SECTION 3

The Effects on Latitudinal Shift of Plant Growth Potential

3.1. Introduction

The main purposes of this section are:

(1) To study the latitudinal distribution of thermal resources important for the cultivation of rice.
(2) To estimate the extent of latitudinal shift due to climatic variations.
(3) To assess variations in plant growth potential which might occur under the different climatic scenarios described in Section 2.

Rice plants, being indigenous to tropical or subtropical humid regions, need enough thermal and water resources throughout their growing season to yield a good crop. Since rice cultivation has been introduced into Japan, much effort has been concentrated on the development of agricultural techniques for increasing its yield. The breeding of rice varieties more tolerant to cool summer conditions and the development of irrigation systems for water supply have succeeded in expanding the boundary of rice cultivation as far north as Hokkaido (located between 41°N and 45°N) and at as high an altitude as the foot of Mt. Yatsugatake (at about 1000 m, and at latitude 36°N). With the development of rice cultivation techniques, the main producing area of rice in Japan has moved northwards from Kyushu district in the Meiji era (1868–1912), to Hokkaido, Tohoku and Hokuriku at the present.

The climate in Japan varies considerably from south to north Japan, because the four main islands – Hokkaido, Honshu, Shikoku and Kyushu – stretch in an arc 2200 km long between 24°N and 46°N. Temperature conditions in the northern districts are not favorable for rice production and rice cultivation

M. L. Parry et al. (eds.), *The Impact of Climatic Variations on Agriculture*

here is very sensitive to variations of climate, particularly to cool summer damage. It is this sensitivity of rice production in marginal areas of Japan that is the focus of this section.

3.2. Statistical Characteristics of Thermal Resources

3.2.1. Latitudinal distribution of thermal resources

Meteorological data from about 150 stations in Japan and about 229 stations with an altitude of less than 150 m elsewhere in the northern hemisphere, have been analyzed to study the latitudinal change in thermal resources important to plant productivity (Uchijima, 1976a, 1976b, 1976c; Uchijima and Horibe, 1977). Four agroclimatic indexes – effective accumulated temperature (ΣT_{10}, degree-days), effective period (D_{10}, days), warmth index (WI, degree-months) and coldness index (CI, degree-months) – were calculated from the following relations:

$$\Sigma T_{10} = \sum_{i=1}^{k} T_{d,i} \qquad \text{for } T_d \geq 10\,^{\circ}\text{C} \tag{3.1}$$

$$D_{10} = \sum_{i=1}^{m} i \qquad \text{for } T \geq 10\,^{\circ}\text{C} \tag{3.2}$$

$$WI = \sum_{j=1}^{m} (T_{m,j} - 5) \qquad \text{for } T_m \geq 5\,^{\circ}\text{C} \tag{3.3}$$

$$CI = \sum_{j=1}^{n} (5 - T_{n,j}) \qquad \text{for } T_n \leq 5\,^{\circ}\text{C} \tag{3.4}$$

where $T_{d,i}$ is mean temperature on day i, $T_{m,j}$ is mean temperature in month j, k is the number of days on which daily mean temperature was equal to or above 10 °C, m is the number of months in which monthly mean temperature was equal to or above 5 °C and n is the number of months in which monthly mean temperature was equal to or below 5 °C. The effective period (D_{10}) characterizing the duration of period in which summer crops and plants can grow vigorously is the length of the consecutive period with T_d equal to or above 10 °C, in days.

The computed data for the respective indexes were grouped over latitudinal bands, each with a width of 5 degrees, to illustrate their latitudinal distribution. They are plotted along with mean annual temperature over the northern hemisphere, in *Figure 3.1*. The points in *Figure 3.1(a)* and *3.1(c)* denote the zonal average of the climatic indexes. The number of stations representing each latitude band are shown together with vertical bars on the points that indicate the standard deviation of the indexes in the respective latitudinal bands. As can be seen in these plots, $\overline{\Sigma T}_{10}$, $\bar{D}_{10}$ and $\overline{WI}$ are nearly constant in a latitudinal range lower than about 20°N, and then decrease sharply in the middle latitudes, becoming approximately zero at a latitude of about 75°N.

On the other hand, the mean coldness index ($\overline{CI}$) is zero at latitudes lower than 30°N, and increases considerably with increasing latitude. The change in