Final report

MONITORING AND QUANTIFYING FACTORS THAT AFFECT THE GROWTH AND YIELD OF POTATOES

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Disclaimer

Vrywaring

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OPSOMMING (Afrikaans)

Gereelde groeianalises is volgens beplanning op plantmonsters vanaf drie lokaliteite, naamlik Dendron, Petrusburg and Bultfontein uitgevoer. SWB model simulasies is vir elke datastel geloop en model uitsette is met die gemete data vergelyk. Gewas parameters wat vantevore vir elke cultivar bepaal is, is vir die simulasies gebruik. Model uitsette het oor die algemeen goed met gemete waardes vergelyk, indien die groeiseisoen ooreengestem het met die seisoen waarvoor die gewasparameters bepaal is. Byvoorbeeld, gewasgroei vir cv. Darius in ‘n somer aanplanting te Petrusburg is oor die algemeen akkuraat gesimuleer indien somer gewas parameters vir hierdie cultivar gebruik is. Indien dieselfde stel parameters egter gebruik is om ‘n herfs seisoen vir Petrusburg te simuleer, was model uitsette nie akkuraat nie. Hierdie resultate bevestig die huidige beperkings van SWB, wat nie in staat is om die effek van verskillende omgewings (met dieselfde gewasparameters) op aartappel groei, ontwikkeling en opbrengs akkuraat te simuleer nie.

Dit is bekend dat aartappels gevoelig is vir veranderinge in fotoperiode (daglig lengte), wat tesame met temperatuur die tempo van groei en ontwikkeling van die gewas beïnvloed. Kort dae en koel temperature bevorder knolinisiasie, terwyl lang dae en hoë temperature knolinisiasie weer uitstel. Sodra knolinisiasie ‘n aanvang neem, word meer assimilate na die knolle verdeel en minder na die loofgroei. Afhangend van wanneer knolinisiasie plaasvind (vroeg of laat in die groeiseisoen), sal dit ‘n invloed uitoefen op die grootte van die loof en die uiteindelike knolopbrengs.

Simulasiemodelle behoort dus die effek van fotoperiode op aartappel groei en ontwikkeling in ag te neem ten einde hierdie veranderlikes akkuraat te kan simuleer. Die SWB model is ‘n generiese gewas model, wat ontwikkel is as hulpmiddel vir die besproeiingskedulering van ‘n reeks gewasse, insluitend aartappels. SWB is reeds vantevore suksesvol vir aartappels onder plaaslike toestande gekalibreer en gebruik. Die toepassingsmoontlikhede van die model is egter gekortwiek deur die feit dat verskillende stelle gewasparameters vir verskillende seisoene gebruik moes word om akkurate simulasies te verseker. Die verbetering van SWB om aartappel groei, ontwikkeling en opbrengs akkuraat in ‘n verskeidenheid omgewings te kan simuleer sal dus beslis die model se toepassingsmoontlikhede aansienlik verbeter.

‘n Studie is gedoen om vas te stel watter benaderings deur toegewyde aartappelgroeimodelle gebruik word om die effek van fotoperiode op aartappels te

akkommodeer. Hieruit is sewe verskillende metodes saamgestel waarvolgens die termiese tyd behoefte tussen opkoms en knolinisiasie beraam kon word. Die verskillende metodes is gebruik om die aanvang van knolinisiasie vir uiteenlopende groeiseisoene te bereken. Die berekende aantal dae tussen opkoms en knolinisiasie is dan vergelyk met gemete data vanaf vyf historiese datastelle wat oor verskillende seisoene en lokalitiete versamel is. Die SWB metode aangepas met ‘n relatiewe daglengte faktor het die beste beraming van die kumulatiewe termiese tyd behoefte tussen opkom en knolinisiasie gegee.

Hierdie resultate dui daarop dat die vermoë van SWB om die aanvang van knolinisiasie by aartappels akkuraat te voorspel verbeter kan word deur die effek van fotoperiode by die model in te bou. Vervolgens sal die nodige aanpassings aan die model gemaak word om die effek van fotoperiode te kan simuleer. Die verbeterde SWB model sal dan op onafhanklike data evalueer moet word om vas te stel of die veranderinge die gewenste akkuraatheid teweeg gebring het.

In hierdie eerste modellering poging is slegs op die SWB model gekonsentreer. Dit moet egter benadruk word dat die data wat tydens hierdie projek versamel word, voortaan gebruik sal kan word vir die evaluasie en kalibrasie van toegewyde aartappel modelle vir plaaslike cultivars en toestande. Sulke modelle kan baie handig deur beplanners en beleidmakers gebruik word in besluitneming en scenario analises. Die uiteenlopende toestande waaronder aartappels in Suid-Afrika verbou word, en die ernstige tekort aan opgeleide gewaskundiges, dui daarop dat modellering een van die min oorblywende alternatiewe is waarmee aartappel produksie probleme aangespreek kan word.

SUMMARY

Growth analyses were conducted frequently on plant samples collected from three different localities, namely Dendron, Petrusburg and Bultfontein. SWB model simulations were run for each data set and model outputs were compared to the growth analyses data. For these simulation runs, previously determined crop parameters per cultivar were used. Comparison of growth analysis data with SWB simulation results indicated that model performance was generally good when the crop parameters used were for the same growing season. For example, crop growth of cv. Darius in a summer planting at Petrusburg was simulated well, provided that summer crop parameters for Darius were used. However, if the same set of crop parameters were used for a different growing season (e.g. an autumn season at Petrusburg), model simulations were not accurate. These results confirm the limitations of the SWB model, which is currently not able to simulate the effects of different growing seasons on potato crop growth, development and yield accurately.

It is known that the potato is sensitive to changes in photoperiod, which together with temperature, influence the rate of growth and development of the crop. Short days and cooler temperatures promote tuber initiation, while long days and higher temperatures postpone tuber initiation. Once tuber initiation has commenced, more assimilates are partitioned to the reproductive parts (tubers) and less to the canopy. Depending whether tuber initiation is early or later in the growing season, this will impact on the dry matter production and distribution, which will determine canopy size and final tuber yield.

In order to accurately simulate potato growth and yield, models should be able to accommodate the effects of photoperiod on these processes. The SWB model is a generic crop model, which was developed for the irrigation management of various crops, including potatoes. In the past SWB was locally calibrated and successfully used for the irrigation scheduling of potatoes. However, the application value of the model was limited by the fact that different sets of crop parameters had to be used for different planting seasons to ensure accurate simulations. The improvement of SWB to accurately simulate plant growth and water usage in different environments will, therefore, benefit the application value of the model.

The approaches followed by dedicated potato models were studied to establish whether the effect of photoperiod on crop growth and development could be accommodated into SWB. Seven different methods of calculating the thermal time required to reach tuber initiation were investigated. These methods were used to calculate the onset of tuber initiation for different growing seasons. The calculated days between emergence and tuber initiation were compared to measured data from five historical data sets, collected over several seasons and locations. The SWB method corrected by a relative day length factor gave the best estimations of the cumulative thermal time required from emergence to tuber initiation, which was a substantial improvement on the standard SWB method.

These results strongly suggest that the ability of SWB to correctly simulate the onset of tuber initiation could be improved by incorporating the effect of photoperiod. The next step would be to build the suggested changes into SWB and to evaluate whether the suggested improvements will indeed improve model simulations of crop growth in diverse growing conditions.

This first modelling attempt on potatoes only focussed on the SWB model. However, the collected data sets could in future be very valuable for the calibration and validation of potato specific growth models for locally produced potato cultivars. Such models can be very useful for planning and scenario analysis purposes in the hands of decision and policy makers. The divergent conditions under which potatoes are grown in SA, and the acute shortage of potato agronomists, dictates the use of modelling as one of the few remaining viable options for solving production problems in the future.

OBJECTIVES 2005/2006

The overall objective of the project is to investigate the effect of climate and production practices on the growth, development and yield of potatoes in two production areas, namely Vivo and Petrusburg. For the reporting period frequent destructive harvests during the growing season were planned. The collected plant samples were destined for growth analysis, which would help to quantify potato growth response to the different environments.

PROGRESS REPORT

Introduction

Potatoes are produced in sixteen geographic production areas in South Africa (Theron, 2003). These production areas can differ vastly in soil, climate and production practices applied. As planting dates can vary to almost any time of year, there is almost a year round supply of freshly harvested potatoes, which eliminates the need for long term storage. However, this broad production base often results in substantial differences in yield and quality obtained from different production areas. This requires optimization of cultivar and area specific production programmes.

Temperature, photoperiod and water supply are the most important abiotic factors affecting the growth and yield of potatoes. Both photoperiod and temperature influence the rate of crop growth and development. Temperature determines the onset and duration of different growth stages (emergence, tuber initiation, bulking and senescence) and partitioning of assimilates to different plant parts (leaves, stems, roots and tubers). This is called the thermal time requirements of a crop. Daylength or photoperiod mainly governs the time of tuber initiation and the length of the growing season of potatoes (Kooman and Haverkort, 1996). Since many interrelated factors play a role in this, a modelling approach is best suited to describe the plant's response to these variables.

A wide range of simulation models that differ in complexity, user friendliness and application value are available world wide. Some of the well-known potato specific models include SUBSTOR (Ritchie *et al*, 1995) and LINTUL (Kooman & Haverkort, 1995). The locally developed SWB model (Annandale *et al*, 1999) is not a dedicated potato model, but a generic crop irrigation scheduling tool. It can be used for the irrigation management of a range of commonly irrigated crops. SWB has previously been calibrated successfully for the most important South African potato cultivars, but as it is not a dedicated potato model, is does not take photoperiod into account. As a result, different sets of crop parameters were developed for different growing seasons and planting dates to ensure accurate simulation of crop growth and water use. This is not ideal, as it detracts from the application value of the model. In both the SUBSTOR (Ritchie *et al*. 1995) and LINTUL (Kooman & Haverkort, 1995) models the time of tuber initiation is a function of cultivar response to both temperature and photoperiod. Therefore, any of these models could potentially be employed to study the effect of environment on crop growth and yield. However, before crop models can be explored to help understand the effect of environment on crop response, field data is required for the calibration and validation of such models. The purpose of the current research work was, therefore, to collect plant growth data from diverse production areas for the calibration and validation of crop models.

Materials and Methods

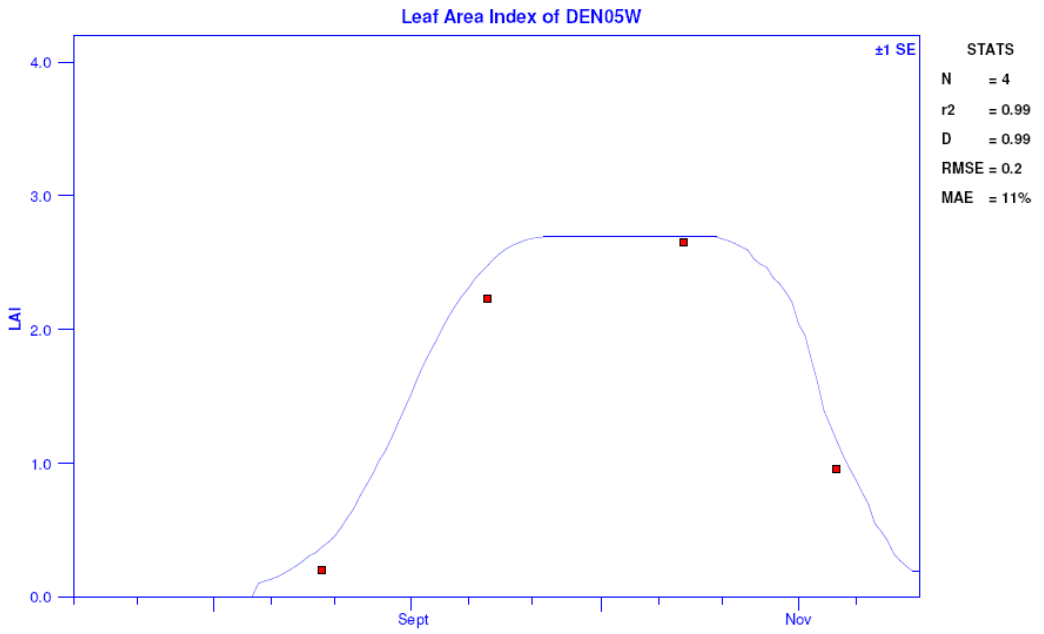
Plant samples were frequently collected from two production areas according to plan, as well as from a third site that was added during the course of the year. In Limpopo province plant samples of the cultivar BP1 were collected from a farm in the Dendron production area (instead of Vivo) during the winter 2005 season (planted July). In the Free State samples of the cultivar Darius were collected from Petrusburg during the summer 2005/6 season (planted September). At this site the monitoring programme was expanded to also include the mid summer / autumn season (planted January 2006). In this planting the cultivar Mondial was used, as requested by producers in that area. Furthermore, the project was expanded to the Bultfontein area, on demand of producers in that area. This site was also planted in January 2006 and the cultivar Mondial was also used.

