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**GROWTH AND PHYSIOLOGICAL RESPONSES OF ASPARAGUS
(*Asparagus officinalis* L.) AT HIGH TEMPERATURES**

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fulfilment of the requirements for the degree
of Doctor of Philosophy in
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Abstract

Asparagus is now planted in tropical climates, hence a series of experiments were carried out to examine the physiological responses of asparagus to high temperature. These included analysis and modelling of growth, and the measurement of heat tolerance of four asparagus cultivars at high temperatures.

Asparagus seeds of four cultivars were sown and grown in controlled climate rooms. These results showed that growth of young asparagus plants was exponential, and thus the parameters RLGR (relative leaf area growth rate), RFGR (relative fern dry weight growth rate), RCGR (relative crown dry weight growth rate), RPGR (relative total plant dry weight) were constant for any specific temperature regime or cultivar. The growth rate could be classified according to the parameters NAR (net assimilation rate), LAR (leaf area ratio) and RGR (relative growth rate), and could be grouped into high : 'D25/N25°C and D30/N30°C', normal : 'D20/N20°C, D30/N20°C, D35/N15°C, and D35/N25°C', and poor growth rates : 'D35/N35°C, D40/N20°C, and D40/N30°C'. The effects of these temperature regimes on growth were greater than the differences among cultivars, although there were different responses at high temperature among cultivars.

Generally, NARs decreased with increasing age, while LARs increased with age. Both NARs and LARs varied with temperature regime, plant age and cultivar. The effects of high temperature on NAR or LAR were greater than the differences between cultivars.

The leaf production rate was the largest contributor to total plant relative growth rate, followed by the root, the stem, and the rhizome production rate. The stem and the rhizome production rates declined with age, the leaf production rate increased, and the root production rate was maintained nearly constant.

The allometric coefficients of root in relation to fern for cultivars and for the various temperature regimes were essentially the same. On the contrary, the allometric intercepts between plants at various temperatures or between cultivars were significantly different, with Tainan No.1 having the highest and Larac the lowest root/ shoot ratio except at supra-optimal temperatures. The lower temperature regimes had the higher root : shoot ratios. The root : shoot ratio was higher with a 10°C day/night temperature differential compared to the equivalent constant temperature regimes.

Day or night temperatures around 26.5°C were optimal for RLGR, RFGR and RPGR, but a night temperature of 23.8°C was optimal for RCGR.

The experiment on spear yield and fern development showed that not only did high temperature depress spear yield and quality, but it also depressed total fern weight and individual fern height. The plant characteristics such as the first branch height and fern height were also depressed at high temperature. Brocks and UC157 maintained better fern characteristics than the others at high temperatures. From the parameters of Richard's equation on fern, and of the RSGRs on spear, the ability of adaptation to high temperature was in the order: Tainan No.1 > Brocks > UC157 > Larac.

In a high temperature study with germinated asparagus seedlings, the higher the temperature was the more stunted the growth. High concentrations of ABA application also markedly depressed seedling growth. There was an additive effect of heat stress and application of high ABA concentration on seedling growth, while there was an ameliorative effect with the application of ABA at a low concentration (0.1 - 1 μ M) on heat stressed seedlings. At high temperature the sensitivity difference to ABA between cultivars was clearly expressed and thus the difference in heat tolerance of asparagus cultivars may be determined by ABA insensitivity.

The studies of the effect of high temperature on endogenous ABA levels showed that the endogenous ABA levels decreased with temperature and then increased to a peak around 38°C for Larac and Tainan No.1, but peaked at around 36°C or lower for Brocks and UC157 for both roots and shoots. The spears of Tainan No.1 had an extremely high ABA content at 28°C and 33°C and fell to similar levels as the other cultivars at 36°C. It is concluded that the peak of endogenous ABA occurred at supra-optimal temperature and then decreased to low levels at extreme high temperatures.

The assay of membrane thermostability (T_m) is a potentially valuable means of determining heat tolerance of asparagus. T_m varied with genotype, age, and heat acclimation. Heat acclimation may increase the membrane thermostability of young tissues. UC157 may be expected to be best adapted to tropical climate on the basis of membrane thermostability, because UC157 had the highest T_m of spears grown at high temperature. Tainan No.1, Larac and Brocks grown at high temperature also had increased heat tolerance, presumably due to heat acclimation.

The study on the differences between cultivars in heat shock protein production showed that changes in protein synthesis occurred when asparagus was heat shocked at 34°C or 37°C for 2 or 6 hours. Specific heat shock proteins were produced and the levels of normal proteins changed. Most of the HSPs were of low molecular weight (about 24 kD to 13 kD). A small number of the HSP's appeared to be cultivar specific. A number of ABA induced proteins might be HSPs, but ABA also depressed the production of some HSPs. However most HSPs were induced at high temperature even in the presence of ABA.

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List of Abbreviations

<u>Abbreviation</u>	<u>Meaning</u>
ABA	Abscisic acid
D20/N20°C	D : day; N : night; Day 20°C/night 20°C
GA	Gibberellic acid
HMW	High molecular weight
HSPs	Heat shock proteins
IEF/SDS-PAGE	Isoelectric focus/sodium dodecyl sulfate polyacrylamide gel electrophoresis
J_{leaf}	Leaf production rate
$J_{rhizome}$	Rhizome production rate
J_{root}	Root production rate
J_{stem}	Stem production rate
kD	Kilo-Dalton
LAR	Leaf area ratio
LMW	Low molecular weight
MAGR	Mean absolute growth rate
NAR	Net assimilation rate
RCGR	Relative crown growth rate
RFGR	Relative fern growth rate
RGR	Relative growth rate
RLGR	Relative leaf area growth rate
RPGR	Relative plant growth rate
RSGR ₁₀₀	Relative spear growth rate of spear from 10 to 100 mm.
RSGR ₂₀₀	Relative spear growth rate of spear from 10 to 200 mm.
SDS-PAGE	Sodium dodecyl sulfate polyacrylamide gel electrophoresis
WMRGR	Weighted mean relative growth rate