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Understanding tuber formation to decrease tuber greening

Tuber greening is a substantial cause of waste in the potato industry, costing millions of pounds each year. On average, 5% of yield is affected, but it can be 20% in the most severe cases. Tubers turn green when they are exposed to light, causing the production of chlorophyll and glycoalkaloids. While chlorophyll is tasteless and harmless, glycoalkaloids are bitter-tasting and can occur at potentially toxic concentrations in green tubers. Some consumers are aware that green tubers may be dangerous and will not purchase or consume them. Consequently potato packers have very low thresholds for tuber greening, in contrast to tuber blemishing diseases, where infection of 5% surface area can be acceptable.

Factors known to influence tuber greening include row width, planting depth, ridge shape, soil cracking and variety. Differences between varieties are considered anecdotally to be caused by differences in stolon length and stolon depth between varieties. If tubers develop on stolons close to the surface, or on long stolons, they are more likely to turn green. Stolon length is considered to vary between varieties but differences between varieties have generally not been quantified. The influence of stolon length on the position of tubers in the ridge, and subsequently on their susceptibility to tuber greening, had not been investigated. A fellowship awarded to NIAB CUF from AHDB, and additional support from Cambridge University Potato Growers Research Association (CUPGRA), provided an opportunity to investigate the physiological and agronomic causes of tuber greening.

Seven varieties (Estima, Jelly, King Edward, Marfona, Maris Piper, Markies and Melody) were grown in replicated experiments in Cambridge over three years to investigate the relationship between stolon architecture and tuber

Figure 1. A plant of Marfona excavated to allow the position of tubers to be measured

Table 1. Average stolon length and depth and tuber greening over three years of the variety experiment

Variety	Stolon length (cm)	Relative stolon depth (%) †	Tuber greening (% yield)
Estima	5.1	76.1	19.5
Jelly	7.5	81.1	15.1
King Edward	4.8	76.4	18.8
Marfona	5.8	82.5	20.1
Maris Piper	3.9	78.1	9.5
Markies	6.1	77.1	11.1
Melody	5.9	76.0	7.1
S.E. (54 D.F.)	0.20	1.27	1.94

† Mean stolon depth as a percentage of planting depth

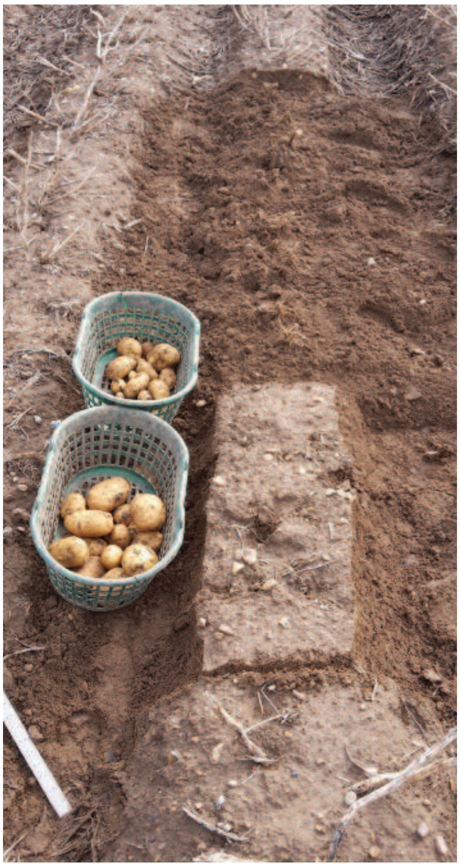

Figure 2. Tubers were collected separately depending on their position in either the flanks (sides) or upper 5 cm of soil

greening. Plots were sampled around the time of tuber initiation and the length and depth of every stolon was measured. In the middle of the season, stolon length and depth, and the position of each tuber were measured, by painstakingly removing soil from around each plant (Figure 1). Samples were taken after desiccation to assess for tuber greening. The core experiments were complemented by others investigating the influence of temperature, nitrogen rate and seed size on stolon architecture. In addition, 36 commercial crops were surveyed to quantify stolon architecture and to relate the position of tubers in the ridge to tuber greening.

The average stolon length in the variety experiment ranged from two to 11 cm across years and varieties, and directly determined where the stolon ends of tubers were found. On average, however, tuber length was a more important determinant of where the furthest end of tubers were found.

While there were substantial differences in stolon length within varieties between years, it was difficult to determine what caused them. Laboratory studies have reported an influence of nitrogen on stolon length, but in the field, the effect was so small to be of no practical significance. Temperature is the most likely factor causing differences within varieties, but the vagaries of British weather meant that altering planting date had only a minor effect on soil temperature. Differences in stolon depth between varieties were smaller than anticipated and did not directly influence the depth of tubers. The survey of commercial crops found a similar range in stolon length, as in the experiments, and the average stolon depth was c. 75% of planting depth.

Both within and between years differences in stolon architecture between varieties did not account for differences in tuber greening (Table 1). This was probably due to tuber depth not being directly related to stolon depth, because of differences in tuber size. In commercial crops, planting depth varied widely, both between and within crops. The average planting depth ranged from 12 to 22 cm, but there was typically a 7 cm range within rows and 4 cm range between rows. At shallower planting depths, more tubers had less than 5 cm of soil coverage, with some crops having less than 50% of yield protected, whereas other had over 80% protected (Figure 2). Relatively little yield was found in the flanks of the ridges, indicating that they were sufficiently large to accommodate the length of stolons and tubers. Few green tubers were exposed at the soil surface, with the majority still covered by soil indicating that cracking of the soil was important in allowing light to reach the tubers. On sandy and peat soils, few green tubers were found with more than 2.5 cm soil coverage, but on clayey soils, green tubers were found with more than 5 cm of soil coverage. Tuber greening was most severe on sites where more tubers were close to the soil surface and where the clay content of soil was higher.

Unfortunately, planting deeper is known to delay emergence and therefore reduce yield, so growers must find the balance between achieving a high yield while also minimising tuber greening. The variation in planting depth encountered between rows will have either decreased total yield or increased greening, and growers should monitor planting depth more closely to reduce this variation. Further research is required to determine what factors, other than clay content, influence the propensity of ridges to crack. Where tuber greening is substantial, growers should investigate where the green tubers are in the ridge, e.g. exposed at the surface, growing out of the flanks or unexposed, and adjust their planting depth and ridge geometry accordingly.

The full project report titled "Understanding tuber formation: maintaining the capability to improve tuber quality attributes including greening" is available on AHDB Potatoes website.

Figure 3. Proportion of yield in different parts of the ridge in commercial crops and whether (G) or not (NG) it was affected by tuber greening. Distances refer to the depth from the soil surface