For Petrusburg and Bultfontein plant samples were collected fortnightly and sent to Pretoria with the help of PSA field staff. At Dendron samples were only taken once per month. At each sampling time point three samples (replications) were taken from randomly selected positions in the field. For each sample all the plant material from a 1 m row length was harvested. Depending on the row spacing, the sample area ranged from 0.7 to 0.88 m^2 each. Samples were carefully packed and sent to Pretoria by overnight courier. On arrival growth analyses were performed on the collected samples, which included measurement of leaf area and determination of fresh leaf, stem and tuber mass. Plant samples were then dried for determination of dry mass per component. Hourly weather data was collected during the growing season for each site, using automatic weather stations. This data was used as input for model simulations.

SWB model simulations were run for each of the sites and seasons where plant growth data had been collected. Crop parameters previously determined for the cultivars BP1 and Darius were used in the model simulations. As crop parameters were not previously determined for Mondial, new parameters had to be calculated for this cultivar, using the current data sets. The collected plant growth data was processed and used for comparison with model simulations.

Results and Discussion

Model outputs for simulated leaf areas index (LAI), total (top) and tuber (harvestable) dry matter yields are presented in Figures 1 to 5. Actual measurements of these variables are also presented on the graphs to establish how well crop growth and yield were simulated, using the exiting crop parameters for each cultivar. Four different statistical parameters (r^2, Wilmott D-index, RMSE and



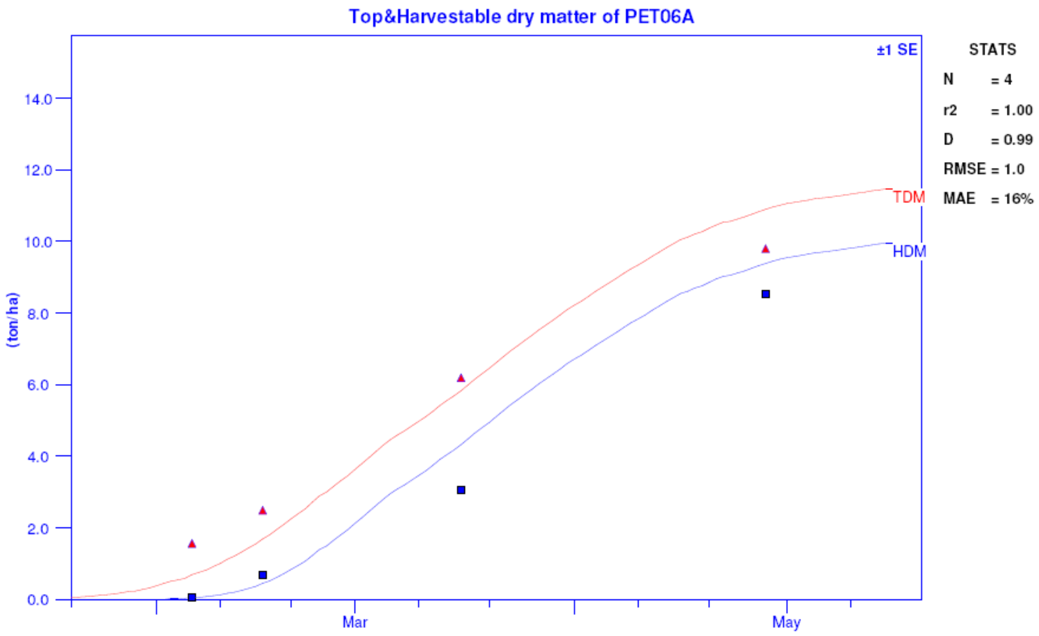


Figure 1 Simulated (lines) and measured results (points) for leaf areas index, tuber (HDM) and total dry matter (TDM) yields for the cultivar BP1 during the 2005 winter season at Dendron. Red lines and points represent total dry matter yields and blue lines and points represent tuber dry matter yields.

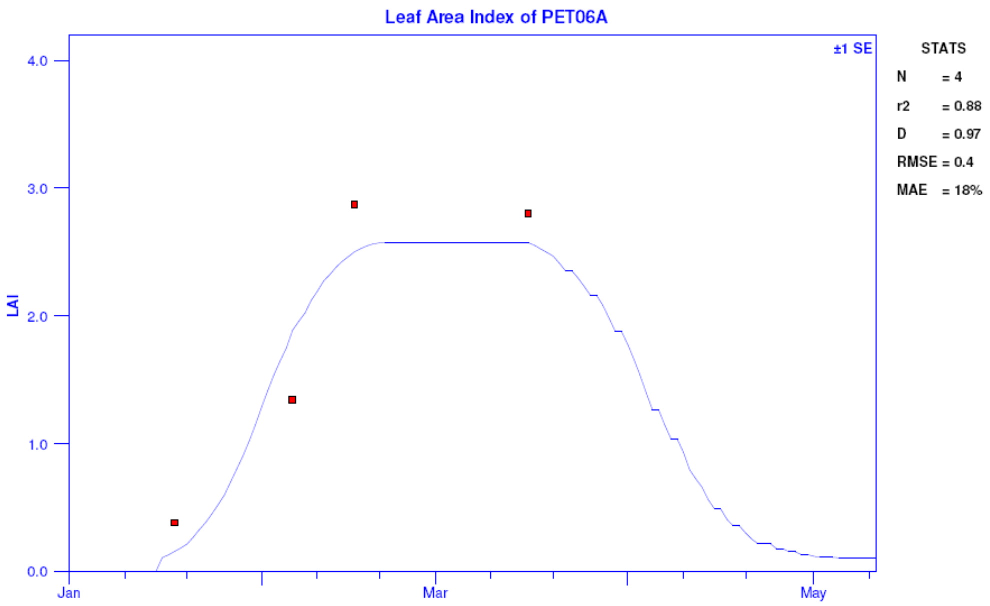
MAE) were employed to evaluate the agreement between simulated and measured values (De Jager, 1994).

According to Figure 1 the simulated values for LAI, tuber and total dry matter yields compared relatively well with measured values collected for the Dendron locality. In this case existing parameters for BP1 summer plantings were used.

From previous experience it was expected that simulation results would not compare well with measured values when using BP1 summer parameters for a winter planting. However, this could probably be explained by the fact that the potatoes were planted relatively late (July 2005) and only emerged during the first half of August. Therefore, these plants actually reacted like in a spring planting, rather than a winter planting as intended.

The simulated and measured values for LAI, tuber and total dry matter yields for the cultivar Mondial during the autumn 2006 planting at Petrusburg and Bultfontein are presented in Figures 2 and 3. Simulated values generally compared well with measured values for both sites. This confirms that under optimal growing conditions the same set of model parameters could be used for different localities, provided that the growing season is the same.

Figure 4 shows the simulated and measured values for LAI, tuber and total dry matter yields for the cultivar Darius during the summer 2005 planting at Petrusburg. The data generally compared well with measured values when using existing summer parameters for Darius. In order to establish model performance for Darius over different seasons, simulations were also run for the 2005 autumn season (the growth analysis data were collected at Petrusburg during the 2004/05 report year). Simulation results for autumn generally performed poorly with measured values when using summer model parameters for Darius (Figure 5). Both canopy size and dry matter yields were over estimated. This clearly illustrates the current limitation of SWB, namely that growth parameters determined for a certain growing season cannot be used for simulating another season.



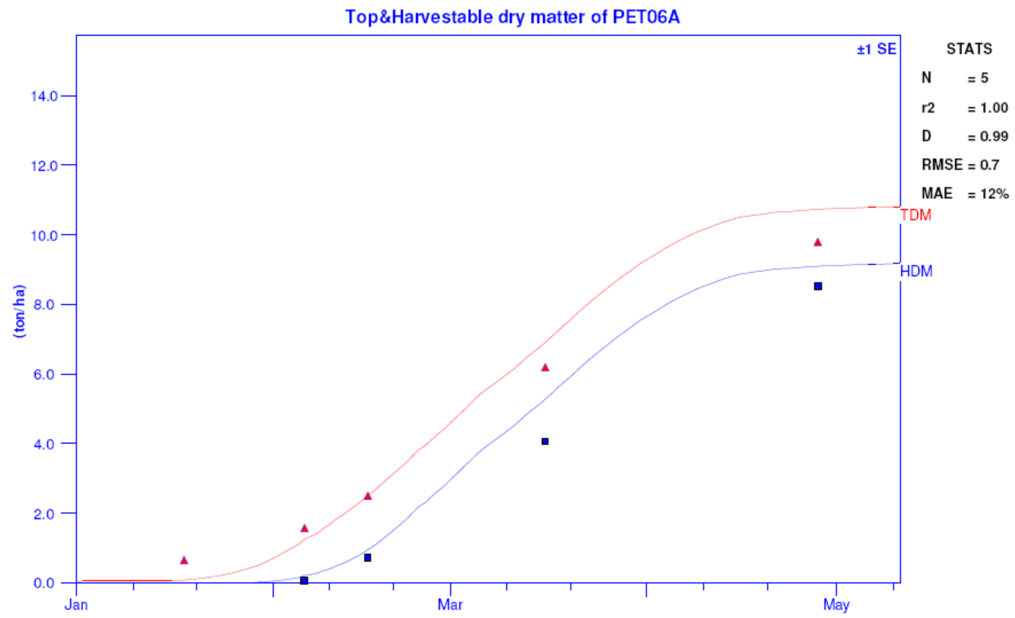
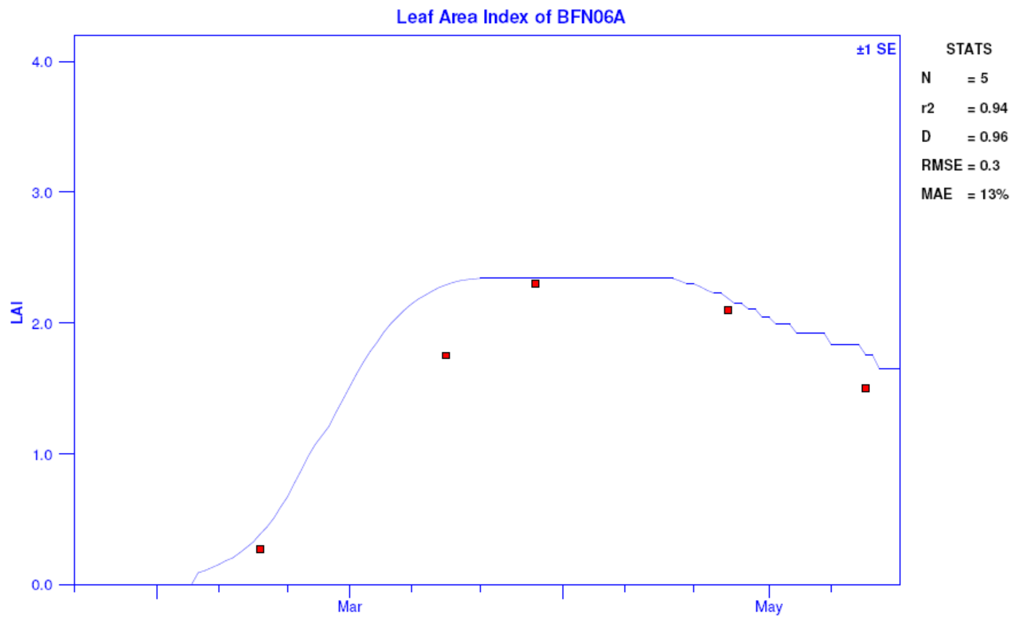


Figure 2 Simulated (lines) and measured (points) results for leaf areas index, tuber (HDM) and total dry matter (TDM) yields for the cultivar Mondial during the 2006 Autumn season at Petrusburg. Red lines and points represent total dry matter yields and blue lines and points represent tuber dry matter yields.



