Potato Crop Growth, Development, and Water Use

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Our objective over many years at Cambridge University Farm has been to use water more efficiently when growing crops of potatoes. This requires growers to understand crop demand for water, and for them to maximize the quantity and rate of water extraction from the soil, and then minimize losses from irrigation, particularly during early season when soil moisture deficits (SMDs) are small (e.g. control of common scab in packing crops). Crop growth creates a leaf surface, which together with the atmospheric conditions, determines crop water demand. This demand can only be met if the crop root system can extract sufficient water from the soil. This capacity changes with growth as root penetration continues to access deeper horizons, but the process is greatly influenced by soil conditions.

Since the major developmental processes, flower and tuber initiation, occur early in crop growth, only 2-3 weeks after emergence, much emphasis is placed on achieving the optimal conditions for crop growth during this period. For tubers, their subsequent number, size and quality is largely determined by the grower's ability to meet the crop's water requirement later in the season, although some aspects of quality (e.g. common scab) occur during this early period of crop development when canopy cover is expanding rapidly.

In the UK, typical rates of evapotranspiration (ET) demand on the crop during July and August are 3-3.5 mm/day; compare this with Washington State where ET often exceeds 7-8 mm for substantial periods (Figure 1).

The growth of the canopy in relation to the increasing ET demand as the days become hotter and sunnier influences how much water is required to be taken up from the soil by the rooting system. In some seasons in the UK, rainfall is scarce during the period after emergence and, in the absence of irrigation, the inadequate supply of water reduces the rate of canopy expansion (Figure 2).

In other seasons, sufficient rain falls to allow unrestricted rates of canopy expansion (Figure 3), although in unirrigated crops in most seasons in the east of the UK, the maintenance of the canopy is compromised by a lack of rainfall later in the season. This shortage of water can be manifested in several ways. First, at moderate SMDs, stomatal closure may occur to reduce water flow through the plant; if not prolonged, wilting of leaves may not occur.

If the period of water shortage is lengthened, leaf wilting will occur, compromising light interception for substantial periods during the day (Figure 4). Lastly, as the soil dries further, premature leaf senescence will occur, leading to irreplaceable loss of canopy in determinate varieties, and a severely compromised loss of light interception in indeterminate cultivars.

The question that must be asked is how to maximize the uptake of water in order to prevent slow initial rates of canopy expansion and minimize wilting and premature senescence later in the season? The answer is to maximize the rate of expansion and ultimate depth and horizontal spread of the root system. This is achieved by creating soil conditions that maximize the growth of roots both vertically and horizontally during the weeks between emergence and canopy closure.

Without impediment to growth, rates of vertical root growth in the first 3 weeks after emergence are *c*. 1.2-1.6 cm/day, with roots meeting under the furrow *c*. 21-30 days after emergence, even on rows as wide as 90 cm. It is therefore important to avoid soil compaction at shallow depths, and also avoid late subsoiling, tie-bunding, hoeing or ridging cultivations which may prune roots and reduce the water absorbing capacity of the root system. Shallow compaction severely reduces the maximum depth of rooting and the total length of roots in each horizon, and the effects on rooting and crop growth are visible as soon as 3 weeks after emergence (Figures 5 & 6).

Compaction occurs on all soil types, and shallow compaction is far worse than a deeper restriction to growth where roots can proliferate sufficiently extensively in shallower horizons to avoid restrictions on water uptake during early growth. Compaction often delays initial emergence, increases the time over which plants emerge and slows the initial rate of canopy expansion, resulting in incomplete ground cover with a consequential loss in light absorbing capacity and tuber yield (Figure 7). Owing to the poor rooting density in compacted soils, premature wilting and leaf senescence are frequently observed. Most importantly, irrigation can only partially alleviate the effects of compaction, it cannot undo them completely (Figure 8).

The ability to produce a seedbed free from compaction can often change over very short periods of time. Even on sandy soils, a 3-day delay in planting after rainfall can have a significant effect on reducing the soil resistance measured in the uppermost 45 cm of soil after the planting operation (Figure 9).

