Use of Ground Cover Grids in Crop Monitoring

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In order for growers and agronomists to discover reasons behind seasonal or field-to-field variation in crop yields, or for them to understand the poor performance of one (or more) of their fields, these crops have to be monitored in an efficient, quantitative and repeatable way. The data have to be taken accurately, precisely and methodically over the course of the season, and then subjected to analysis. Recording date of planting and harvest alone are not sufficient!

Since biological dry matter yield is directly proportional to the amount of light absorbed by the leaf surface, crop (i.e. tuber) yield is a function of biological yield and partitioning of the accumulated dry matter into tubers (i.e. harvest index). In order to grow bigger yields farmers need to ensure that a) their crops intercept more light, b) there is nothing that reduces the efficiency of conversion of intercepted light to dry matter (e.g. disease, or insufficient nutrients or water) and c) partitioning of dry matter to tubers is efficient (i.e. an excessive amount of foliage remaining at burn-down is inefficient).

Most growers cannot influence radiation levels, but they can alter date of planting, emergence, burn-off and harvest which may change intercepted radiation. There is a very poor relationship between yield and the amount of incident radiation from planting to harvest or even from emergence to harvest, so merely obtaining data relating to radiation incidence (or sunshine hours) and hoping to quantify crop performance without a measure of crop light interception capacity often proves a waste of time. Explanations for yield variation often involve all or a combination of the following:

- Late, protracted or non-emergence of plants
- Poor early ground cover (GC) development
- Failure to maintain GC (prolonged wilting or premature senescence)
- Excessive use of nitrogen which produces leaf area which does not contribute to light absorption and encourages poor partitioning of dry matter to tubers
- Poor soil conditions resulting in restricted rooting and slow uptake of water and nutrients
- Waterlogging caused by over-irrigation which reduces root length and the efficiency of uptake of water and nutrients.

The benefits of accurate crop monitoring have been highlighted in a number of surveys of commercial crops by Cambridge University Farm. Some of these are ongoing, thereby permitting comparison of performance between seasons which is helping in future planning. One study is highlighted as an example. It involved a single farming company growing *c*. 400 acres of ware crop over a radius of 15 miles in Eastern England. Although many varieties were grown to satisfy different markets, Maris Piper was chosen since its performance had been variable in the years prior to the study commencing. This variety is also the most widely-grown in the UK, with *c*. 18 % of the area cropped with potatoes. It has a dual-purpose use as a French-fry and table-stock potato. The study was conducted over six seasons (1992-1997) and 4-7 fields per season were monitored (31 crops in total). All crops received irrigation according to scheduled need, but some crops became stressed when pump failure occurred, or where there was inadequate irrigation capacity to satisfy evaporative demand.

Some crucial information highlighted by monitoring was that 90 % of crops:

- Were planted over a 24 day period (10 March-3 April)
- Commenced emerging over a 25 day period (13 April-8 May)
- Reached 50 % emergence over a 21 day period (19 April-10 May)
- Commenced tuber initiation over a 15 day period (7 May-22 May)
- Reached full GC over a 33 day period (2 June-5 July).

The last point is the most crucial one; that crops had variable rates of canopy expansion prior to closure. Combined with differences in the timing of the onset of senescence and the rate of decline in GC, this created large differences in light interception capacity between seasons and crops (Figures 1 & 2). This resulted in concomitant differences in tuber yield, both potential and measured. The potential yield of each crop was calculated from light absorption based on GC, a conversion coefficient of 1.3 g dry matter/MJ of absorbed light, a harvest index of 75 % and a tuber dry matter concentration of 20 %.

Over the duration of the study, the potential yield averaged across all crops was calculated to be 93 t/ha, whilst the grower achieved an average measured yield of 63 t/ha from trial digs conducted in late August, close to the commercially-harvested yield obtained in September or October. This farm's average actual yield was only 68 % of average calculated potential. Given that the national average yield of Maris Piper was only 46 t/ha over the same period (Potato Marketing Board/British Potato Council yield dig data) which equates to only 50 % of potential of the crops being monitored in this study, where are growers getting it wrong?

Which measurements give us the best chance of understanding the reasons for poor crop performance? As a start, recording date and duration of emergence every 2-3 days, not just date of planting is the first crucial operation that needs to be performed on the crop in the field. This should be followed subsequently by frequent (i.e. weekly) measurements of GC throughout the season, not just until the point when full cover is reached. The most important areas involved in poor performance were the failure to establish rapid rates of increase in GC early in the crop's life, and the inability to maintain GC as long as required as a consequence of premature senescence. In some cases, over-fertilization with nitrogen owing to a failure to take account of the nutritional contribution of pig slurry produced excessive leaf rather than tuber growth, thereby reducing harvest index.