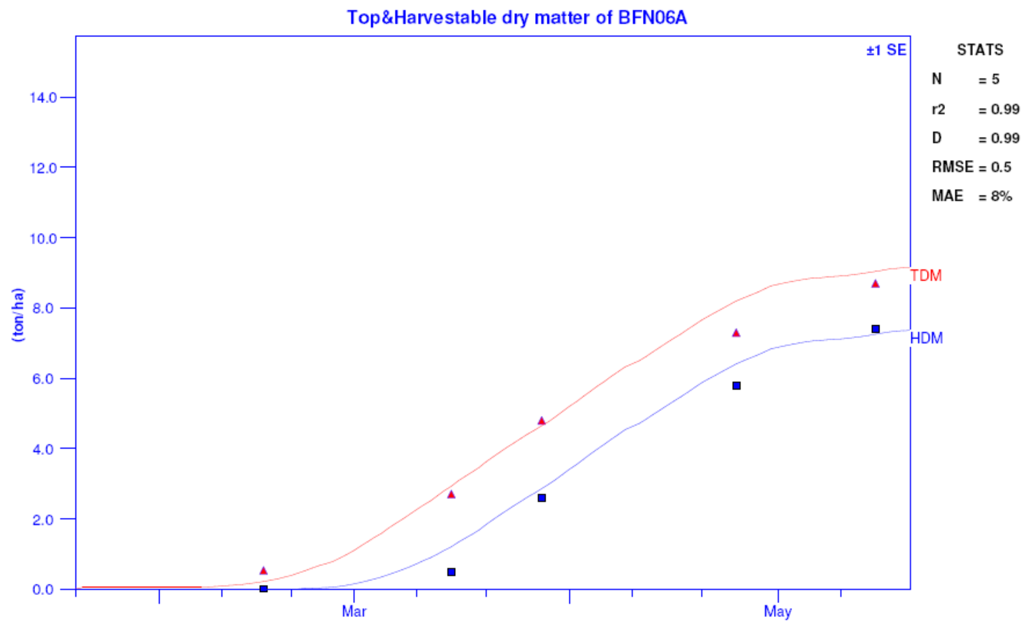
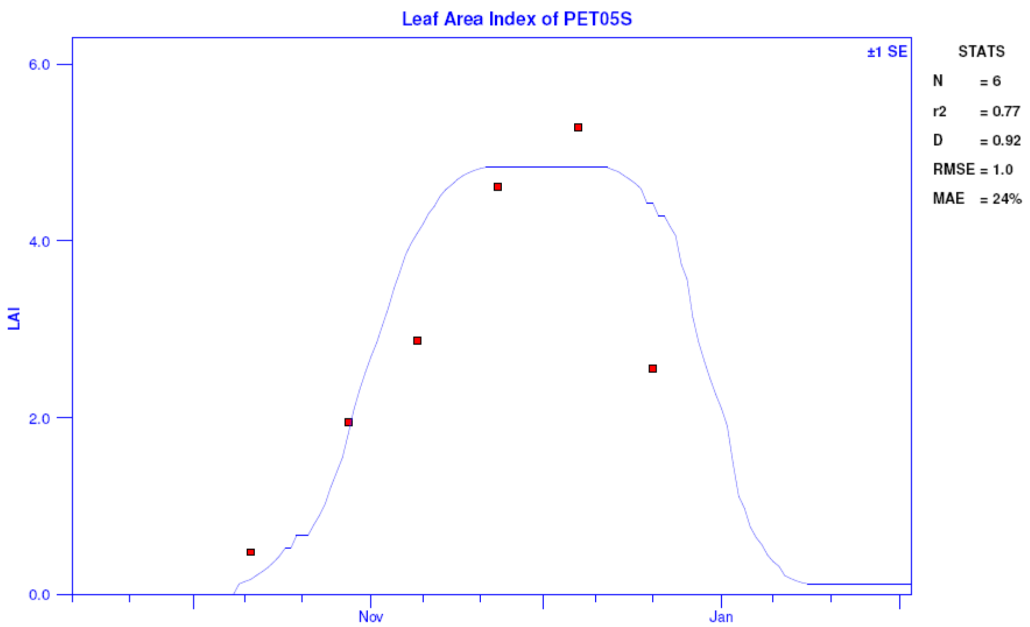


Figure 3 Simulated (lines) and measured (points) results for leaf areas index, tuber (HDM) and total dry matter (TDM) yields for the cultivar Mondial during the 2006 Autumn season at Bultfontein. Red lines and points represent total dry matter yields and blue lines and points represent tuber dry matter yields.



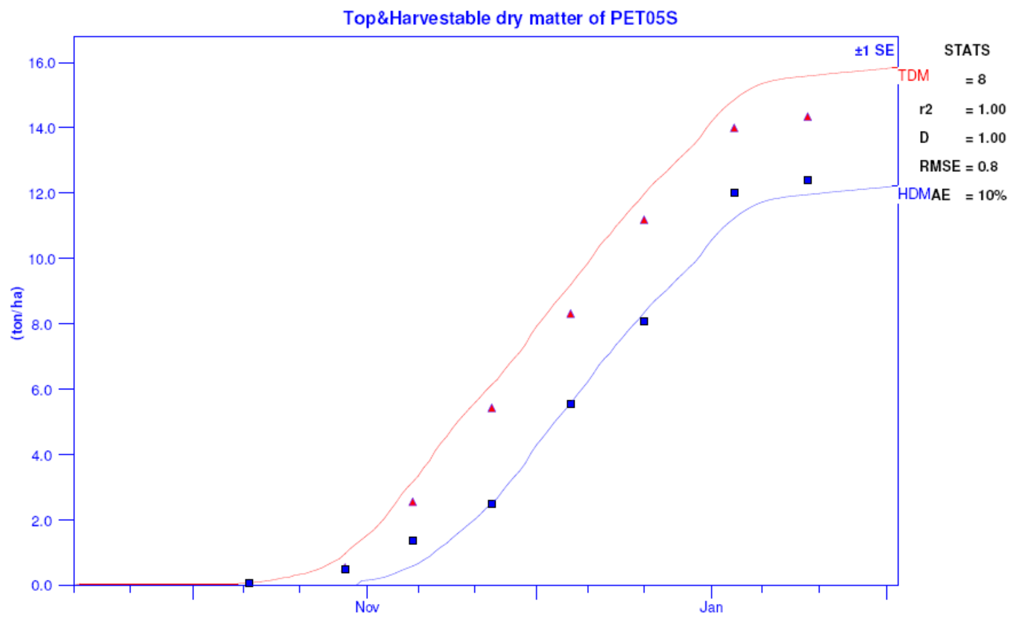
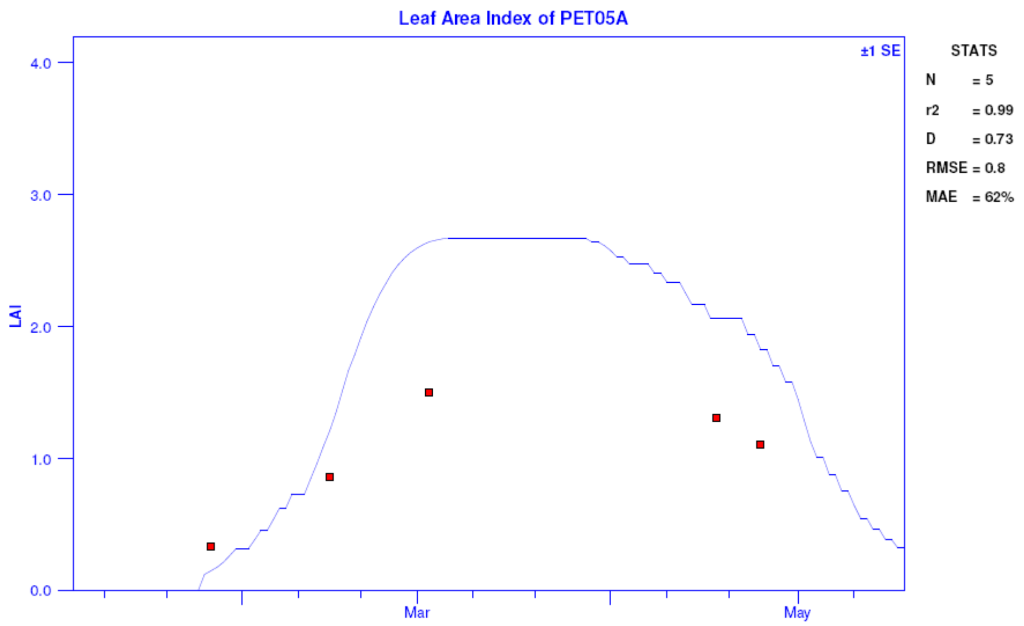


Figure 4 Simulated (lines) and measured (points) results for leaf areas index, tuber (HDM) and total dry matter (TDM) yields for the cultivar Darius during the 2005 Summer season at Petrusburg. Red lines and points represent total dry matter yields and blue lines and points represent tuber dry matter yields.



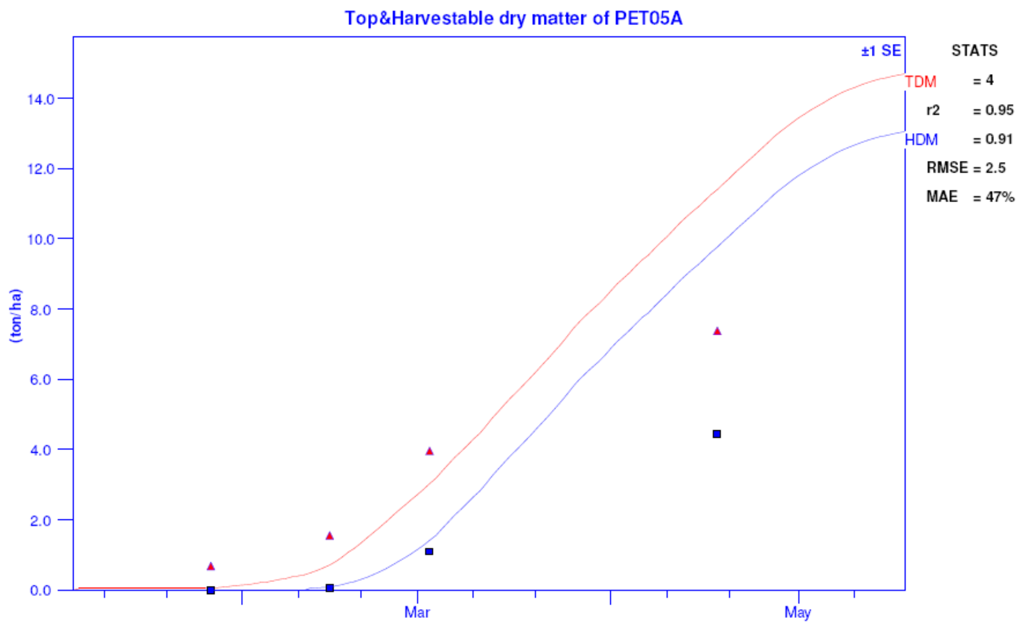


Figure 5 Simulated (lines) and measured (points) results for leaf areas index, tuber (HDM) and total dry matter (TDM) yields for the cultivar Darius during the 2005 Autumn season at Petrusburg. Red lines and points represent total dry matter yields and blue lines and points represent tuber dry matter yields.

