Physiological Aspects of the Adaptation of the Potato to the Hot Humid Tropics

Author: B. Sattelmacher, Institute for Plant Nutrition, University of Hohenheim, 7000 Stuttgart 70, P.O. Box 70 05 62, West Germany.

ABSTRACT

Clones from the same seedling family were selected for early --and late--tuberization under high temperature conditions. In field experiments at two lowland tropical sites in Peru, the later tuberizing clones outyielded the early tuberizing ones. This was correlated with early senescence of the early tuberizing clones. High temperatures significantly reduced root growth. A causal correlation between the high temperature effect on root growth and the early senescence of the early tuberizing clones is discussed.

Introduction

The main potato growing areas are concentrated in regions with moderate to cold climates. High temperature represents one of the major physiological constraints for extension of potato production into lowland tropical areas. At temperatures encountered there, tuber yield is depressed severely (Marinus and Bodlaender, 1975). Yield is a product of length of the filling period and bulking rate. Filling period is determined by the onset of tuberization and senescence. At high temperatures tuberization is delayed and earlier senescence of the shoot is also common. Consequently the length of the filling period may be severely shortened. There is evidence that in potato the root system is involved in the control of tuberization (Tizio and Biain, 1973) as well as in the control of senescence (Iwana et al., 1981). At high temperatures the size of the root system is decreased and anatomical abnormalities occur (Krauss, 1980), suggesting a causal correlation between temperature effect on root growth, tuberization and shoot senescence. It is well established from studies with other plant species that activity of cytokinins (synthesized in root tips and involved in control of shoot senescence) decreases at high root temperatures and that shoot application of Kinetin increases heat tolerance (Itai et al, 1978). It was the objective of this work to provide further evidence for the involvement of roots in the heat tolerance of potato.

Material and Methods

Screening procedure

Segregated seedling families were selected in a glasshouse for onset of tuberization. In the glasshouse a minimum night temperature of 22°C and a maximum day temperature of 38°C were maintained. (For further details of the screening procedure see Sattelmacher, 1982).

Field experiments

Evaluation of selected material was in San Ramon and in Yurimaguas. San Ramon is in the foothills of the Peruvian Andes, 800 m.a.s.l. Mean temperature during the experimental period was 24°C. Yurimaguas is in the Peruvian Amazon Basin, 180 m.a.s.l. Mean temperature during the experiment was 27°C (for further experimental details see Sattelmacher, 1982).

Root experiments

Rooted stem cuttings of different potato cultivars were grown under controlled environmental conditions in water culture (for composition of nutrient solution see Sattelmacher and Marschner, 1978). For the temperature treatment nutrient solution in one set of plants (n = 3) was maintained at 30°C while the control plants were kept at 20°C. Air temperature was 20°C day and 15°C night in both treatments. For determinations of root tip number, roots were stained with neutral red (0,1%), spread on a polyethylene sheet from which a photographic contact print was taken. From this contact print root tips can easily be counted. Root surface area was determined according to Sattelmacher et al, 1982.

Results and Discussion

A wide range of genetic variation exists in ability of potato clones to tuberize early under high temperature conditions (Figure 1). Selecting for early tuberization appeared therefore possible. However evaluation of clones selected out of the same seedling family for time of tuberization at high temperature conditions revealed that early tuberizing clones were outyielded in Yurimaguas by later tuberizing ones (Figure 2). This was possibly due to the small leaf area at the onset of tuberization (Ivins and Bremner, 1964) and to earlier senescence of the shoot (Figure 3). In the potato the onset of senescence appears to be closely correlated with root growth (Iwana et al, 1981) and earlier tuberizing clones show a smaller root system than later tuberizing clones (Swiezynsky et al, 1978). This seems to be due to the dominance of the growing tuber in competition for carbohydrates.

Root growth is also highly affected by high root zone temperatures (Krauss, 1980). Although root surface area and number of root tips are reduced at 30°C, considerable genetic variation does exist (Table 1).

Table 1. Effect of high root temperature on root surface area and number of root tips in different potato clones.

