POTATO POTENTIAL YIELD BASED ON CLIMATIC ELEMENTS AND CULTIVAR CHARACTERISTICS

André Belmont Pereira[1]; Nilson Augusto Villa Nova[2]

[1]Eng. Agrônomo, Prof. Associado, Dep. de Agronomia, UEPG, Ponta Grossa – SP, Fone: (0xx42) 32203777, andre.pereira@pq.cnpq.br

[2]Eng. Agrônomo, Prof. Associado, Dep. de Ciências Exatas, ESALQ/USP, Piracicaba – SP

Apresentado no XV Congresso Brasileiro de Agrometeorologia – 02 a 05 de julho de 2007 – Aracaju – SE

Abstract: There is currently a great deal of interest in estimating crop productivity as a function of climatic elements by means of different crop weather models. In this manuscript an agrometeorological model based on carbon dioxide assimilation maximum rates for C_3 plants, fraction of photosynthetically active radiation, air temperature, photoperiod duration, and crop parameters is assessed as to its performance under tropical climate conditions. Such crop parameters include leaf area and harvest indexes, dry matter content of potato tubers, and crop cycles to estimate potato potential yields. Field data from observed productivity obtained with the cultivar Itararé (IAC-5986), grown under adequate soil water supply conditions at four different sites in the State of São Paulo, Brazil, were used to test the model. The results revealed an excellent performance of the agrometeorological model in study, with an underestimation of irrigated potato productivity less than 10%.
Keywords: modelling, *Solanum tuberosum L.*, climatic elements, crop indexes, yield.

PRODUÇÃO POTENCIAL DA BATATEIRA EM FUNÇÃO DE PARÂMETROS CLIMÁTICOS E FITOTÉCNICOS

Resumo: Há um grande interesse em estudos de estimativa da produtividade de culturas agronômicas em função de elementos climáticos através do uso de diversos modelos agrometeorológicos. No presente estudo, um modelo agrometeorológico baseado em taxas máximas de assimilação de dióxido de carbono para plantas de metabolismo C_3, radiação fotossinteticamente ativa, temperatura do ar, comprimento do dia e parâmetros fitotécnicos, tais como índice de área foliar, índice de colheita, conteúdo de matéria seca dos tubérculos e duração do ciclo fenológico da cultura foi empregado para estimar a produtividade potencial da batateira. Dados de campo obtidos a partir de produtividades observadas com o cultivar Itararé (IAC-5986), sob condições de suprimento adequado de água no solo para quatro localidades distintas do Estado de São Paulo, Brasil, foram utilizados para testar o modelo. Os resultados obtidos revelaram um excelente desempenho do modelo climático em estudo, tendo o mesmo apresentado subestimativas de rendimento potencial inferiores a 10%.
Palavras-chave: modelagem, *Solanum tuberosum* L., elementos de clima, índices culturais, produção.

1. Introduction

Meteorological factors directly influence crop potential productivities. By means of studies on determination techniques for assessing physiological crop responses to environmental factors under field conditions it is possible to come up with mathematical models to estimate crop potential production as a function of meteorological variables. Potato yield improvements might be obtained by increasing net daily photosynthetically radiation through higher solar irradiance or longer photoperiod (STUTTLE et al., 1996).

Knowledge of climatic requirements and its physiological responses to the environment is extremely important to help growers produce high yields with good tuber quality under site-specific atmospheric conditions. Such knowledge aims to provide a scientific support to research programs related to crop weather modelling. The SUBSTOR-Potato model simulated fresh tuber yields ranging from 4 t ha^{-1} to 56 t ha^{-1} due to differences in weather patterns, soils, cultivars, and management practices (BOWEN, 2003).

Similarly to the potential productivity estimation model employed by VILLA NOVA et al. (2005) for sugar cane, we tested the performance of a model based on studies of maximum rates of carbon dioxide assimilation for a C_3 crop species as a function of air temperature, a fraction of global solar radiation flux density, photoperiod duration and leaf area index to estimate the potential productivity of potato crop, cultivar Itararé (IAC-5986), grown under adequate soil water supply conditions at four distinct sites of the State of São Paulo, Brazil. In order to assess the performance of the proposed mathematical model, the estimated values of tuber yield were compared to observed productivity data under irrigation conditions for the studied sites.