In potatoes the partitioning of assimilates to leaves, stems, roots or tubers depends on the phenological stage of the crop (Ewing *et al*., 1990). Manrique, Hodges & Johnson (1990), Kooman & Haverkort (1995), and Wheeler & Tibbitts (1997) showed that under optimal growing conditions, phenological development of the potato is primarily influenced by temperature and photoperiod. The effects of photoperiod and temperature on growth and development are interrelated and difficult to separate (Van Dam *et al*., 1996). It is known that shorter days and cooler temperatures hasten tuber initiation, whereas long days and high temperatures postpone it. Once the crop has reached the reproductive stage (tuber initiation), more assimilates are partitioned to the tubers and less to vegetative parts. If tuber initiation starts very early due to short day conditions, tubers are initiated at the cost of a small canopy, which cannot sustain high tuber yields. This is typical of autumn plantings, when day lengths and temperatures decline dramatically towards winter. On the other hand, a later commencement of tuber growth leads to an extension in crop growth and increased yields, which results from a combination of prolonged leaf growth and slower leaf senescence (Kooman, 1995).

Dedicated potato crop models like POTATO (Ng & Loomis, 1984), SUBSTOR (Ritchie *et al*. 1995) and LINTUL (Kooman & Haverkort, 1995), take the effects of temperature and photoperiod into account. SWB, on the other hand, is a generic crop model and the onset of the reproductive stage is only determined by thermal time (temperature dependent). SWB calculates thermal time by using an algorithm developed by Monteith (1977). According to this approach plant development rate increases as a linear function of average temperature between a base and an optimal temperature. However, for potato, a non linear dependence of development on temperature was suggested (Sands, Hackett & Nix, 1979). Manrique & Hodges (1989) used the non linear temperature response function developed by Sands *et al*. (1979) and found it adequate to describe the thermal time required for the onset of tuber initiation. Since SWB is a generic model, the linear relationship between development and temperature is convenient because it must not only apply to potato but also to other crops. Gayler *et al*. (2002) suggested that generic models may require modification from a single process formulation where differences occur in physiological and ecological principles between crop classes, such as cereals and root crops. To overcome these limitations in SWB, different sets of parameters were developed for spring and autumn plantings. This approach worked reasonably well (Steyn, 1997), but there are clearly shortcomings in the mechanistic description of potato growth and development. The challenge is, therefore, to have one set of crop parameters per cultivar that could be used to accurately simulate potato growth, development, yield as well as the soil water balance components for different growing seasons.

The approaches followed by dedicated potato models were studied to establish whether the effect of photoperiod on crop growth and development could be accommodated into SWB. Most of these models consider photoperiod only for the first part of the growing season (from emergence until tuber initiation). Seven different methods of calculating the thermal time required to reach tuber initiation were investigated (Kagabo, 2006). These methods were used to calculate the onset of tuber growth for different growing seasons, using the cultivar BP1. The calculated days between emergence and tuber initiation were then compared to measured data from five historical data sets, collected over several seasons and locations. The seven calculation methods were as follows:

<u>Method 1</u>: Daily thermal time was calculated using the SWB (Annandale *et al*., 1999) approach, in which plant development rate increases as a linear function of average temperature between a base and an optimal temperature:

$$\mathrm{GDD} = \sum \frac{\mathrm{T_x} + \mathrm{T_n}}{2} - \mathrm{T_b} \qquad (1)$$

where,
Tx is maximum temperature, Tn is minimum temperature and Tb is base temperature below which there is no more growth and development.

Method 2: This method uses the SUBSTOR approach (Ritchie *et al*., 1995) to calculate thermal time required for tuber initiation. In SUBSTOR, thermal time for tuber initiation is calculated as a function of relative temperature and photoperiod factors. The relative temperature factor for tuber initiation (RTFTI) is calculated as shown in equation 2. Mean temperature is more heavily weighted towards the minimum temperature (Eq. 3), as the onset of tuber initiation is more dependent on minimum than maximum temperature (Ritchie *et al*., 1995).

$$\mathrm{RTFTI} = \begin{cases} 1-(1/36)(10-\mathrm{TEMPM})^2 & ;\quad 4<\mathrm{TEMPM}<10 \\ 1 & ;\quad 10\le \mathrm{TEMPM}<\mathrm{TC} \\ 1-(1/64)(\mathrm{TEMPM}-\mathrm{TC})^2 & ;\quad \mathrm{TC}\le\mathrm{TEMPM}<\mathrm{TC}+8 \end{cases} \qquad (2)$$

where,

RTFTI is a relative temperature factor for tuber initiation,

$$\mathrm{TEMPM} = 0.25*\mathrm{T_x} + 0.75*\mathrm{T_n} \qquad (3)$$

T_x is the maximum temperature, T_n is the minimum temperature and TC is a critical temperature above which growth and development are negatively affected to some degree. In SUBSTOR, time to tuber initiation is a function of temperature and photoperiod. To integrate the photoperiod effect as a modifier of tuber induction, a photoperiod factor for tuber initiation (RDLFTI) was introduced and is calculated as follows:

$$\mathrm{RDLFTI} \quad \begin{cases} 1 & ;\mathrm{PHPER}\le 12 \\ (1-\mathrm{P2})+\mathrm{P2}/144\,(24-\mathrm{PHPER})^2 & ;\mathrm{PHPER}>12 \end{cases} = \qquad (4)$$

where,

RDLFTI is a relative day length factor for tuber initiation, PHPER is photoperiod (h), which is calculated from the latitude and day of year, according to the method developed by Campbell and Norman (1998), and P2 is a dimensionless genetic coefficient for cultivar sensitivity to photoperiod.

Under optimal growing conditions, RDLFTI is used to calculate the tuber induction index (TII) on each day after emergence as a function of the relative temperature factor for tuber initiation (RTFTI) as follows:

$$CTII = RDLFTI * RTFTI \tag{5}$$

where,

TII is tuber induction index and CTII is cumulative tuber induction index.

<u>Method 3:</u> In this method, thermal time required for tuber initiation was calculated using the standard SWB approach, combined with a relative photoperiod factor for tuber initiation:

$$GDD = \sum\left(\frac{T_x + T_n}{2} - T_b\right) * RDLFTI \tag{6}$$

<u>Method 4:</u> Thermal time was calculated using the SWB approach, combined with photoperiod and temperature factors, similar to the SUBSTOR approach:

$$GDD = \sum\left(\frac{T_x + T_n}{2} - T_b\right) * RDLFTI * RTFTI \tag{7}$$

<u>Method 5:</u> Thermal time required for tuber initiation was calculated using the standard SWB approach, but the mean temperature in the thermal time calculation was weighted according to Equation 3.

<u>Method 6:</u> For this method thermal time was calculated by using the weighted mean temperature method, combined with a relative photoperiod factor for tuber initiation:

$$TEMPM = (0.25 * T_x + 0.75 * T_n) * RDLFTI \tag{8}$$

<u>Method 7:</u> Daily thermal time for tuber initiation was calculated using a mean weighted temperature and relative temperature for tuber initiation factor and relative photoperiod factor for tuber initiation as follows:

$$TEMPM = (0.25*T_x + 0.75*T_n)*RDLFTI*RTFTI \quad (9)$$

The results from the different calculation methods for the five data sets are presented in Table 1. The SWB method corrected by a relative day length factor (RDLFTI) gave good estimations of the cumulative thermal time required from emergence to tuber initiation. The required day degrees ($^oC\ d^{-1}$) to TI for the five data sets ranged from 344 to 376, with a CV of only 3.8%. This gives a maximum range of 32 $^oC\ d^{-1}$ and standard deviation (SD) of 13.4 $^oC\ d^{-1}$, which represents a SD of less than one day between the different data sets. This is a substantial improvement on the standard SWB method, for which the range was 70 $^oC\ d^{-1}$, with a standard deviation (SD) of 28.5 $^oC\ d^{-1}$.

The above results strongly suggest that the ability of the SWB model to correctly simulate the onset of tuber initiation could be improved by incorporating the effect of photoperiod. The next step would be to build the suggested changes into SWB and to evaluate whether the suggested improvements will indeed improve model simulations of crop growth in diverse growing conditions. This approach assumes that the time of tuber initiation is the most critical factor in determining the partitioning of assimilates, as well as the rate and duration of tuber growth. However, photoperiod and temperature may also affect growth and development after tuber initiation and may need to be incorporated as more knowledge is gained.

Table 1: Thermal time required for tuber initiation estimated according to seven different methods, namely, SWB, SWB*RDLFTI, SWB*RDLFTI*RTFTI, TEMPM, TEMPM*RDLFTI, TEMPM*RDLFTI*RTFTI, and SUBSTOR for potato cultivar BP1 grown at different localities during autumn and spring seasons.

Season	Year	SWB	SWB*RDLFTI	SWB*RDLFTI*RTFTI	TEMPM	TEMPM*RDLFTI	TEMPM*RDLFTI*RTFTI	SUBSTOR
Autumn	2005	355	345	331	338	328	314	17
	2000	399	376	376	378	356	356	16
	1999	381	348	347	349	319	318	15
Spring	2004	362	344	301	338	321	296	15
	2000	425	348	252	371	304	220	16
Mean		384	352	321	355	326	301	15.8
SD		28.5	13.4	47.3	18.7	19.1	50.7	0.8
CV		7.4	3.8	14.7	5.3	5.9	16.7	5.2

SD = Standard deviation.
CV = Coefficient of variation.

Conclusions

Frequent growth analyses were conducted on plant samples collected from three different localities, according to plan. SWB model simulations were run for each data set and model outputs were compared to the growth analyses data. Comparison of growth analysis data with SWB simulation results indicated that model performance was generally good if the crop parameters corresponded with the growing season. For example, SWB simulated crop growth of Darius in a summer planting at Petrusburg well when summer crop parameters were used. However, if the same crop parameters were used for a different growing season (e.g. autumn season at Petrusburg), model performance was poor. These results confirm the limitation of SWB not being able to accommodate the effects of different growing seasons on potato crop growth, development and yield.

The potato is photoperiod sensitive, as it influences the rate of growth and development of the crop. Short days and cooler temperatures promote tuber initiation, while long days and higher temperatures postpone tuber initiation. Once tuber initiation has started, more assimilates are partitioned to the reproductive parts and less to the canopy. Depending whether tuber initiation is early or late, this will impact on dry matter production and distribution, which will determine the canopy size and final tuber yield.

Models should be able to accommodate the effects of photoperiod on growth in order to ensure accurate simulations. The SWB model is a generic model, which was not specifically developed for potatoes, but has been used successfully for the irrigation management of this crop. Improvements to SWB in order to accurately simulate plant growth and water usage in different environments will widen the application value thereof. It is, therefore, proposed that an algorithm that takes the effect of photoperiod into account be incorporated into SWB.

From the results presented above it can be concluded that all the objectives set for the year were attained. This first modelling attempt only focussed on the SWB model as an irrigation scheduling tool for potatoes. However, the collected data sets could also be very valuable if the need arise to calibrate and validate other potato specific growth models for locally produced potato cultivars. Such models can be very useful for planning and scenario analysis purposes in the hands of decision and policy makers. The divergent conditions under which potatoes are grown in SA, and the acute shortage of potato agronomists, dictates the use of modelling as one of the few remaining viable options for solving production problems in the future.

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REPORT YEAR 2006-8

GOAL

To investigate the effect of climate and production practices on the growth, development and yield of potatoes.

ABSTRACT - 2008

In South Africa, potatoes are produced in different geographical areas with a wide range of soils and climatic conditions. This requires cultivar and area specific production programmes in order to produce good yields of high quality. The most important environmental factors influencing potato yield and quality are radiation, temperature and day length. Crop growth and yield responses to different environments were studied at three localities (Dendron, Petrusburg and Bultfontein) over the past four years. Complete data sets containing daily weather data, growth analyses data and final tuber yields were recorded for each location.

The collected data clearly illustrated that crop growth and yields varied substantially for the different localities, growing seasons and cultivars. Many interrelated factors affect crop growth, development and tuber yield, which often make it difficult to predict crop response to a specific environment. Crop models are useful tools to help us understand the mechanisms involved and to predict how potato growth and yield will respond to a certain set of conditions. Such models are useful for management, planning, policy making and scenario analyses. In practice, crop growth models can, for example be used to estimate yield potential for a certain production area.