	Root surface area (cm^2)		Number of root tips	
Clone	20°C	30°C	20°C	30°C
DTO-2	2,450	2,136	10,000	7,000
DTO-33	1,391	502	4,000	2,300
LT-1	2,360	400	7,000	4,000
LT-2	4,335	2,765	25,000	14,000
Mariva	3,200	377	9,000	3,500

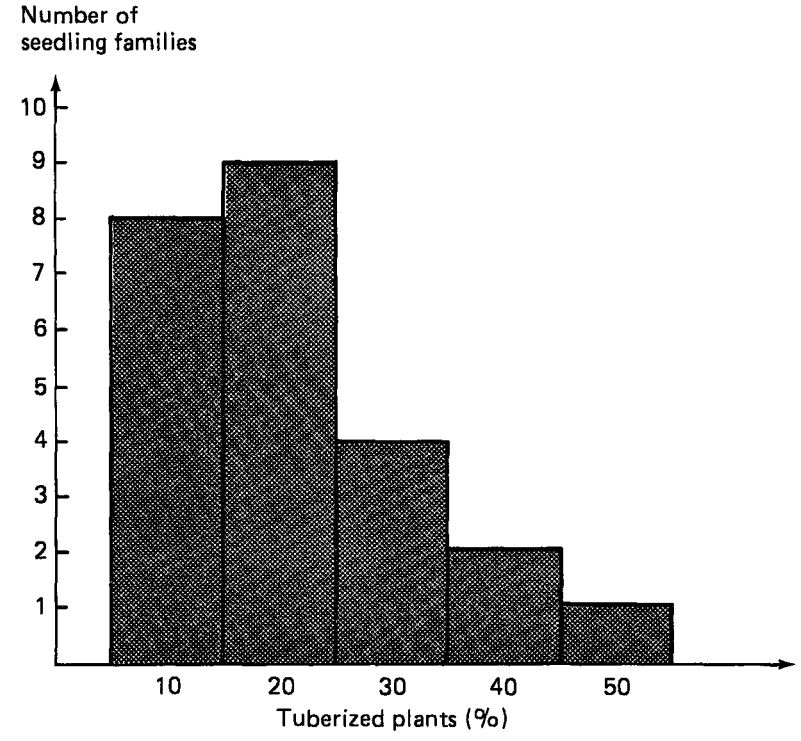

Figure 1. Percent of tuberized plants in 24 seedling families 7 weeks after sowing. Plants were grown in a glasshouse at minimum night temperature of 22°C and maximum day temperature of 38°C respectively. Each seedling family contained a minimum of 60 plants.

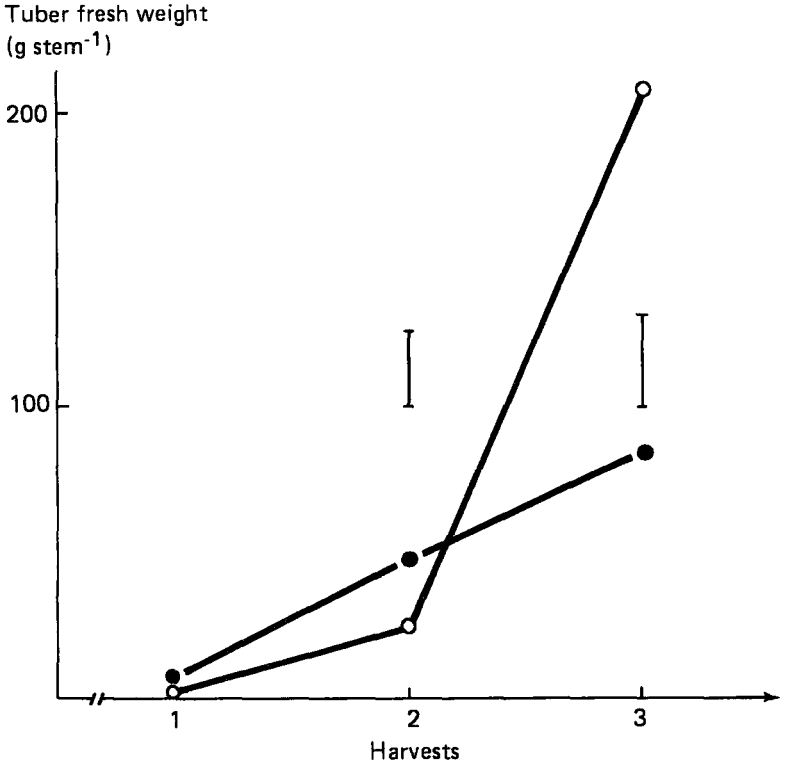

Figure 2. Tuber fresh weight of progenies of seedlings selected for onset of tuberization at high temperatures (●——● early tuberizing, o——o late tuberizing clones) grown in the field in Yurimaguas.