Increases in soil resistance created in compaction-prone soils are likely to reduce the early rate of rooting, and thereby the maximum depth of rooting achieved. Varieties differ in their maximum depth of rooting as a consequence of their duration of root growth not the rate at which they root (Stalham & Allen 2001), and this has significant effects on the quantity of water that can be extracted from the soil before irrigation is required (Figures 10 & 11).

A requirement of the UK packing industry is a freedom from common scab, and many growers irrigate early in the season, starting at tuber initiation. Most crops initiate tubers 16-21 days after 50 % plant emergence, but protracted plant emergence caused by poor soil conditions within the seedbed can increase the duration of initiation within a field. This often results in frequent irrigation being applied for 5-8 weeks after initiation, rather than the usual 3-4 weeks required by crops emerging over a concise period.

Since the SMDs required to avoid common scab are small (10-18 mm), the risk of over-irrigating is high with the equipment typically used in the UK. If soils have impeded drainage as a consequence of compaction or over-consolidation (e.g. slumping), then root systems can have inadequate oxygen for maximal growth, thereby compromising the potential for water uptake still further. Growers are increasingly becoming aware that valuable water is being wasted during the early part of the season that could be used later in the crop's life when tuber yield is often compromised by inadequate water supply.

In summary, growers have to understand the relationship between the supply of water from the root system and soil and the demand for water created by the atmospheric conditions on the crop canopy. They also have to realise that the potential yield of their crops is markedly influenced by the growth rate of the crop in the first 2-3 weeks after emergence. Most important is the understanding that root growth is severely compromised by poor soil conditions and compaction, and that irrigation can only partially alleviate the restrictions on water and nutrient uptake.

References

STALHAM, M.A. & ALLEN, E.J. (2001). Effect of variety, irrigation regime and planting date on depth, rate, duration and density of root growth in the potato (*Solanum tuberosum*) crop. *Journal of Agricultural Science, Cambridge* **137**, 251-270.