All collected information was collated in a complete database and can be used to validate or improve existing crop models. As an example, the existing SWB irrigation management model has been improved to accommodate the effects of photoperiod on potato growth, water use and yield. It is foreseen that the data will also be very useful for the evaluation of potato-specific models, such as SUBSTOR, under local conditions. Such models can be useful to estimate yield potential and identify yield-limiting factors. This approach has been applied successfully in other parts of the world, such as Europe and the USA.

OPSOMMING (Afrikaans) - 2007

Plantmonsters vir groeianalises is gereeld vanaf drie lokaliteite geneem, naamlik Dendron, Petrusburg and Bultfontein. Die drie lokaliteite verteenwoordig verskillende groeiseisoene (winter, somer en herfs) en drie cultivars is gebruik (Darius, BP1 and Mondial).

Die versamelde data het aansienlike verskille getoon in die groeitempo's en finale loofbedekking, knolopbrengste en totale droëmateriaal opbrengste wat verkry is. Hierdie verskille was te wagte en kan hoofsaaklik toegeskryf word aan cultivarverskille, asook die effek van omgewing.

Hierdie groeianalise resultate benadruk die feit dat verskeie interafhanklike faktore aartappel groei, ontwikkeling en knolopbrengs bepaal. Die invloed van hierdie faktore is gekompliseerd en dikwels moeilik om te verstaan. Gewasmodelle verskaf aan ons een van die beste hulpmiddels om die meganismes wat betrokke is te help verstaan. Dit kan verder ook gebruik word om te voorspel hoe aartappelgroei en opbrengs sal reageer op 'n sekere kombinasie van eksterne faktore.

Die SWB model is primêr ontwikkel as 'n besproeiing skedulering hulpmiddel, maar simuleer ook gewasgroei en opbrengs. Die model is in die verlede al suksesvol gebruik om besproeiing by aartappels te simuleer, hoewel dit nie 'n toegewyde aartappel model is nie. Een van die beperkings was dat SWB nie voorsiening gemaak het vir fotoperiode sensitiewe gewasse nie. Aartappels is egter fotoperiode sensitief, aangesien daglengte die tempo van gewasgroei en ontwikkeling beïnvloed. Om hierdie probleem te oorkom, is verskillende stelle gewasgroei parameters in die model gebruik vir verskillende seisoene. Dit het egter nie altyd akkurate simulasies verseker nie en daar is voorgestel dat SWB verbeter moet word om te verseker dat gewasgroei en waterverbruik meer akkuraat in verskillende omgewings voorspel kan word met 'n enkele stel parameters per cultivar.

'n Eerste poging is aangewend om 'n algoritme wat die effek van fotoperiode in ag neem, in SWB in the bou. Die SUBSTOR model se benadering tot fotoperiode is gevolg. Die einddoel is om een stel gewasparameters per cultivar te hê wat akkurate simulasies in 'n verskeidenheid van omgewings sal verseker. Voorlopige resultate na afloop van die verbeteringe was belowend en het getoon dat gewasgroei simulasies aansienlik verbeter het, veral vir 'n herfs seisoen wat voorheen problematies was. Verdere evaluasies en moontlike modifikasies mag egter nodig wees om te verseker dat die verbeterde SWB model akkurate simulasies onder 'n wyer reeks klimaatstoestande en vir 'n verskeidenheid cultivars sal lewer. Daar word geglo dat indien hierdie verbeteringe suksesvol is, dit die toepassingswaarde van die model aansienlik sal uitbrei.

Die huidige benadering neem aan dat fotoperiode die belangrikste faktor is by die bepaling van knolinisiasie. Ons weet egter dat temperatuur ook 'n belangrike rol daarin kan speel. Dit mag gevolglik nodig wees om die effek van temperatuur op die aanvang van knolinisiasie ook aan te spreek.

Die gevolgtrekking kan gemaak word dat al die doelwitte wat vir die afgelope jaar gestel is, wel bereik is. As eerste stap is daar gepoog om die SWB model vir aartappels te verbeter. In die toekoms kan die groeianalise data wat in die uitvoering van hierdie studie ingesamel is, ook waardevol aangewend kan word om toegewyde aartappelmodelle te kalibreer en valideer vir Suid-Afrikaanse cultivars en toestande.

SUMMARY

Plant samples for growth analyses were frequently collected from three localities, namely Dendron, Petrusburg and Bultfontein. The three sites represented different growing seasons (winter, summer and autumn) and three cultivars were used (Darius, BP1 and Mondial).

The collected data showed substantial variation in crop growth rates and final values obtained for canopy size, tuber yields and total dry matter yields. These variations were to be expected and could mainly be attributed to cultivar differences, as well as the effect of growing season.

These growth analysis results highlighted the fact that many interrelated factors affect potato crop growth, development and tuber yield. The effects of these factors are complicated and often difficult to understand. Crop models provide us with one of the best tools to help understand these mechanisms involved, as well as to predict how potato growth and yield will respond to a certain combination of external factors.

The SWB model is primarily an irrigation scheduling tool, but also simulates crop growth. It has previously been used successfully to schedule potatoes, although it is not a dedicated potato model. One limitation of SWB was that it did not cater for the effect of photoperiod on crop growth. The potato is photoperiod sensitive, which influences the rate of crop growth and development. To overcome this problem, different sets of crop parameters were used for different seasons. This did not always work well, and improvements to SWB were proposed in order to more accurately simulate plant growth and water usage in different environments, using a single set of crop parameters per cultivar.

A first attempt was made to build an algorithm into the SWB model that would take the effect of photoperiod into account. The SUBSTOR model approach was followed, with the ultimate goal to be able to use only one set of crop parameters per cultivar that would work well in a range of different environments. Initial results obtained after these modifications indicated that the accuracy of crop growth simulations was substantially improved, especially for an autumn planting, which proved to be problematic in the past. However, further evaluation and improvements are necessary to ensure that the adapted SWB model will perform well for all the

cultivars used and under a wider range of climatic conditions. It is believed that if successful, this will broaden the application value of the model.

The current approach assumes that photoperiod is the overriding factor that determines the time of tuber initiation. However, we know that temperature also plays a major role in this and it may also be necessary to incorporate temperature effects on tuber initiation in future.

It can be concluded that all the objectives set for the year were achieved. As a first step the focus was only on the improvement of the SWB model for potatoes. In future the collected field data sets will be valuable for the calibration and validation of other potato specific growth models for local conditions and potato cultivars.

OBJECTIVES FOR 2006/2007

The objectives for the reporting period were to conduct frequent destructive harvests during the growing season, with the aim of investigating the effect of different environments (climatic conditions) on potato growth, development and yield. The growth analyses were planned for potatoes produced in three production areas, namely Dendron (winter planting), Bultfontein (autumn planting) and Petrusburg (summer planting).

A second objective was to investigate the possibility of improving the SWB model by incorporation photoperiod into the model.

PROGRESS REPORT

Introduction

In South Aftrica potatoes are produced almost all year round in the various production areas. The result thereof if that the crop is exposed to diverse climatic conditions, which will influence crop growth and development. As a consequence thereof, substantial differences in yield and quality are often obtained from different production areas. From a scientific point of view, it is often difficult to explain or predict crop response to a certain set of conditions. Crop models can be very useful tools that could help scientists understand and predict possible outcomes in this regard.

It is well known that the potato is a cool weather crop, which is grown under sub-optimal conditions in most production regions of South Africa. Unfavourable temperatures and photoperiods are the most important climatic factors that can influence potato growth, yield and quality. Temperature is the main driving variable that influences the rate of crop growth and development and, therefore, it also determines the onset and duration of different growth stages (emergence, tuber initiation, bulking and senescence) and partitioning of assimilates to different plant parts (leaves, stems, roots and tubers). Daylength or photoperiod influences the onset of tuber initiation and the length of the growing season of potatoes (Kooman and Haverkort, 1996). The onset of tuber initiation plays a very important role in crop growth and development and finally on tuber yield. Tuber initiation is postponed by high temperatures and long days during the vegetative crop growth stage.

In order to predict potato crop response to the different environments resulting from the various production areas, it is essential to understand the effect of these environments on the crop. Science has proven in the past that modelling is one of the best approaches to try to describe plant response to these interrelated factors.

SUBSTOR (Ritchie *et al*, 1995) and LINTUL (Kooman & Haverkort, 1995) are examples of two potato-specific models that were developed word-wide. The complexity and purpose of models vary tremendously. LINTUL Potato is an example of a model that is aimed at predicting crop yields accurately, but it is mainly used by scientists. On the other hand, SUBSTOR, which forms part of the DSSAT suite of models, has been tested and used widely for crop growth and yield predictions. The latter model is simpler and easier to use, with only a limited number of inputs required. The SWB model (Annandale *et al*, 1999) was developed locally as a user friendly irrigation scheduling tool. Although not a dedicated potato model, it has previously been calibrated and successfully used for the irrigation management of a range of potato cultivars in different regions of South Africa. However, as it is not a dedicated potato model, one important factor, namely photoperiod, is not taken account of. As a result, different sets of crop parameters had to be developed for different growing seasons and planting dates to ensure accurate simulation of crop growth and water use. However, this detracts from the application value of the model and ideally a universal set of parameters per cultivar should be used. For that to be possible, the effect of photoperiod on crop growth and development must be incorporated in SWB.

Potentially, any good potato crop growth model could be used to help us understand crop response to the above-mentioned climatic variables. Independent of which model is used, actual crop growth data is essential for the calibration and validation of any crop growth model. The growth analysis data collected in this study is essential for the calibration and validation of such growth models. The purpose of the current research work was, therefore, to build up a database of plant growth and weather data from diverse production areas for the calibration and validation of crop models.

Materials and Methods

Data collection

Trials were not specifically planted for this study, but plants were rather sampled from existing commercial potato plantings of producers in three production areas. Plants were frequently sampled throughout the growing season to follow the crop growth curve. These production areas were selected to represent diverse growing seasons and different cultivars were used. In the Dendron production area (Limpopo province) the cultivar BP1 was used in a winter / spring season (planted in June 2006). Two locations in the Free State province were used, namely Petrusburg and Bultfontein. At Petrusburg the cultivar Darius was used in a summer season (planted August 2006) and at Bultfontein the cultivar Mondial was used in a summer / autumn season (planted January 2007).

Plant samples were taken about monthly at Dendron, while for Petrusburg and Bultfontein samples were collected at fortnightly intervals. At each sampling time point three replicated samples were taken from randomly selected positions in the field. For each sample all the plant material from a 1 m row length was harvested. The sample area ranged from 0.88 to 0.9 m^2 each, depending on the row spacing used. Samples were carefully packed and transported to Pretoria by courier. Growth analyses were subsequently performed on the collected samples, including the following measurements: leaf area, fresh leaf, stem and tuber mass. Plant samples were then dried, whereafter dry leaf, stem and tuber masses were determined. For each of the sites hourly weather data was collected throughout the growing seasons, using automatic weather stations. The growth analyses and weather data were collated in a database for possible inputs to future model simulations.

Modelling

During the report period, a first attempt was made to incorporate photoperiod sensitivity into the SWB model with the aim of improving model accuracy for potatoes grown in diverse climatic locations. The progress and preliminary findings are reported here.

SWB model simulations were run for some of the sites and seasons where plant growth data had been collected. The collected plant growth data was processed and used for comparison with model simulations.

Results and Discussion

Growth analyses

The measured data for leaf areas index (LAI), tuber and total dry matter yields for the different locations and cultivars are presented in Figures 1 to 3. Fresh masses of the plant foliage components followed trends similar to the dry mass yields and are, therefore, not presented.