2. Material and Methods

The proposed model for the estimation of potato potential yield (EPY), expressed by equation 1, is based upon the preconception that the maximum rate of dioxide carbon assimilation by the plants for production of carbohydrate is related to the active photosynthetically fraction of the solar spectrum (PAR) and air temperature:

$$EPY = 1.27 * 10^{-6} * CDA * LAI * GS * N * C(LAI) * C(T) * HI * 100 / DM \quad (1)$$

where CDA is the carbon dioxide assimilation maximum rates (μL cm^{-2} h^{-1}), LAI is the maximum leaf area index, GS is the number of days of the crop growing season, N is the mean photoperiod or day length duration throughout of the crop growing season (hours), C(LAI) is the correction factor for leaf area index variation over time, C(T) is the correction factor for maintenance respiration, HI is the harvest index, and DM is the dry matter content of the potato tubers (%).

Applying the necessary corrections to the aforementioned equation in order to express the estimates of potato potential yield in tons per hectare per crop cycle, we have:

$$EPY = 1.27 * 10^{-4} * CDA * LAI * GS * N * C(LAI) * C(T) * HI * 100 / DM \quad (2)$$

Without considering HI, the product of the other terms of the equation 2 depicts the estimation of the total dry matter produced by the potato plants, including roots, leaves and shoots. The values of CDA were obtained as a function of the ambient temperature (T) and photosynthetically active radiation (PAR).

PAR, expressed in cal cm^{-2} min^{-1}, was calculated by the equation down below:

$$PAR = \frac{Qg}{60 * N} * \left[0.5 - 0.1 * \frac{n}{N}\right] \quad (3)$$

where Qg is the mean global solar radiation flux density throughout the crop growing season (cal cm^{-2} day^{-1}), N is the mean photoperiod during the crop cycle (hours), and n/N is the mean insolation ratio of the period.
The values of C(T) equal to 0.6 and 0.5 were adopted, respectively, whenever the mean air temperatures throughout the crop growing season were below or above $20^{o}C$. The value of C(LAI) was calculated by the equation as follows:

$$C(LAI) = \frac{1 - e^{-0.8 * LAI}}{2} \quad (4)$$

For potato crop, whose commercial product is the tuber, HI varies from 0.55 to 0.65. For practical purposes, we adopted the mean value corresponding to 0.6 to calculate the final crop production.
The dry matter content of the tubers is intimately related to the tuber specific gravity. Thus, specific gravity (SG) was calculated using the following formula:

$$SG = \frac{Wair}{Wair - Wwater} \quad (5)$$

Dry matter content (DM) of the tubers in percentage, was determined as a function of the specific gravity as follows:

$$DM = 24.182 + 211.04 * [SG - 1.0988] \quad (6)$$

The calculated values of the potential yield obtained by the proposed method were correlated with the observed data from the production fields.

3. Results and Discussion

Making use of the mean values of global solar irradiance, photoperiod duration, photosynthetically active radiation and air temperature along with the maximum rates of carbon dioxide assimilation (data not shown herein), required as the input variables of the proposed model in the current study, potato potential yield for the cultivar Itararé (IAC-5986) was calculated throughout fifteen crop growing seasons at four different regions of the State of São Paulo, Brazil (Tables 1 and 2).
The differences observed on the dry matter content throughout different years and growth periods of the potato crop (Table 2) might be ascribed to climatic variations on tuber specific gravity. Figure 1 indicates that both accuracy, given by the trend line, and the exactness of the model, demonstrated by the dispersion of the data around the fitted 1:1 line of the estimates, were rather satisfactory. The value of *c* was higher than 0.93, exceeding, however, values of *d* considered as satisfactory, whose lower limit is of 0.75.
Tuber potential yields calculated by the agrometeorological model in study and potential yields harvested from the production fields were highly correlated, since the statistical analysis shows that over 92% of the potential yield variations can be explained by the calculated values. The corresponding values of tuber dry matter estimated by the model varied from 16.8 to 35.7 t ha^{-1}, whereas those of tuber dry matter obtained from the production areas with an adequate soil water supply were within the range varying from 17.5 to 39.0 t ha^{-1} (Table 2). The larger difference between measured and estimated tuber yield was observed for the growing period September through January of the years 1998 and 2003, when the model slightly underestimated and overestimated potential yield at 3.3 and 3.5 t ha^{-1}, respectively.

