Waterer 2010). However, the apparent correlation between skin color and scab resistance is not absolute, as Peregrine Red has a darker red skin color

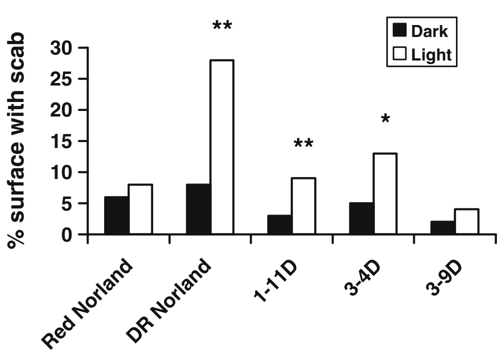

Fig. 4 Common scab rating on dark and light red sections of tubers with non-uniform skin color derived from established Red Norland lines and new lines derived from chimeras of Red Norland—2007 trial. *, ** indicate that the value is significantly different from Red Norland at $P=0.05$ or 0.01, respectively

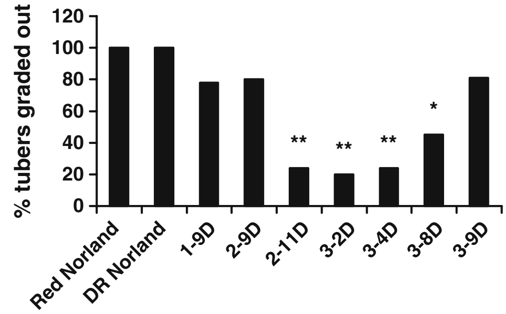

Fig. 5 Percent grade-out due to excessive common scab for established lines of Red Norland and new lines derived from chimeras of Red Norland—2007 trial. *, ** indicate that the value is significantly different from Red Norland at $P=0.05$ or 0.01, respectively

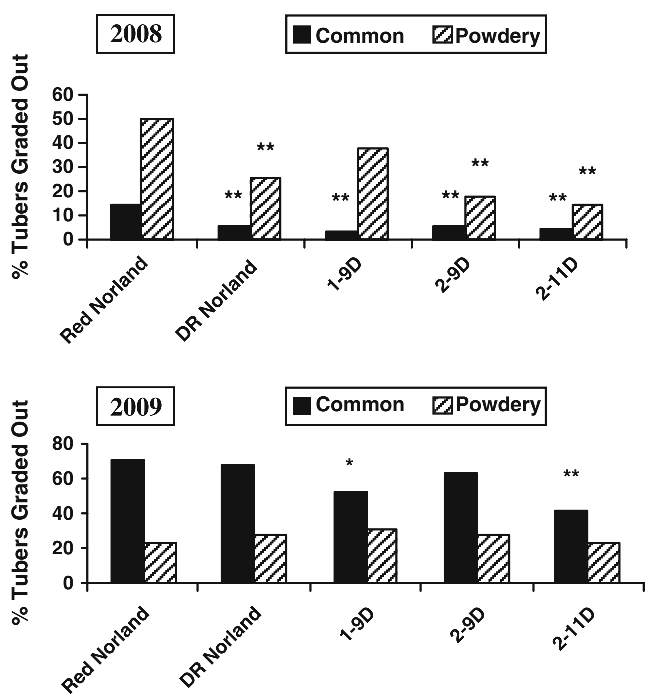

Fig. 6 Percent grade-out due to excessive levels of common and powdery scab for established lines of Red Norland and new lines derived from chimeras of Red Norland in 2008 and 2009. *, ** indicate that the value is significantly different from Red Norland at $P=0.05$ or 0.01, respectively

than Red Norland, yet it is much more sensitive to both types of scab (Waterer 2010).

There are several potential explanations for the apparent positive relationship between dark skin color and common scab resistance in Red Norland. The genes controlling skin color may not be the same genes controlling common scab resistance, but they may be closely linked. A second possibility is that dark skin color reflects the accumulation of compounds which also confer a degree of resistance to common scab. Scab control via biochemical pathways might involve: (i) the production of compounds that slow infection by and/or development of *S. scabies*, (ii) darker skin color may also be associated with thickening of the pigmented layers of the skin. A thick skin may represent a physical barrier to development of *S. scabies* lesions (Kawchuk 2007 pers. comm.).

Yield Analysis

There were no significant differences in tuber size distribution, tuber conformation or tuber specific gravity between the established Norland lines and the lines derived from the chimeras in any of the yield trials conducted from 2007 to 2009 (data not shown).

2007 trial Standard Red Norland produced a greater yield than Dark Red Norland or any of the chimera line selections (Fig. 7a). This was unexpected, as multi-year trials indicate little yield difference between standard Red Norland and Dark Red Norland (Waterer 2009a,b). However, after grade out due to excessive common scab (>5% of tuber surface affected) standard Red Norland had effectively no marketable yield in the 2007 trial (Fig. 7a). The same applied to the Dark Red Norland. By contrast, several of the new lines derived from the dark skinned area of the Red Norland chimeras produced a relatively high percentage of marketable tubers, even under the extreme common scab pressure present at this site.