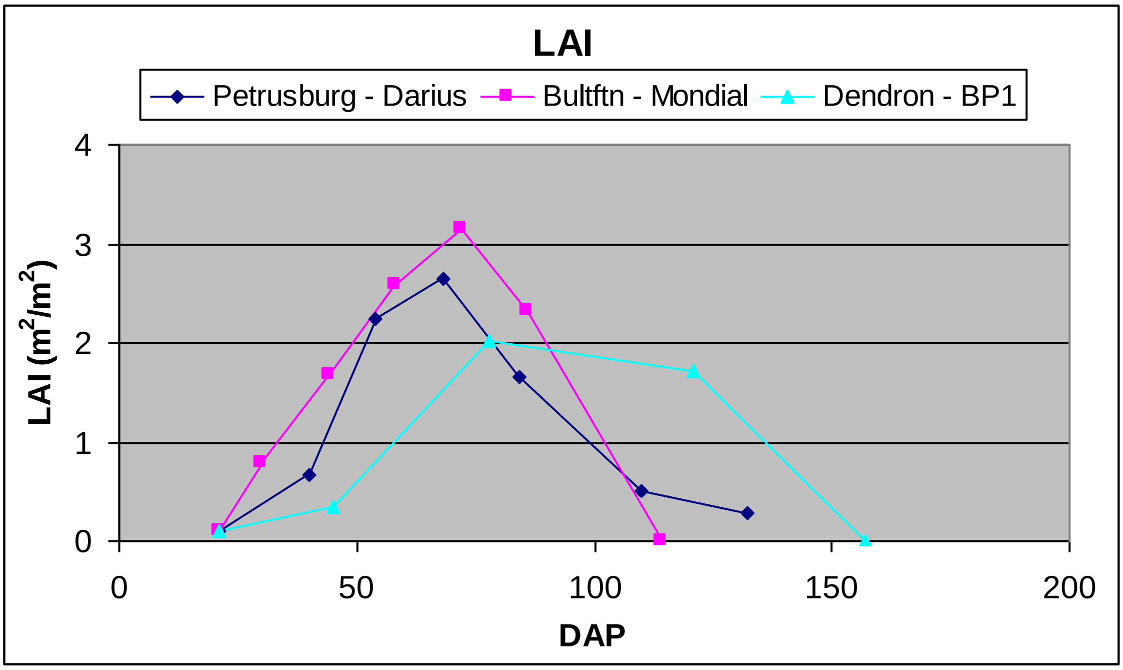


Figure 1 Leaf areas index (LAI) values recorded over the growing season for three cultivars (Darius, Mondial and BP1) grown at three different localities and seasons (Petrusburg – summer, Bultfontein – autumn, Dendron – winter).

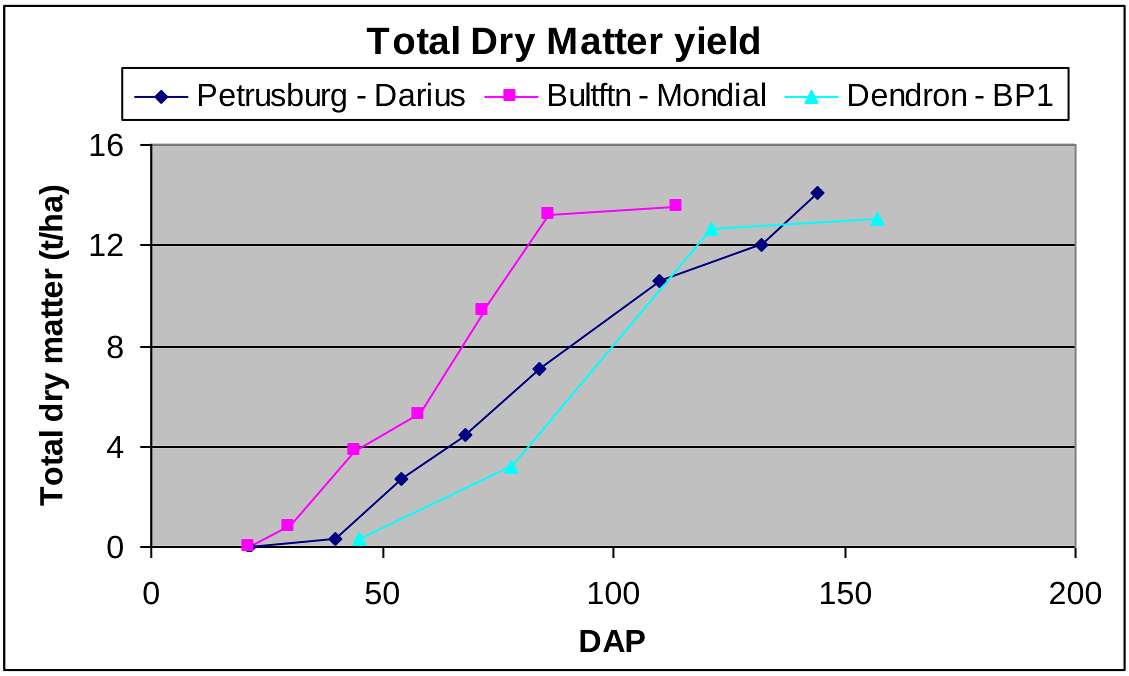


Figure 2 Total dry matter (TDM) yields recorded over the growing season for three cultivars (Darius, Mondial and BP1) grown at three different localities and seasons (Petrusburg – summer, Bultfontein – autumn, Dendron – winter).

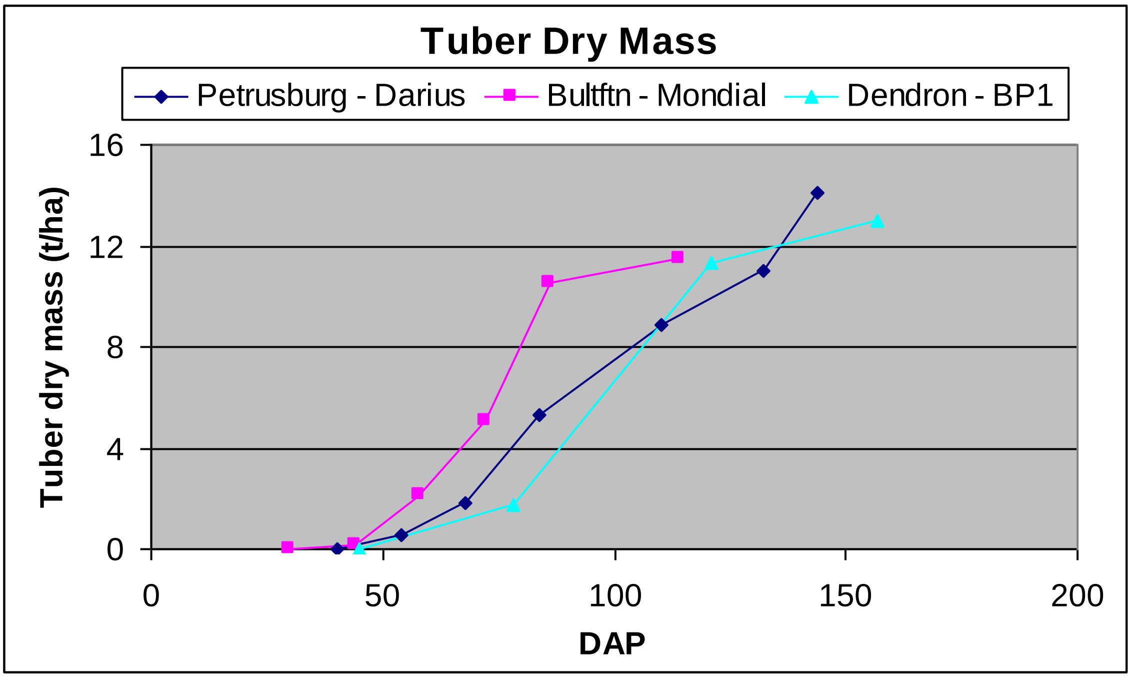


Figure 3 Tuber dry mass yields recorded over the growing season for three cultivars (Darius, Mondial and BP1) grown at three different localities and seasons (Petrusburg – summer, Bultfontein – autumn, Dendron – winter).

The graphs (Figures 1 to 3) show substantial cultivar / environment differences in the rate of growth and the final maximum values obtained for all the measured variables. These differences can firstly be ascribed to cultivar characteristics, e.g. late maturity cultivars (long growing season), such as Darius, usually takes longer to reach maximum canopy size. Late varieties usually also senesce later than medium or early varieties, if grown under the same climatic conditions.

A second explanation for the observed differences is the difference in environments under which the three cultivars were grown. At Dendron the crop was planted when days are at their shortest and daily temperatures are low (June). This resulted in slow initial growth rates, which accelerated as temperatures started to rise towards summer. Days were also short (<12 hours) during the vegetative stage, which was conducive to early tuber initiation. Conditions at Petrusburg was similar to those for Dendron at planting (late August/September), except that days were already longer and temperatures higher. This might have resulted in later tuber initiation and larger canopies. At Bultfontein the crop was planted in late summer/autumn (late January), when temperatures were very high and days long, which probably stimulated fast initial crop growth. The crop then grew into a period of shorter and cooler days, which probably resulted in earlier tuber initiation and a shorter growing season.

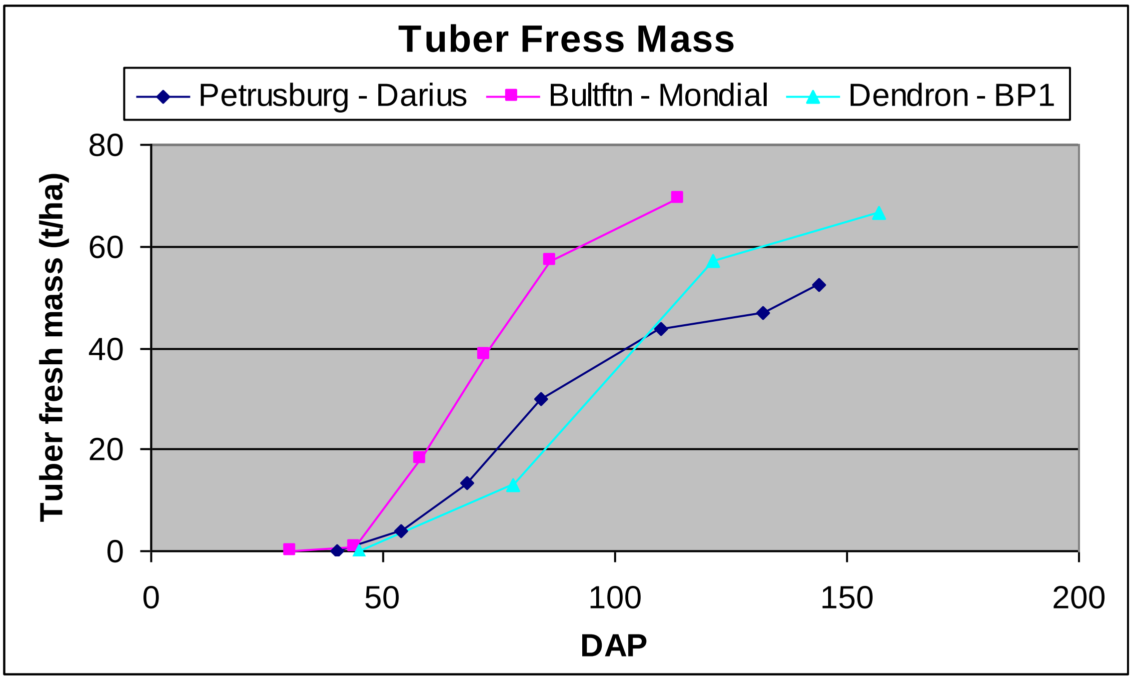


Figure 4 Fresh tuber mass recorded over the growing season for three cultivars (Darius, Mondial and BP1) grown at three different localities and seasons (Petrusburg – summer, Bultfontein – autumn, Dendron – winter).

There if often also in interaction between the effects of cultivar and season, as cultivars may react differently in different seasons. Some cultivars, for example Darius and Vanderplank, may not perform well in cooler seasons, while others are very sensitive to high temperatures. From this it becomes clear that the factors affecting crop growth, development and tuber yield are often interrelated and complicated to understand. A modelling approach is, therefore, one of the best ways of trying to understand the mechanisms involved. Models can also be useful for predicting potato growth and yield response to a certain combination of conditions.

Fresh tuber yields obtained for the three locations and different cultivars are illustrated in Figure 4. Under the specific set of conditions Mondial produced the highest final fresh tuber mass, followed by Darius and BP1. If compared to the dry tuber yields (Figure 3), it is interesting to note that cultivar differences were minor for final dry tuber yields. This can mainly be ascribed to cultivar differences in tuber dry matter percentages (DM%). Darius had the highest tuber DM%, followed by BP1 and Mondial.

