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Conversion coefficients between intercepted solar radiation and tuber yields of potato crops under tropical highland conditions

A. J. HAVERKORT[1]* and P. M. HARRIS[2]

[1] International Potato Center (CIP), Apdo 5969, Lima, Peru
[2] Department of Agriculture, Early Gate, Reading University, Reading, England

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Summary

A relationship between intercepted solar radiation and tuber yield was established in field experiments in Rwanda involving seed size, planting density, NPK and different clones. The experiments were planted at 2350 m above sea level under rainfed conditions. The conversion coefficient between intercepted radiation and tuber dry matter production tended to increase when the apparent tuber initiation of the crop took place at higher values of intercepted radiation. These findings were quantified and their causal relation is discussed.

Introduction

Since Scott & Wilcockson (1978) related measurements of light interception in potato crops to growth, the number of reports on this relationship has grown rapidly. For potatoes over a wide range of treatments and cultivars, dry matter production of disease and drought free crops has been shown to be linearly related to the amount of intercepted solar radiation for each environment. Earlier, Gallagher & Biscoe (1977) found close relationships between absorbed radiation by the canopy and dry matter production in wheat and barley and Scott & Jaggard (1978) in sugar-beet.

Deviations in the relationship for potato crops between sites could be due to errors in measurement, temperature differences, drought stress and diseases. The relationships clearly show the need to maximize the amount of intercepted radiation in each environment to maximize yields.

The proportion of total dry matter produced by the potato plant partitioned to the roots is very low and in field experiments root dry matter can only be estimated. Tuber initiation may take place at different plant sizes according to genotype, treatment and environment, but subsequent distribution of dry matter between the 'foliage' (leaves, stems and stolons) and the tubers has been shown to be unaffected and relatively constant under conditions encountered at higher latitudes (Allen & Scott, 1980). This pattern suggests that there is a linear relationship between the quantity

* Present address: CIP, 11 rue des Orangers, 2080 Ariana-Tunis, Tunisia.

of intercepted radiation and tuber yield as has been reported for northern Europe by Allen & Scott (1980) and Khurana & McLaren (1982).

Such linear relationships were also found in field experiments involving planting density, seed size, fertility and clones in tropical highlands in Rwanda (Haverkort, 1985), but they did not yield a constant coefficient relating intercepted solar radiation to tuber yield. The range of coefficients found and the factors that influence their magnitude are discussed.

Materials and methods

Between May 1983 and March 1985, a number of clonal, NPK and stem density trials were carried out at the Kinigi seed farm of the Rwandese national Potato Programme (PNAP). The farm is located at 1°24′ latitude South and 29°25′ longitude East, at 2350 m above sea level. Annual precipitation is about 1600 mm divided over two rainy seasons and evaporation is about 900 mm/year. Potato cropping is possible throughout the year, although crops may suffer from drought stress in the short dry seasons and from late blight caused by *Phytophthora infestans* (Mont.) de Bary in the long rainy seasons when the disease is not chemically controlled. The mean maximum temperature is 20.3 °C and the mean minimum temperature is 10.2 °C resulting in a mean daily temperature of 15.2 °C with little variation throughout the year. Mean daily total incident solar radiation for the period that the experiments were in the field was 11.8 MJ m^{-2} day^{-1}. The soil is a deep andept on cinders and lava.

All experiments were planted in rows 80 cm apart and, except the stem density trials, with 30 cm between the tubers. At planting, 350 kg/ha of diammonium hydrogen phosphate (18-46-0) was applied in the furrow except in the fertility experiments where N, P and K levels varied. The plot size was 3.2 m × 6.0 m and the experiments were laid down in complete randomized block designs with four replicates. In the clonal and in part of the fertility experiments, 16 plants were harvested per plot at intervals of 10 to 15 days. The percentage of tuber dry matter was estimated using specific gravity data obtained by weighing 5 kg of freshly harvested tubers under water using the conversion tables between mass density (specific gravity) and dry matter content for sandy soils in the Netherlands (de Jonge, 1981). Deviations from true dry matter contents are likely to be systematic.