In order for estimates of GC to be consistently accurate between seasons, crops and operators, it is essential to manufacture and use a grid which divides the area being studied into smaller, more easily-measured fractions. The grids used at Cambridge University Farm are based on wooden frames divided into 100 equal rectangles using orange nylon string (which is easily visible against the leaf surface and does not stretch when wet). One dimension of the grid should be the same as the row width of the crop, the other dimension a multiple of plant spacing (e.g. 25 cm x 3 = 75 cm, 12" x 2 =24"; Figure 3). If the grid is made too long, it becomes difficult to make estimates of leaf cover without parallax reducing accuracy.

The grid is placed over a representative area of plants in the field (Figure 4). The grid must be kept level with the top of the plants (*i.e.* not squashing plants so that the leaf area distorts). The left-hand edge of the grid (A) should be aligned directly over the wheel furrow, with the right-hand edge (B) immediately over the central furrow (or centre row if using 3-row beds) of the bed (Figure 3). This positioning will then take account of any 'staggered' bed arrangement (*e.g.* where the two rows within a bed are closer together than the two rows either side of a wheeling). It is important for the operator to keep their eyes directly over each square when assessing area covered by leaf, since this will reduce the error created by parallax when viewing the squares at an acute angle (Figure 4). All squares with 50 % or more of their area covered with leaf (not stem) material are counted as 1 % (Figure 5). All squares with less than 50 % full are counted as zero.

It is important not to add up fractions of squares to make an entire one (the only time this should be attempted is when GC is clearly close to 100 %, and the area of partial squares can be estimated to give a more accurate reading over the range 96-99 %. At least five estimates with the grid should be made per field. The use of the grid is especially important at GCs between 20 and 80 %, since operator error using visual assessment without a grid can easily result in differences of ±10 % GC (Figure 6).

Where trained operators use the same grid on the same area of field or experimental plot, it is possible to produce repeatable measurements of GC over the course of the season with no bias (Figure 7). Potential errors in estimating GC have been raised by some researchers, namely parallax and the fact that potato leaves from plants arranged in rows are not randomly orientated Korva (1996). If grids are made of manageable size then the error caused by parallax sighting is reduced, and from work conducted at Cambridge University Farm, there seems to be no benefit in using an intercept technique (counting where leaves are underneath the point where a horizontal and vertical string cross) compared with the standard technique.

It has been reported by some workers that a non-linear relationship exists between light interception (LI) and GC (Haverkort *et al*. 1991). Experiments at Cambridge University Farm have shown that during early growth, GC percentage and LI percentage were very similar up to *c*. 75-80 % GC, but as GC increased to >80 %, LI increased at a slower rate, such that in irrigated Cara LI at full GC ranged from *c*. 85-98 %. The coefficient of extinction estimated from LI and leaf area index (LAI) differed between years, but was greater in Desiree than Cara so that the LAI required to intercept 90 % of incident radiation was lower in Desiree (4.1, 4.5 and 3.8 for 1990, 1991 and 1992, respectively) than in Cara (5.4, 5.2 and 4.8). The extinction coefficient estimated from photosynthetically-active radiation (PAR) absorption and LAI was greater than for LI, so that the LAI required to intercept 90 % of PAR was < 3. In dense canopies, PAR absorption exceeded 99 %, which is a function of the wavelengths of light within PAR being absorbed preferentially by the leaf canopy.

Analysis of LI over the course of the day showed that there was a substantial diurnal variation for much of the growth period in dry seasons such as 1990. The LI % after midday was up to 9 % lower than in early morning in unirrigated crops, but also up to 2 % lower for irrigated plots. This wilting of leaves under water stress may influence the accuracy of GC readings taken at different times of the day, as will windy conditions which causes leaves to move around under the grid or suffer mechanical damage.
In summary:

- Crop yields vary as a consequence of differences in the amount of light absorbed by the leaf canopy during the growing season
- Understanding this variation means measuring the light absorption capacity of the crop canopy
- Weekly measurement of GC from emergence to burn-off using a grid permits accurate, precise estimates of this absorption capacity
- This allows comparisons to be made on crop performance.

References

HAVERKORT, A.J., UENK, D., VEROUDE, H. & VAN DE WAART, M. (1991). Relationships between ground cover, intercepted solar radiation, leaf area index and infrared reflectance of potato crops. *Potato Research* **34**, 113-121.

KORVA, J.T. (1996). Grids in ground cover measurements. *Potato Research* **39**, 533-540.