All the growth analyses and weather data collected from the different locations were collated in a database for possible future use as inputs to simulation models.

SWB Model

The sensitivity of potato growth and development to photoperiod (and temperature) was explained in detail in the 2006/07 progress report. Therefore, these effects are only briefly summarised here.

It is well-known that shorter days and cooler temperatures usually hasten potato tuber initiation, whereas longer days and high temperatures postpone it. The time of tuber initiation onset is critical for canopy growth, development and final tuber yields. Once the crop has commenced initiating tubers, more assimilates will be partitioned to tubers and less to vegetative parts. Therefore, in short day conditions tubers are initiated at the cost of canopy growth, resulting in a small canopy which cannot sustain high tuber yields. This is typical of autumn plantings, when day lengths and temperatures are declining dramatically towards winter. On the other hand, a later commencement of tuber growth (due to long day conditions) leads to an extension in crop growth and increased yields, which results from a combination of prolonged leaf growth and slower leaf senescence (Kooman, 1995). SUBSTOR, one of the dedicated potato crop models (Ritchie *et al*. 1995), suggests 12 hours as the critical photoperiod for tuber initiation in potatoes. From experience it is known that planting in summer is conducive to later tuber initiation due to longer days (>12 hours during vegetative stage), while planting in autumn will result in shorter days (<12 hours during the vegetative stage), which will enhance tuber initiation. Temperature also plays a role in the onset of tuber initiation and these factors are, therefore, interrelated.

The possible approaches employed by dedicated potato models to accommodate photoperiod were reported on previously. Seven different methods of calculating the thermal time required to reach tuber initiation were discussed (Kagabo, 2006). Two of these methods showed the highest accuracy with regard to calculating the number of days between emergence and tuber initiation, compared to measured data from five historical data sets, collected over several seasons and locations. The first is the SUBSTOR approach, in which the thermal time required to tuber initiation is calculated as a function of relative temperature and photoperiod factors. Although the effects of photoperiod and temperature on growth and development of potato are interrelated and difficult to separate (Van Dam *et al*., 1996), initial results indicated that photoperiod inclusion might have the largest impact on SWB accuracy. It was, therefore, decided to first focus on the inclusion of photoperiod in SWB, which might be followed by temperature inclusion at a later stage.

In SUBSTOR a photoperiod factor for tuber initiation (RDLFTI) was introduced to integrate the photoperiod effect as a modifier of tuber induction, which is calculated as follows:

$$\text{RDLFTI} = \begin{cases} 1 & ;\ \text{PHPER} \leq 12 \\ (1 - \text{P2}) + \text{P2}/144\,(24 - \text{PHPER})^2 & ;\ \text{PHPER} > 12 \end{cases} \qquad (1)$$

where,

RDLFTI is a relative day length factor for tuber initiation, PHPER is photoperiod (h), which is calculated from the latitude and day of year, according to the method described by Campbell & Norman (1998), and P2 is a dimensionless genetic coefficient for cultivar sensitivity to photoperiod.

Under optimal growing conditions, RDLFTI is used to calculate the tuber induction index (TII) on each day after emergence as a function of the relative temperature factor for tuber initiation (RTFTI) as follows:

$$CTII = RDLFTI * RTFTI \quad (2)$$

where,

TII is tuber induction index and CTII is cumulative tuber induction index. As soon as a critical CTII value is reached, the crop is deemed to have reached tuber initiation stage.

Although this method seemed to be promising, it cannot be easily accommodated in a generic model such as SWB without major re-programming and it was consequently not used in its current form.

The second promising method of calculating the thermal time required for tuber initiation was a combination of the standard SWB approach (equation 3) and a relative photoperiod factor for tuber initiation (equation 4), similar to that used by SUBSTOR.

$$GDD = \sum \frac{T_x + T_n}{2} - T_b \quad (3)$$

$$GDD = \sum \left(\frac{T_x + T_n}{2} - T_b \right) * RDLFTI \quad (4)$$

where,

Tx is the daily maximum temperature, Tn is the daily minimum temperature and Tb is the base temperature below which there is no growth and development. RDLFTI is a relative day length factor for tuber initiation, according to the method in SUBSTOR.

This method differs from the standard SWB method of calculating thermal time (equation 3), in which plant development rate increases as a linear function of only the average temperature between a base and an optimal temperature. Under short day conditions (<12 hours photoperiod) the RDLFTI = 1 and accumulation of thermal time continues normally. When the photoperiod increases to more than 12 hours, RDLFTI < 1 and the rate of thermal time accumulation is slowed down. Consequently, it takes longer to reach the critical thermal time for tuber initiation.

Initial results suggested that the ability of the SWB model to correctly simulate the onset of tuber initiation could be improved by incorporating photoperiod, according to the method described above. The suggested programming changes to SWB were made recently in order to accommodate photoperiod sensitive crops (Figure 5).

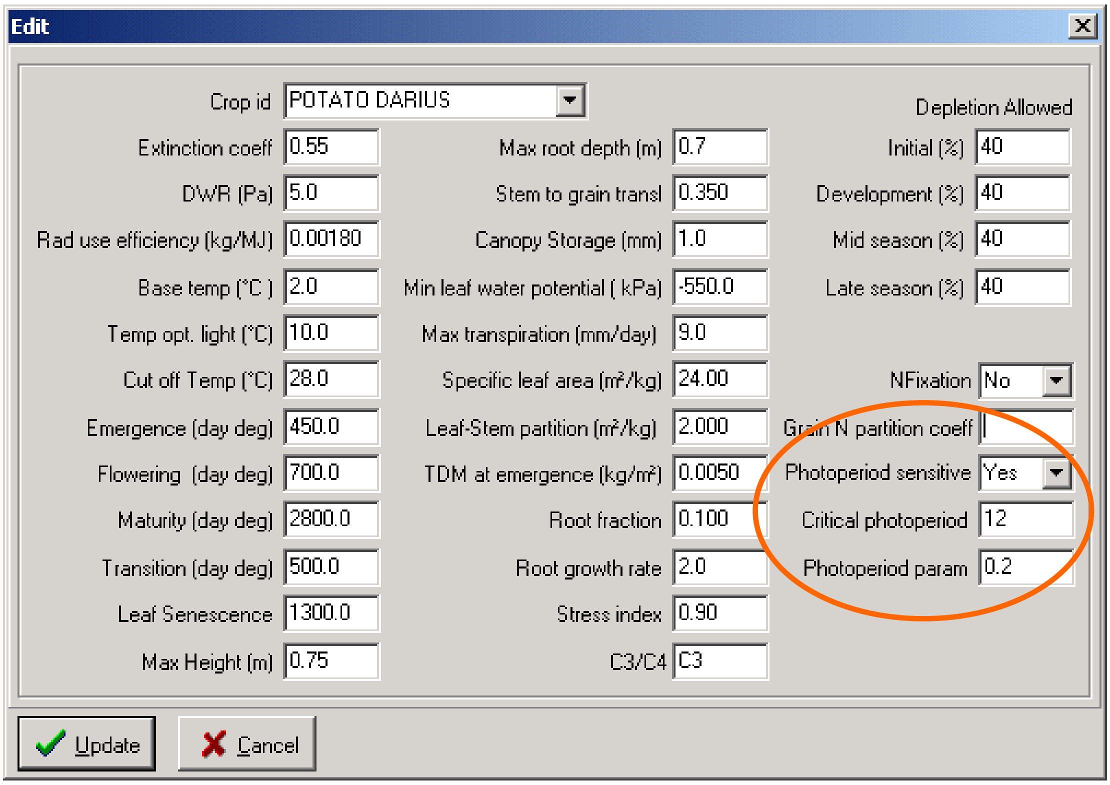
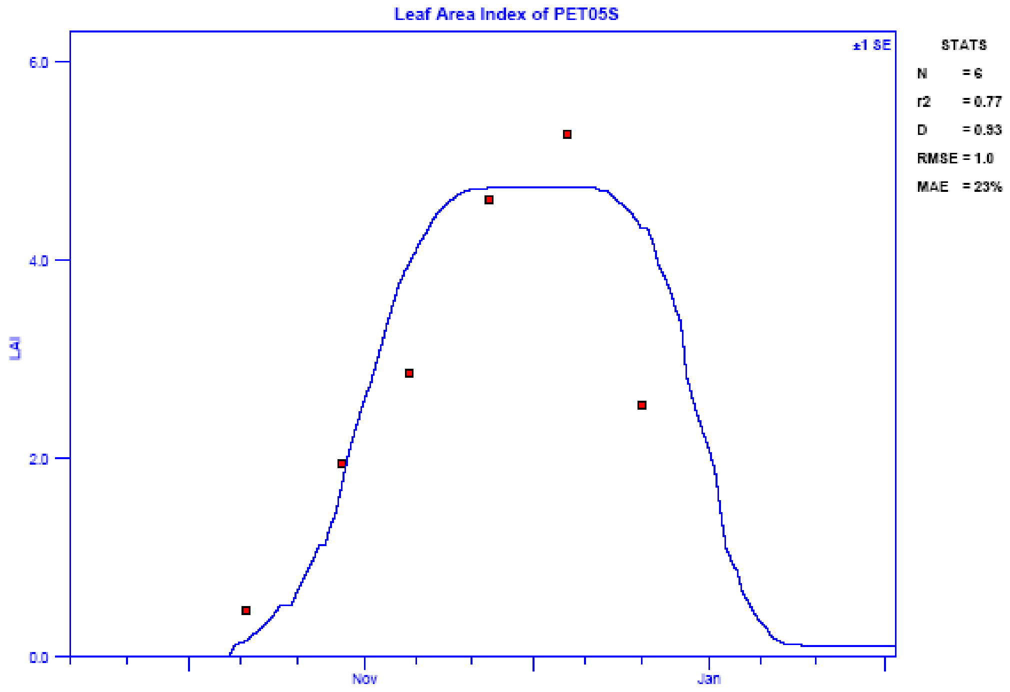


Figure 5: Example of crop parameter input screen, which makes provision for photoperiod sensitive crops, including critical photoperiod and cultivar sensitivity parameter.

After inclusion of photoperiod, SWB was re-calibrated with regard to thermal time requirements for different growth stages to ensure maintained accuracy. Evaluations are currently underway to establish whether the suggested improvements have indeed improved crop growth simulations in diverse growing conditions or seasons.

As an example of the initial progress made so far, model simulations for the cultivar Darius grown in two contrasting seasons (autumn 2005 and summer 2005) during the course of this project are shown and discussed. Model outputs for simulated leaf areas index (LAI), total (top) and tuber (harvestable) dry matter yields, using the universal set of crop parameters with photoperiod effects are presented in Figures 6 and 7. Simulated yield components were compared to actual measurements to evaluate the agreement between simulated and measured values, using four statistical parameters (r^2, Wilmott D-index, RMSE and MAE) (De Jager, 1994).