Total incident solar radiation was recorded daily with a Gunn-Bellani radiation integrator which was calibrated against a Kipp-thermopile solarimeter at the Nairobi Meteorological Institute in Kenya in 1983, just before the start of the experiments. The proportion of the ground covered with green leaves was estimated weekly with the aid of a metal frame, split into 144 rectangles, viewed directly from above. The dimensions of the frame were a multiple of the planting pattern: 80 cm × 90 cm. Two estimates were made per plot. Burstall & Harris (1983) showed that there was linear relationship between the proportion of ground covered with green foliage thus found and the proportion of intercepted radiation.

Results and discussion

Twenty relationships between intercepted radiation and tuber yield were obtained (Fig. 1), with efficiencies ranging from 0.64 to 1.42 g tuber dry matter per MJ. Fig. 1 suggests that when apparent tuber initiation took place at higher levels of intercepted

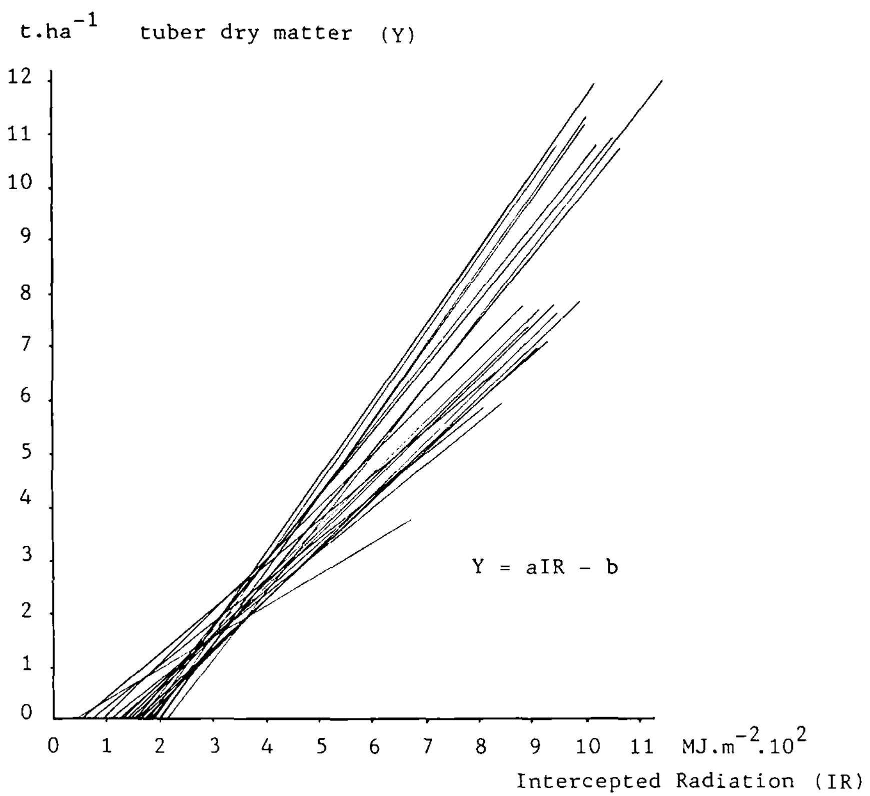

Fig. 1. The relationships between intercepted radiation and tuber yield of the experiments grown at Kinigi.

radiation, the conversion coefficients between intercepted radiation (IR) and tuber dry matter production (Y) increased. Intercepted radiation at apparent tuber initiation (IR_{ti}) is calculated from the equation $Y=aIR-b$ (Fig. 1); assuming $Y=0$, the equation becomes $0=aIR_{ti}-b$, leading to $IR_{ti}=b:a$. These values for IR_{ti} were used to establish the relationship between the conversion coefficients (between intercepted radiation and tuber dry matter production) and the quantity of intercepted radiation at tuber initiation shown in Fig. 2. This figure shows that for the trajectory between IR_{ti} values of 50 and 210 MJ m^{-2}, the conversion coefficients increase by 0.004 g MJ^{-1} per MJ m^{-2}.