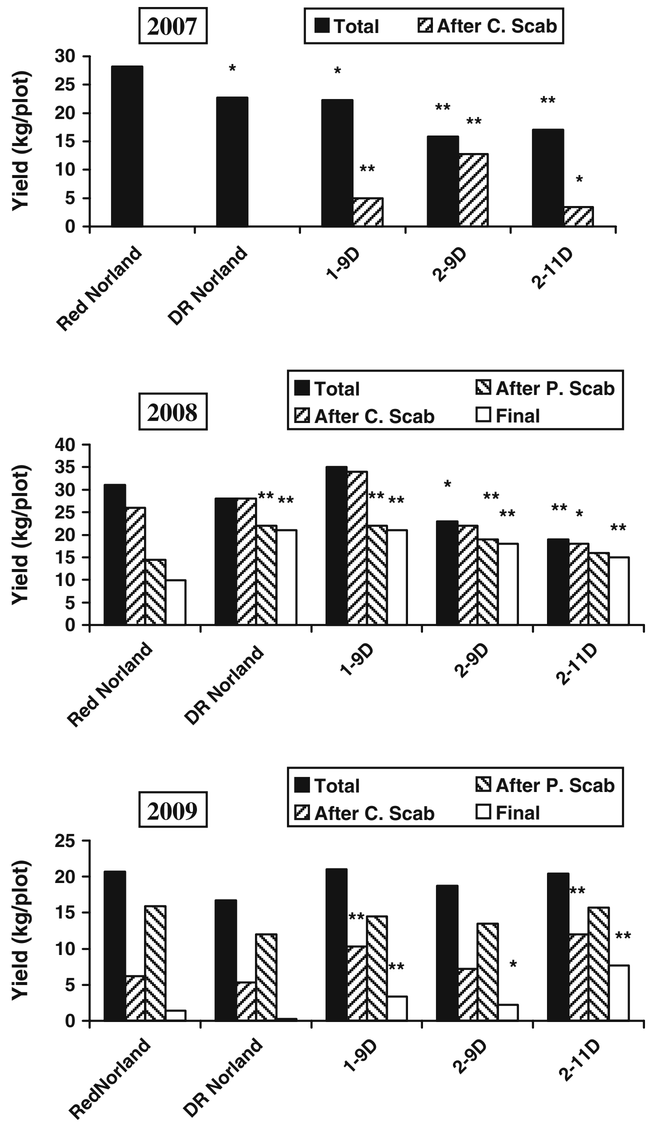

Fig. 7 Total yield and yield after grade out to excessive levels of common and powdery scab in 2007, 2008 and 2009 for established Red Norland lines and for new lines derived from chimeras of Red Norland . *, ** indicate that the value is significantly different from Red Norland at P=0.05 or 0.01, respectively

2008 trial Only lines that had shown good yield potential and a high proportion of tubers expressing superior red skin color in the 2007 trial were included in the 2008 and 2009 yield trials. Total yields of the 1–9D and 2–9D chimera lines in 2008 were statistically equivalent to Red Norland and Dark Red Norland (Fig. 7b). After grade out to excessive levels of both common and powdery scab, standard Red Norland had the lowest marketable yield of any of the lines tested (Fig. 7b). Dark Red Norland and line 1–9D had the highest marketable yields—reflecting the combination of good overall yield potential coupled with some level of reduction of grade-out due to common and powdery scab. Although the 2–9D and 2–11D lines had superior levels of scab resistance, their overall yields were relatively poor in the 2008 trial and this reduced their marketable yield after grade-out due to scab.

2009 trial There were no statistically significant differences between the total yields of any of the chimera lines versus standard Red Norland or Dark Red Norland in 2009 (Fig. 7c). Levels of grade out due to both types of scab were much higher in 2009 than in previous years. Virtually all of the tubers produced by both Red and Dark Red Norland were graded out due to excessive scab. Although grade out to common and powdery scab was still extremely high, all three of the selected chimera lines had greater yields of marketable tubers than the standard lines of Norland in 2009.

Line Assessment

The objective of this project was to determine if Red Norland lines with superior skin color and scab resistance could be created from chimeras. To be widely accepted by the growers, these lines will need to be comparable or superior to Red Norland in agronomic performance and market appeal under a wide range of production conditions, including situations where scab pressure is light. To evaluate the relative merit of the lines a rank analysis (1= highest to 5=lowest) was conducted for the data collected in 2007, 2008 and 2009 utilizing yields and skin color as quality determinants (Table 1). Resistance to both types of scab was included in a separate analysis. In these analyses, all characteristics were given an equal weighting. Skin colors were evaluated based on the CIE **b** values as this parameter allowed the greatest differentiation amongst the lines.