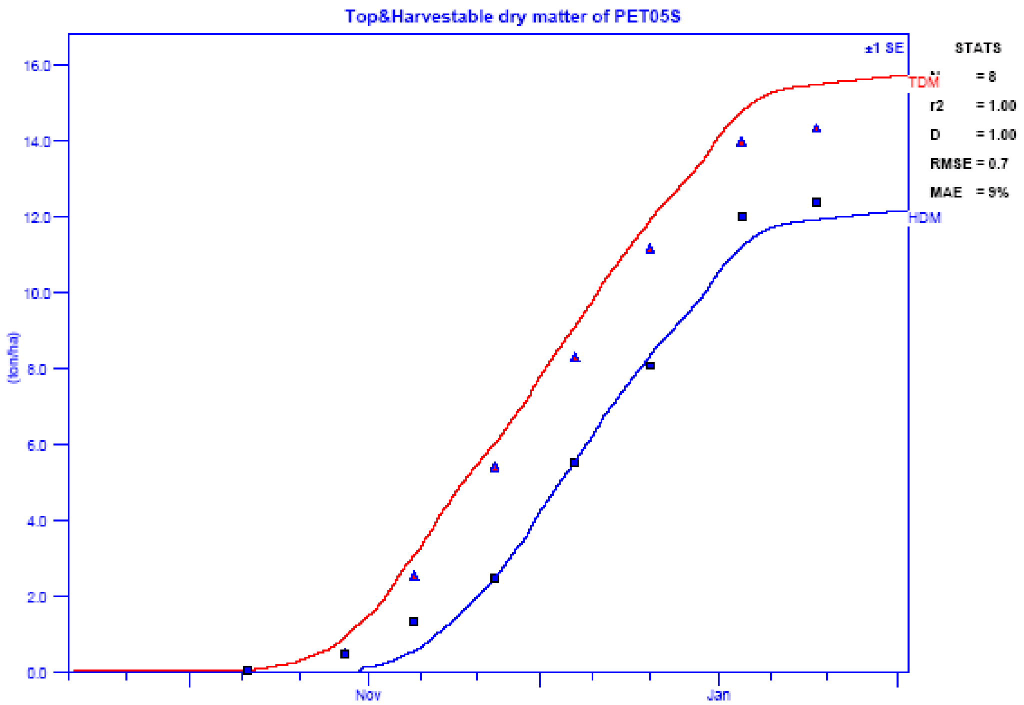


Figure 6 Simulated (lines) and measured results (points) for leaf area index (LAI), tuber (HDM) and total dry matter (TDM) yields for the cultivar Darius during the 2005 summer season at Petrusburg after photoperiod inclusion in SWB. Red lines and points represent total dry matter yields and blue lines and points represent tuber dry matter yields.

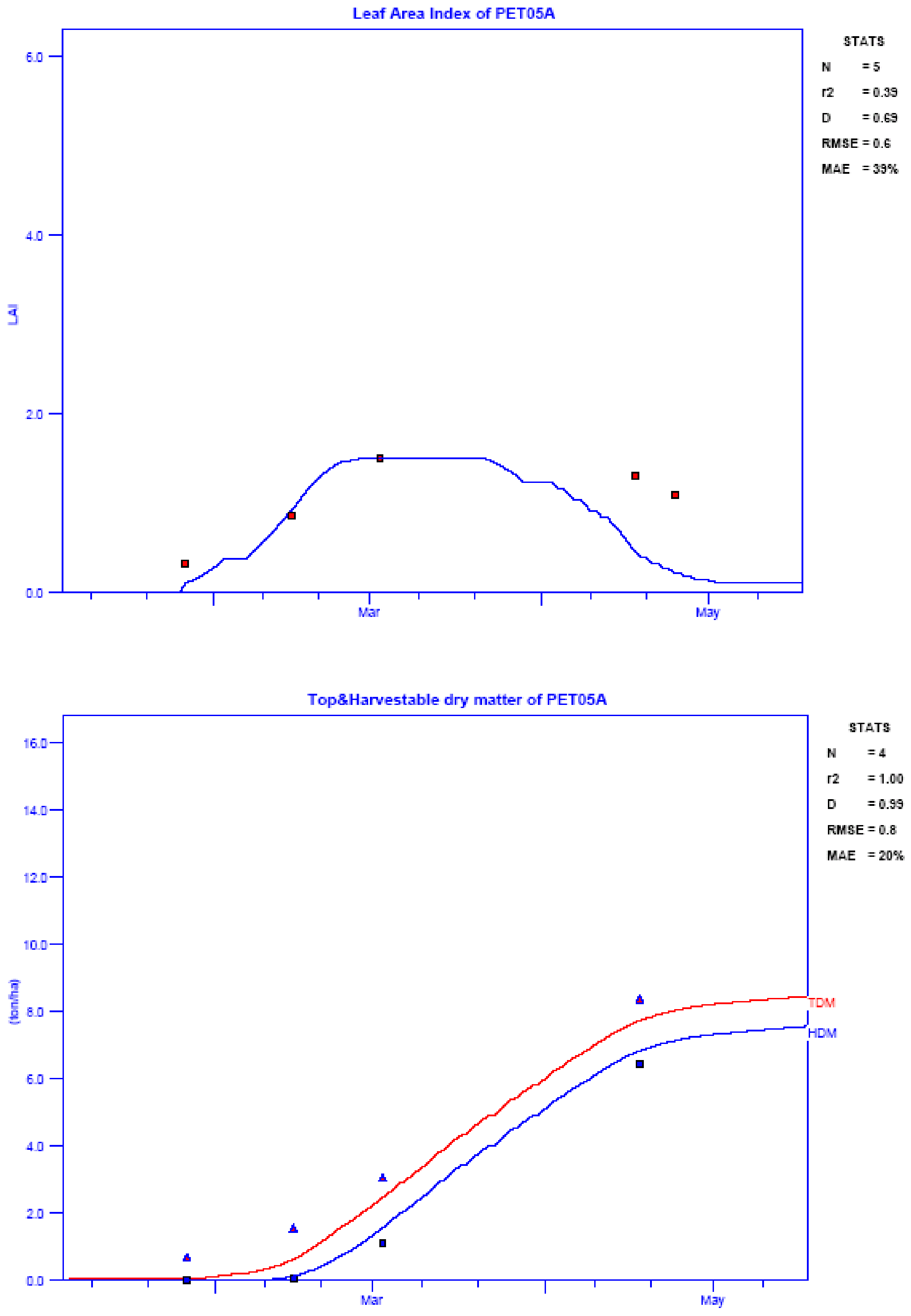
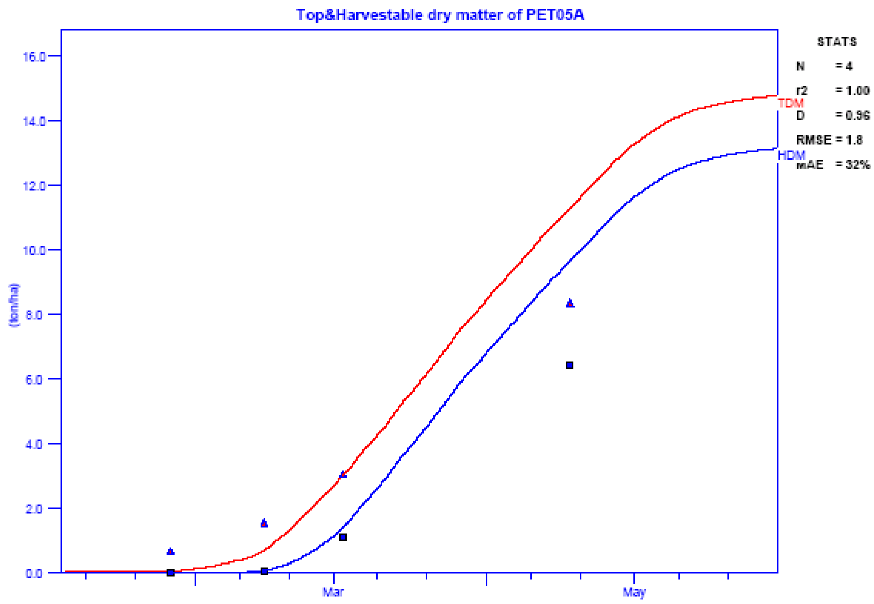


Figure 7 Simulated (lines) and measured results (points) for leaf areas index, tuber (HDM) and total dry matter (TDM) yields for the cultivar Darius during the 2005 autumn season at Petrusburg after photoperiod inclusion in SWB. Red lines and points represent total dry matter yields and blue lines and points represent tuber dry matter yields.

The simulated values for LAI, tuber and total dry matter yields generally compared well with measured values collected for the summer season at Petrusburg (Figure 6). These simulation results remained virtually unchanged from those when the summer crop parameters for Darius were used.

Similarly, reasonable simulation results were obtained for the autumn 2005 season at Petrusburg (Figure 7), after incorporation of photoperiod in SWB. Especially the simulation of tuber and total dry matter yields improved substantially, compared to the results obtained previously, when the summer crop parameters for Darius (without photoperiod effect) were used (Figure 8). Canopy size (LAI), however, was not simulated that well, although it improved from the initial simulations (Figures 7 and 8).

These preliminary results suggest that the inclusion of photoperiod in SWB could hold the key to the development of a single set of crop parameters per cultivar. This will hopefully enhance the universal applicability of the model for any combination of locality and planting time.



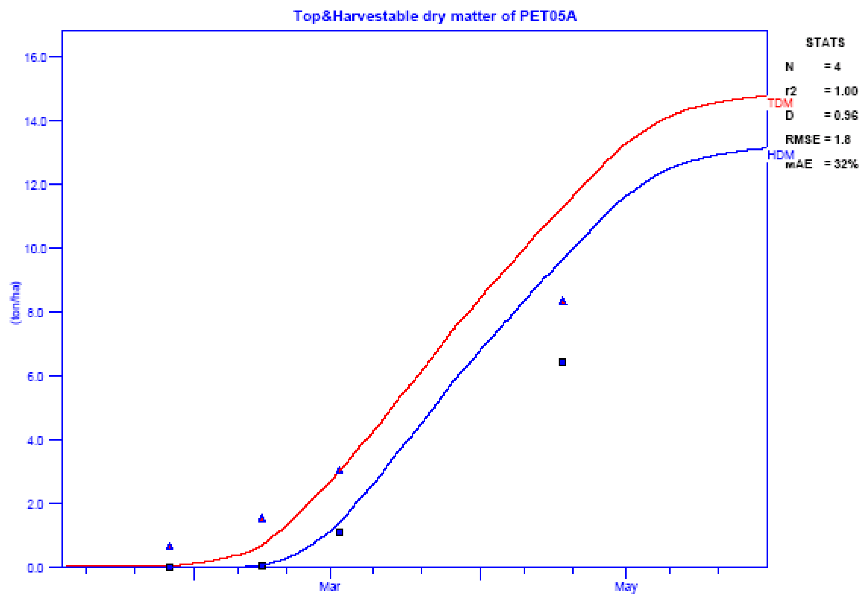


Figure 8 Simulated (lines) and measured results (points) for leaf areas index (LAI), tuber (HDM) and total dry matter yields (TDM) for the cultivar Darius during the 2005 autumn season at Petrusburg before photoperiod inclusion in SWB. Red lines and points represent total dry matter yields and blue lines and points represent tuber dry matter yields.

Conclusions

Plant samples for growth analyses were frequently collected from three different localities, according to plan. The collected data showed substantial variation in crop growth rates and final values obtained for canopy size (LAI), tuber mass and total dry matter yields. These variations could be attributed to cultivar differences, as well as the effect of different growing seasons.

The growth analysis results highlighted the fact that many interrelated factors affect crop growth, development and final tuber yield. It is often difficult and complicated to understand these processes in the plant. A crop model is one of the best tools that could help us better understand the mechanisms involved and to predict potato growth and yield response to a combination of external conditions.

The SWB model is primarily an irrigation scheduling tool, but also simulates crop growth. SWB has previously been used to schedule potatoes, although it is not a dedicated potato model. One limitation of SWB was that it did not cater for the effect of photoperiod on crop growth. The potato is photoperiod sensitive, which influences the rate of crop growth and development. To overcome this problem, different sets of crop parameters were used for different seasons. This did not always work well, and improvements to SWB were proposed in order to accurately simulate plant growth and water usage in different environments, using a single set of crop parameters.

Recently a first attempt was made to build an algorithm that takes the effect of photoperiod into account into the SWB model. Initial results indicated that the accuracy of crop growth simulations was substantially improved, especially for an autumn planting, which proved to be problematic in the past. Further evaluation is necessary to ensure that the adapted SWB model will perform well for all the cultivars used and under a wider range of climatic conditions. It is believed that if successful, this will broaden the application value of the model.

The current approach assumes that photoperiod is the overriding factor that determines the time of tuber initiation. However, we know that temperature also plays a major role in this and it may also be necessary to incorporate this in future as more knowledge is gained.

It can be concluded that all the objectives set for the year were achieved. As a first step the focus was only on the SWB model as an irrigation scheduling tool for potatoes. The collected field data sets could also be very valuable for the calibration and validation of other potato specific growth models for local conditions and potato cultivars.

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