Figure 1. **Comparison of evapotranspiration at Cambridge, UK and Othello, WA**

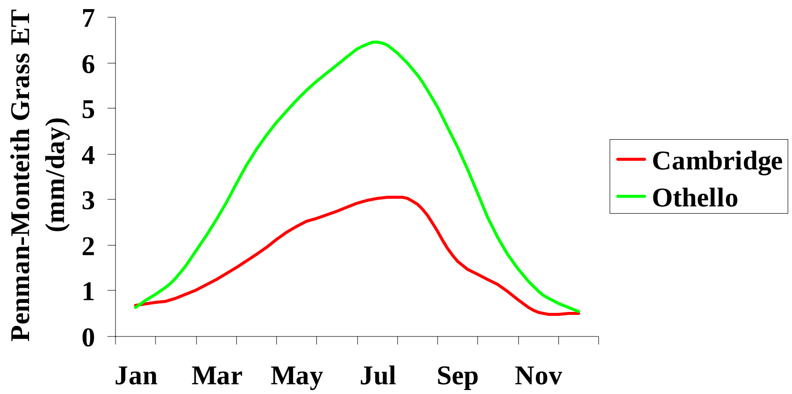

Figure 2. **Ground covers in unirrigated and irrigated Cara 1996**

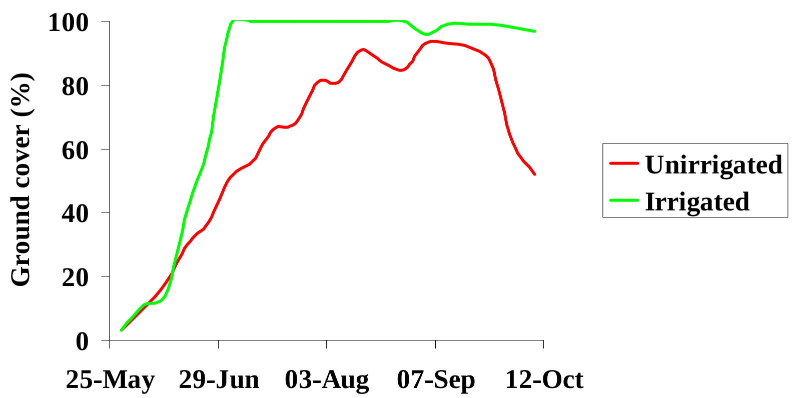

Figure 3. **Ground covers in unirrigated and irrigated Cara 1997**

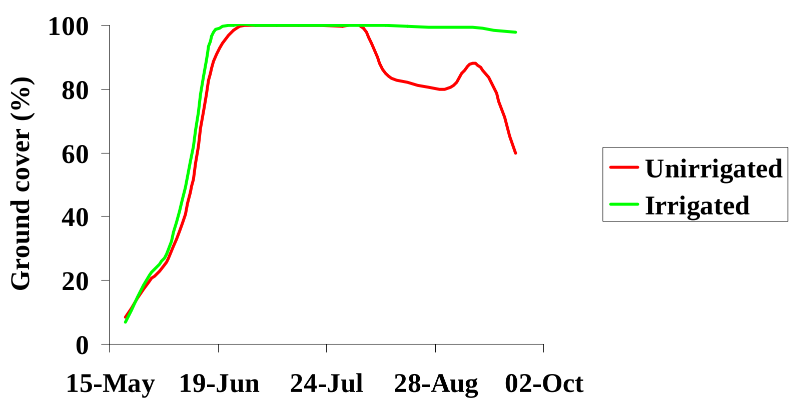

Figure 4. **Effect of irrigation regime on diurnal fluctuations in light interception in Cara**

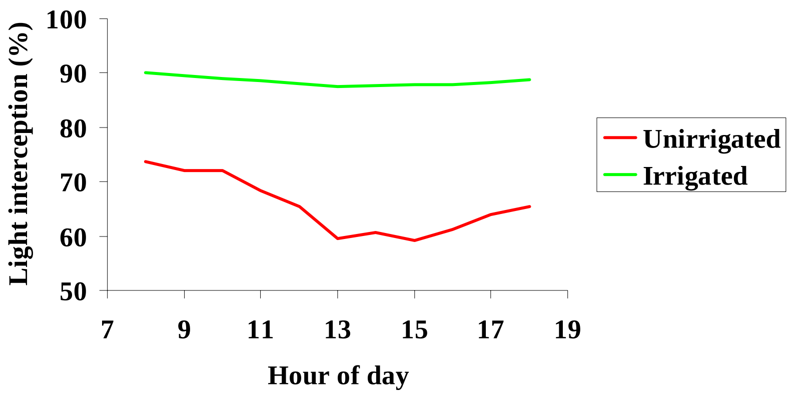

Figure 5. **Effect of soil compaction on root length at 21 days after emergence of plants grown in tubes**

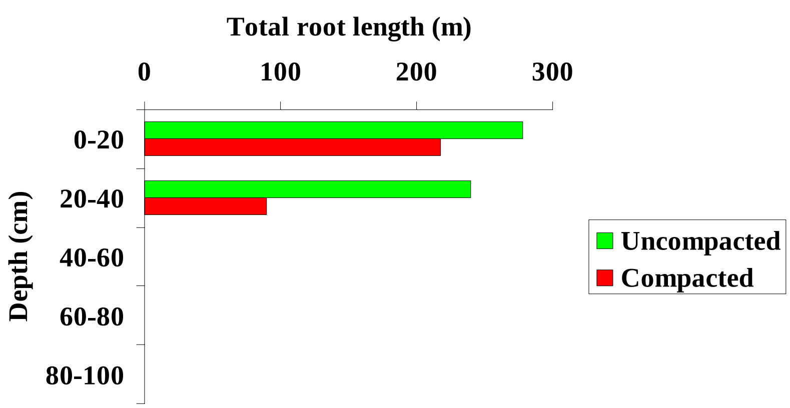

Figure 6. **Plant root systems extracted from a) compacted soil (left) and b) uncompacted soil (right) 21 days after emergence**