Table 1. Climatic elements throughout different years and growth periods of the potato crop, cultivar Itararé (IAC-5986), grown at Itararé, Tatuí, Piracicaba, and São Manuel, State of São Paulo, Brazil.

Site	Year	Growth period	Cycle (days)	T (°C)	n/N	Qg (Ly min^{-1})	PAR (Ly min^{-1})
Itararé	1985	Mar./Jun.	100	16.5	0.57	0.567	0.253
	1993	Sept./Jan.	137	18.0	0.45	0.617	0.279
	1994	Mar./Jul.	114	16.0	0.54	0.549	0.244
	1997	Feb./Jul.	140	16.5	0.57	0.590	0.260
	1998	Apr./Aug.	112	15.0	0.57	0.543	0.241
	1998	Sep./Jan.	117	18.0	0.33	0.534	0.249
	1999	Mar./Jul.	126	15.6	0.55	0.557	0.248
	2000	Nov./Mar.	133	20.2	0.49	0.649	0.293
	2001	Mar./Jul.	102	16.9	0.55	0.563	0.249
	2003	Sep./Jan.	98	17.5	0.43	0.597	0.271
	2005	Mar./Jul.	133	16.7	0.58	0.575	0.254
	2005	Oct./Mar.	122	18.7	0.41	0.594	0.273
Tatuí	2001	Sep./Jan.	115	22.8	0.55	0.689	0.305
Piracicaba	1989	Oct./Feb.	105	23.6	0.58	0.722	0.319
S. Manuel	2000	Aug./Jan.	131	14.8	0.56	0.546	0.242

T = daily air temperature; n/N = insolation ratio; Qg = global solar radiation density flux; and PAR = photosynthetically active radiation. Monthly average values.

Table 2. Cultivar characteristics throughout different years and growth periods of the potato crop, cultivar Itararé (IAC-5986), grown at Itararé, Tatuí, Piracicaba, and São Manuel, State of São Paulo, Brazil, and the respective potential yield data.

Site	Year	Growth period	CDA	LAI	C(LAI)	C(T)	HI	DM	EPY	MPY
Itararé	1985	Mar./Jun.	41.0	4.34	0.480	0.6	0.6	25.0	17.5	17.5
	1993	Sept./Jan.	41.5	4.34	0.480	0.6	0.6	25.0	27.9	26.4
	1994	Mar./Jul.	41.0	4.34	0.480	0.6	0.6	17.8	27.8	28.2
	1997	Feb./Jul.	41.0	4.34	0.480	0.6	0.6	18.9	32.9	30.8
	1998	Apr./Aug.	41.0	4.34	0.480	0.6	0.6	22.3	21.4	20.3
	1998	Sep./Jan.	41.0	4.34	0.480	0.6	0.6	16.5	35.7	39.0
	1999	Mar./Jul.	41.0	4.34	0.480	0.6	0.6	17.8	30.7	31.6
	2000	Nov./Mar.	42.0	4.34	0.480	0.5	0.6	18.0	32.0	31.5
	2001	Mar./Jul.	41.0	4.34	0.480	0.6	0.6	22.3	19.8	19.5
	2003	Sep./Jan.	41.5	4.34	0.480	0.6	0.6	16.8	29.7	26.2
	2005	Mar./Jul.	41.0	4.34	0.480	0.6	0.6	22.3	25.9	25.2
	2005	Oct./Mar.	41.5	4.34	0.480	0.6	0.6	19.7	32.0	32.7
Tatuí	2001	Sep./Jan.	46.7	4.34	0.480	0.5	0.6	17.8	30.9	29.2
Piracicaba	1989	Oct./Feb.	47.7	2.50	0.423	0.5	0.6	16.0	16.8	18.0
S. Manuel	2000	Aug./Jan.	40.7	4.34	0.480	0.6	0.6	16.0	32.0	33.1