Based on the pooled rankings for the 3 years of study, each of the three selected lines derived from the chimera tubers was superior for one trait. Line 1–9D had the greatest yield potential, line 2–9D had the best skin color and 2–11D was most tolerant of scab. In situations where scab is a concern, all three lines developed from the chimera were superior to both standard Red and Dark Red Norland. In fields where scab was not a concern, line 1–9D still provided a combination of yield potential and skin color that was superior to standard Red and Dark Red Norland.

Applying an equal weighting to yields, tuber color and freedom from scab may underestimate the importance of yields to the grower. However, in table potatoes, appearance factors such as color and freedom from defects like scab are paramount in determining market value. While the scab pressure experienced in this test was far in excess of that found in typical commercial potato fields, it should nonetheless provide a useful indication of anticipated scab reactions in less severely infected fields.

Conclusion

Improvement of potatoes through conventional breeding methods is complicated by the complexity of the potato genome, restrictions in compatibility within wide crosses, plus rigid industry expectations in terms of agronomic performance and quality. Naturally occurring or induced mutations can be used in breeding programs if the mutations are stable and beneficial. Use of mutation breeding is particularly beneficial in situations where genetic diversity is limited for the desired trait or where introduction of the trait is made difficult due to crossing restrictions or complex patterns of inheritance. The russetted skin characteristic of Russet Burbank potatoes was widely held to represent a spontaneous L_1 periclinal chimera that arose in a smooth skinned Burbank plant (Miller 1954). However, Nassar et al. (2008) have recently used somatic embryogenesis techniques to show Russet Burbank is more likely a seedling than a chimera.

In this study, new lines of the potato cultivar Red Norland were developed from spontaneously occurring mutations that caused chimeras for tuber skin color. As the only phenotypic changes observed in the chimeras (color and scab reaction) were restricted to the skin this suggests that the mutation was restricted to the L_1 layer of the apical meristem, as this layer gives rise to the epidermal

Table 1 Ranking of established Red Norland lines and new lines derived from chimeras of Red Norland for yield, skin color and scab resistance averaged over trials conducted in 2007, 2008 and 2009

Line	Yield [a]	Skin color[b]	Scab resistance	Overall ranking	
				No scab[c]	Scab fields[d]
Red Norland	1.6	5.0	4.7	3.3	3.8
DR Norland	3.5	3.3	4.3	3.4	3.7
1–9D	1.5	2.2[e]	2.3[e]	1.8[e]	2.4[e]
2–9D	4.0[e]	1.8[e]	2.7[e]	2.9	2.8[e]
2–11D	4.3[e]	2.7[e]	1.0[e]	3.5	2.7[e]

[a] All rankings range from 1 (highest) to 5 (lowest)

[b] Ranking based on Hunterlab **b** values

[c] Rankings based on yields + skin color + uniformity of skin color

[d] Rankings based on yields + skin color + uniformity of skin color + scab resistance

[e] indicates value is significantly different than Red Norland at P=0.05

tissues (Dermen 1960). The change in tuber color appeared to be stable through several generations of vegetative propagation, although some lines tended to produce a high proportion of tubers that were again chimeral for skin color. Although there was significant year to year variability in skin color, several of the new lines had skin color that was consistently superior to the established Red Norland lines based on visual assessments and spectral analysis. The spectral analysis suggests that the color change involved an overall darkening (lower **L** values) of the skin color, along with an increase in the relative amount of blue (lower **b** values), with no real change in the amount of red. Rosen et al (2009) noted a similar shift in the skin color of Red Norland following foliar treatment with the herbicide 2,4-D. They attribute this change to an increase in production of purple colored peonidin derivatives, relative to the orange-red pelargonidin derivatives commonly found in the skin of Red Norland. The new lines also appeared somewhat more resistant to common scab than standard Red Norland. Whether this difference was attributable to the difference in skin color or some other factor could not be definitively determined. The line with the greatest resistance to common scab (2–11D) did not consistently show the most intense skin color. While the yields of some lines developed from chimeral tissues were clearly inferior to standard Red Norland, it was possible to select lines that combined acceptable yields, superior skin color and enhanced resistance to common scab. In trials conducted in fields with extremely heavy scab pressure, yields of several of the new lines were clearly superior to standard Red Norland lines once grade out to excessive common and powdery scab was calculated. Growers faced with common or powdery scab problems presently have few management options, aside from taking the infected field out of production for an extended period. The new lines developed in this project may allow growers to continue to produce a marketable crop on fields that otherwise would need to be taken out of potato production.

From a commercial standpoint, once these lines have been better characterized, it might be possible to recommend specific lines based on their suitability to production conditions (relative yield potential), disease pressure (scab infestation levels in the field) and market expectations (required intensity of skin color). Lines of Russet Norkotah specifically selected for their resistance to either heat or drought stresses are widely employed in North America (Miller et al. 1999).

The new lines generated in this project may also prove useful in a breeding program seeking to improve the skin color and/or scab resistance of Red Norland and other red-skinned table varieties. The fact that the new lines are likely near-isogenic compared to Red Norland should facilitate their use in an improvement program and may also be useful in studying the genetics of skin color and scab resistance.

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