Figure 1. **Variation in ground cover between seasons in commercial survey**

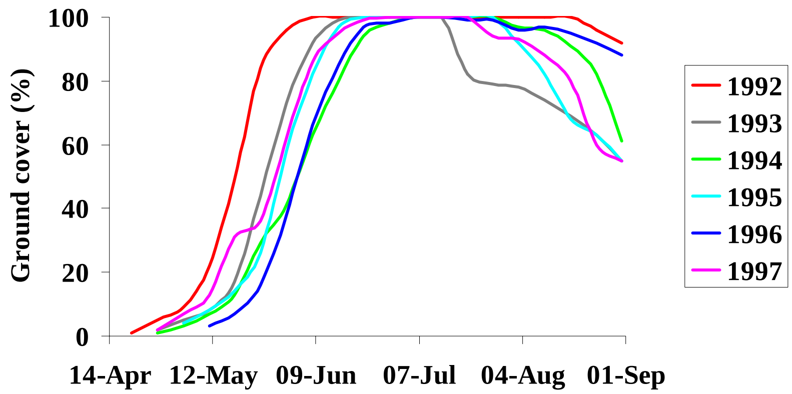

Figure 2. **Variation in ground cover between fields in 1997 in commercial survey**

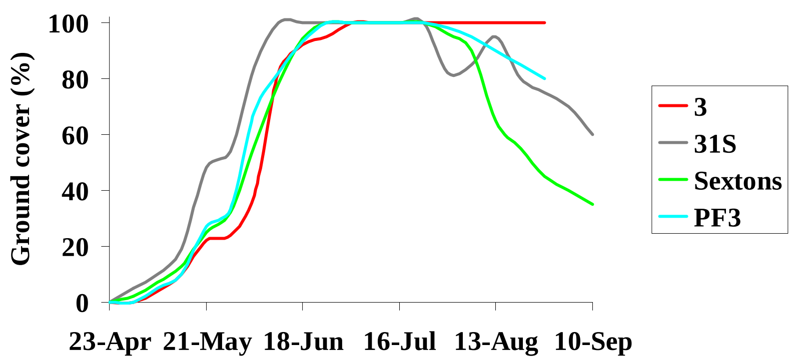

Figure 3. **Grid dimensions and placement with respect to rows**

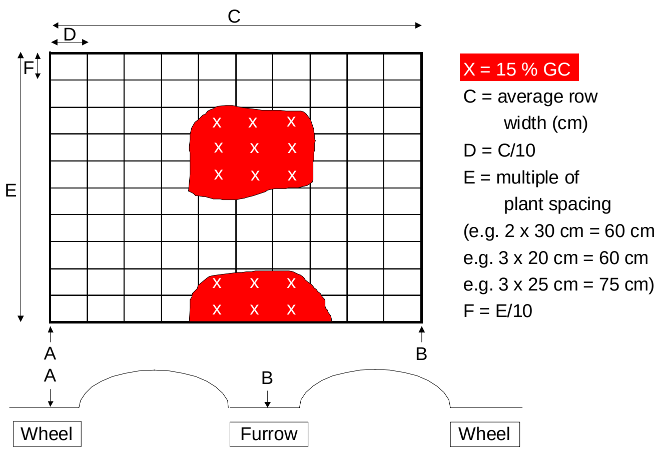

Figure 4. **Grid positioned over row**

Figure 5. **Close-up of grid showing individual plants**

Figure 6. **Comparison between ground cover measurements taken by two operators with the same grid in the same experimental plot**

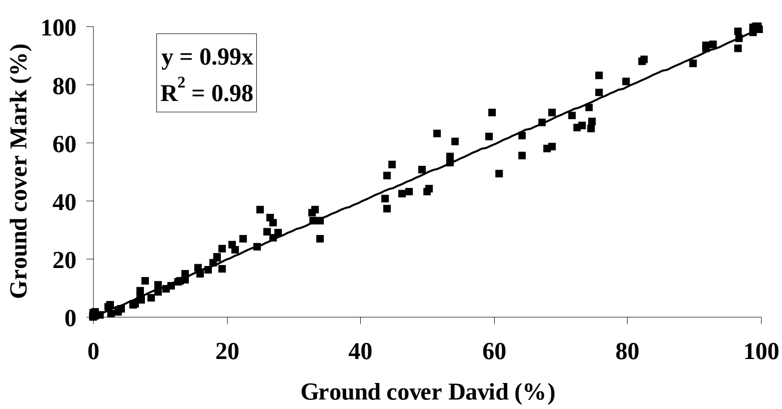

Figure 7. **Comparison between ground cover estimated visually by several operators with measurements made using a grid in the same experimental plot**