CDA = Carbon dioxide assimilation maximum rates (μL cm^{-2} h^{-1}); LAI = leaf area index; C(LAI) = correction factor for leaf area index variation; C(T) = correction factor for maintenance respiration; HI = harvest index; DM = dry matter content (%); EPY = estimated potential yield (t ha^{-1}); MPY = measured potential yield (t ha^{-1}).

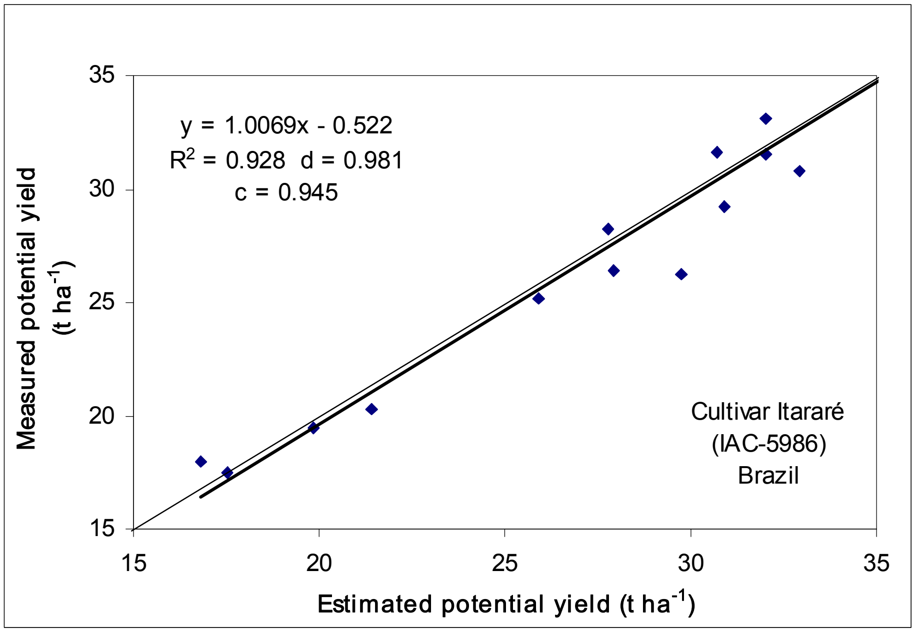

Figure 1. Relation between observed and estimated values of potato crop potential yield, cv. Itararé (IAC-5986), at the State of São Paulo, Brazil.

4. Conclusions

The agrometeorological model taking based on leaf area index, photoperiod duration, photosynthetically active radiation and air temperature is feasible to estimate potential tuber yield. The performance test shows that it can be used to forecast harvest time, and also as an effective tool to predict the suitability of potential regions to the cultivation of potato crop, cultivar Itararé (IAC-5986), at the State of São Paulo, Brazil.

5. References

BOWEN, W.T. Water productivity and potato cultivation. **In:** KIJNE, J.W.; BARKER, R.; MOLDEN, D. (eds.) Water Productivity in Agriculture: Limits and Opportunities for Improvement. CAB International 2003. p.229-238.

STUTTLE, G.W.; YORIO, N.C.; WHEELER, R.M. Interacting effects of photoperiod and photosynthetic photon flux on net carbon assimilation and starch accumulation in potato leaves. **Journal of the American Society of Horticultural Science**, v.121, p.264-268, 1996.

VILLA NOVA, N.A.; PILAU, F.G.; DOURADO NETO, D.; MANFRON, P.A. Estimativa da produtividade de cana-de-açúcar irrigada com base na fixação de CO_2, radiação solar e temperatura do ar. **Revista Brasileira de Agrometeorologia**, v.13, n.3, p.405-411, 2005.