The reasons for this phenomenon give rise to some speculation and further research is needed before firm conclusions can be drawn; the fact that tuber initiation and subsequent tuber growth has taken place at higher leaf area indices which may have intercepted solar radiation more efficiently, even after 100 % ground cover was reached, may also have contributed to the phenomenon.

Fig. 1 shows that increases in radiation use efficiency were accompanied by a tendency for increased values of total intercepted radiation at crop maturity. Tuber yield

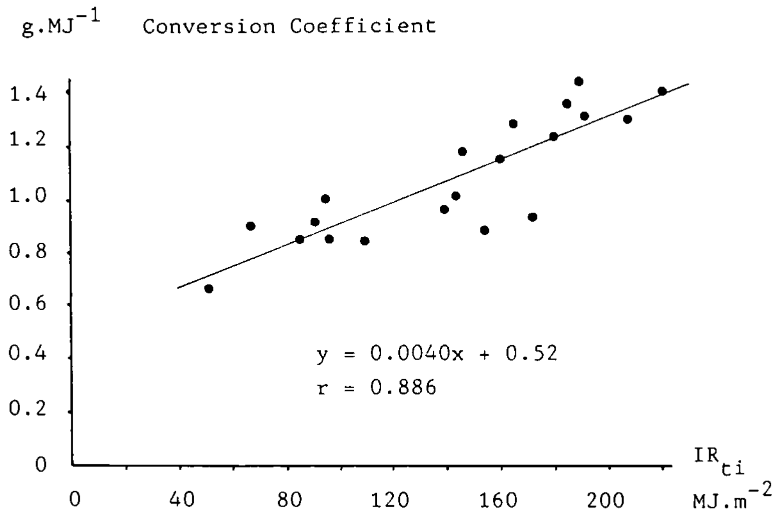

Fig. 2. The relationship between the conversion coefficient between intercepted radiation and tuber dry matter and the quantity of intercepted radiation at tuber initiation of the experiments grown at Kinigi.

at maturity (Y) seems to depend on the total amount of intercepted radiation at maturity (IR_{mat}), at tuber initiation (IR_{ti}) and on the conversion coefficients (CC):

$$Y = (IR_{mat} - IR_{ti}) \times CC$$

It is probably the simplest useful model which could be applied with the available resources. It seems that high yields could be obtained in central Africa with late maturing crops, combining high conversion coefficients with high $IR_{mat} - IR_{ti}$ values. There are two reasons, however, why it is not advisable to strive for late crops in central Africa: first, late crops would mature in conditions unfavourable for growth such as drought or heavy rain; second, extended growing seasons would not allow the common practice of growing two crops per year.

References

Allen, E. J. & R. K. Scott, 1980. An analysis of growth of the potato crop. *Journal of Agricultural Science (Cambridge)* 94: 583–606.

Burstall, L. & P. M. Harris, 1983. The estimation of percentage light interception from leaf area index and percentage ground cover in potatoes. *Journal of Agricultural Science (Cambridge)* 100: 241–244.

Gallagher, J. N. & P. V. Biscoe, 1978. Radiation absorption, growth and yield of cereals. *Journal of Agricultural Science (Cambridge)* 91: 47–60.

Haverkort, A. J., 1985. Relationships between intercepted radiation and yield of potato crops under the tropical highland conditions of central Africa. Ph.D. thesis, University of Reading, 259 pp.

Khurana, S. C. & J. S. McLaren, 1982. The influence of leaf area, light interception and season on potato growth and yield. *Potato Research* 25: 329–342.
Jonge, P. de (Ed.), 1981. Handboek voor de akkerbouw. PAGV, Lelystad, Netherlands, 192 pp.
Scott, R. K. & K. W. Jaggard, 1978. Theoretical criteria for maximum yield. Proceedings 41st Winter Congress of the International Institute of Sugarbeet Research: 179–198.
Scott, R. K. & S. J. Wilcockson, 1978. Application of physiological and agronomic principles to the development of the potato industry. In: P. M. Harris (Ed.), The potato crop: the scientific basis for improvement, p. 678–703. Chapman & Hall, London.