Figure 7. Effect of compaction and irrigation on ground cover

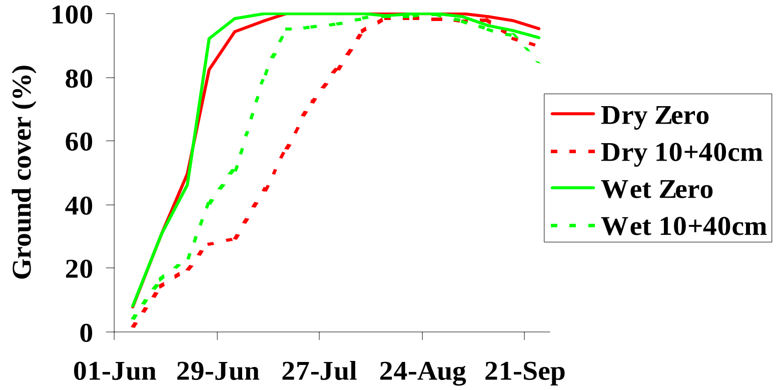

Figure 8. Effect of compaction and irrigation on tuber yield

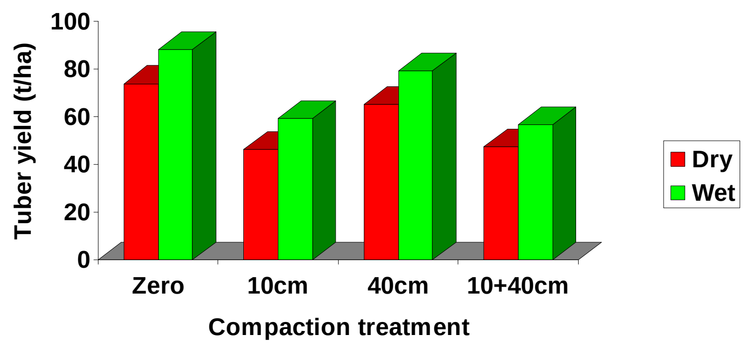

Figure 9. Effect of delay in planting after rainfall on soil resistance

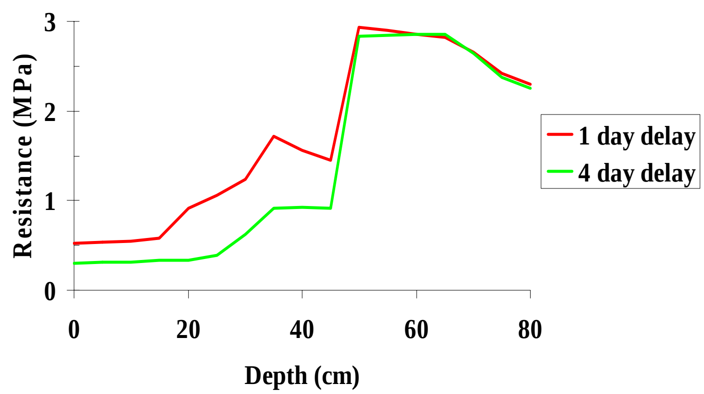

Figure 10. **Varietal differences in rooting depth in 1994**

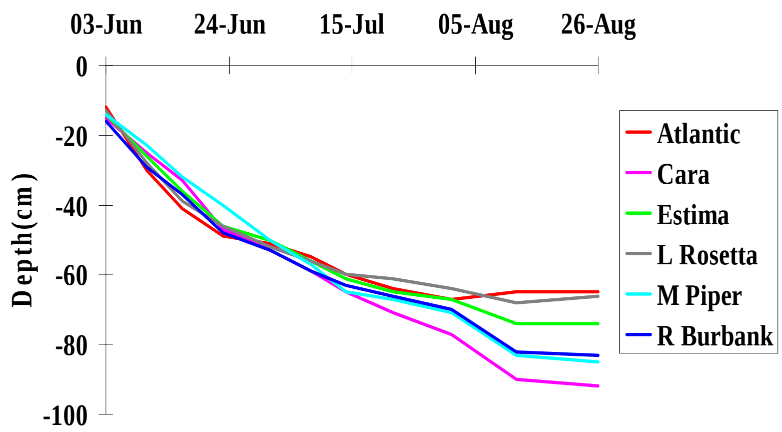

Figure 11. **Effect of variety on limiting soil moisture deficit (SMD) in a loamy medium sand**