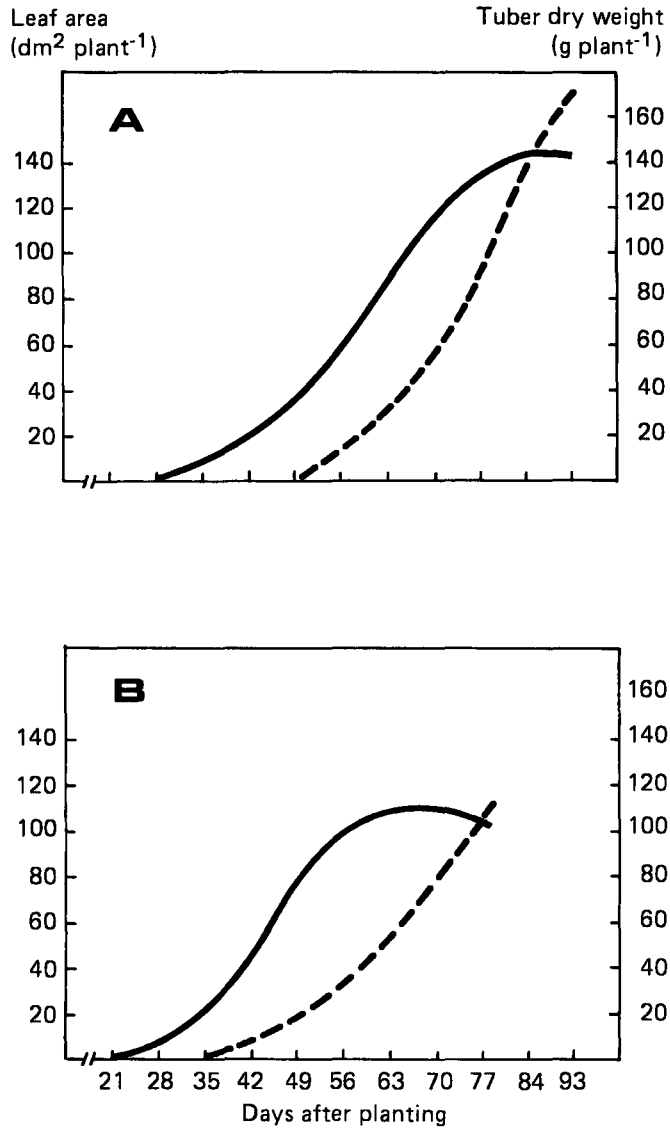

Figure 3. Leaf area development and tuber dry weight increment of an early (A) and a late (B) tuberizing clone. Graphs were drawn from computer fitted data.

Both high temperatures and early tuberization have adverse effects on root growth. The combination of both factors probably lead to particularly poor root development. This could be one factor responsible for observed earlier senescence (Figure 3). It is suggested that root growth must be a major point of attention in any approach to adapt the potato to high temperatures, especially in areas where temporary drought and adverse soil conditions, like low fertility, are common.

References

Itai, C., Ben-Zioni, A., and Munz, S. Heat stress: Effect of abscisic acid and kinetin on response and recovery of tobacco leaves. Plant and Cell Physiol. 19, 453-460 (1978).

Iwana, K., Nakaseko, K., Isoda, A., Gotoh, K., and Nishibe, Y. Relation between root system and tuber yield in the hybrid population of the potato plant. Japan J. Crop. Sci. 50, 233-238 (1981).

Ivins, J.D. and Bremmer, P.M. Growth development and yield in the potato. Outl. Agric. 4, 271-277 (1964).

Krauss, A. Physiological studies on tuberization and tuber growth. The International Potato Center, Apartado 5969, Lima, Peru (1980).

Marinus, J. and Bodlaender, K.B.A. Response of some potato varieties to temperature. Potato Res. 18, 189-204 (1975).

Sattelmacher, B. and Marschner, H. Nitrogen nutrition and cytokinin activity in Solanum tuberosum L. Physiol. Plant. 42, 185-189, (1978).

Sattelmacher, B. A rapid seedling test for adaptation to high temperatures. In preparation (1982).

Sattelmacher, B., Klotz, F., und Marschner, H. Vergleich zweier nicht destruktiver Schnellmethoden zur Bestimmung der Wurzelober-flächen. In preparation (1982).

Swiezynski, K.M., Sykala, A., and Wroblewska, J.K. Differences in early growth of shoots and roots in potato clones. Potato Res. 21, 241-248 (1978).

Tizio, R. and Biain, M. Are cytokinins the specific factor for tuber formation in the potato plant? Phyton. 31, 3-13 (1973).