9 Metabolism of Pyrimidines and Purines

C. Wasternack

1 Introduction

As in bacterial and animal systems, the purine and pyrimidine nucleotides in plants as well as their derivatives are operative as constituents of nucleic acids and coenzymes as well as in regulatory acting compounds. They are involved in the synthesis of thiamine, riboflavine, folic acid pteridines, histidine, or are constituents of cytokinins, purine alkaloids, and further unusual N-compounds representing one way of N-accumulation or N-excretion.

The functions of nucleotides and their derivatives are linked to the synthesis, transfer, and utilization of stored energy in energy metabolism, with the group-transfer reactions by their functions in nucleotide coenzymes, with a structural and functional role in nucleic acids or vitamins, with physiological effects of cyclic AMP or cytokinins, as well as with the allosteric regulations of enzymes and with a role in the energy charge of the cell (Henderson and Paterson 1973).

The present article is focused on synthesis, interconversions, and degradation of pyrimidine and purine nucleotides in plants. This will be discussed in relation to nucleic acid synthesis. Several reviews on this subject have dealt with micro­bial and animal systems (Gots 1970, Murray 1971, Murray et al. 1970, O’Donovan and Neuhard 1970, Hartman 1970, Henderson 1972, Henderson and Paterson 1973). However, purine and pyrimidine metabolism in plants has not been discussed in detail before.

2 Occurrence of Pyrimidines and Purines in Plants

Pyrimidine and purine compounds are detectable in the acid-soluble fraction of plant material as bases, nucleosides, ribonucleotides, and deoxyribonucleotides. Figure 2 shows acid-soluble nucleotides fractionated from bean leaves (Fig. 2A) (Weinstein et al. 1969) and Euglena gracilis (Fig. 2B) (Krauss and Reinbothe 1977). The adenine nucleotides, NAD as well as nucleotide sugars, represent the main part of nucleotides in many different plants, while deoxyri-
bonucleotides, as well as cytidine nucleotides, are present in small or negligible percentage. Adenine, guanine, uracil, and their respective nucleosides were detectable in mature wheat grains (GRZELCZAK and BUCHOWICZ 1975) related to the RNA synthesis. UDP-glucose, ADP-glucose, and GDP-glucose are detectable in young leaves of Phaseolus vulgaris (WEINSTEIN et al. 1969). They are related to the sucrose, starch, and cellulose syntheses respectively. On the other hand, GDP-mannose functions in the glycolipid synthesis.

Some purines and pyrimidines are secondary products, e.g., methylated derivatives, such as caffeine, theobromine, and theophylline, as well as pyrimidine-containing products such as lathyrine, willardiine, isowillardiine, vicine, and convicine. Only some aspects of these will be discussed here.

Pyrimidinyl Amino Acids. (See reviews by REINBOTHE et al. 1981 and LAMBEIN et al. 1976). Pyrimidinyl amino acids have been detected in legume seeds in remarkable amounts. Lathyrine (β-[2-amino-pyrimidine]-4-yl alanine) was found in Lathyrus tingitanus (BELL 1961). Willardiine (β-[2,4-dihydroxy-pyrimidine]-1-yl alanine) as well as isowillardiine (β-[2,4-dihydroxy-pyrimidine]-3-yl alanine) were detected in germinating pea seedlings (cf. LAMBEIN et al. 1976) and other legumes (KRAUSS and REINBOTHE 1973). Biosynthesis of lathyrine, willardiine, and isowillardiine were discussed in terms of two independent routes: (1) Their formation from a preformed heterocyclic compound such as uracil; (2) The cyclization of γ-hydroxyhomoarginine (ASHWORTH et al. 1972, BROWN and AL-BALDAWI 1977). More recently, willardiine and isowillardiine have been synthesized in vitro by use of uracil, O-acetyl-L-serine, and an enzyme extract from Pisum and other sources, this evidence favoring the former pathway (MURAKOSHI et al. 1978). Different synthases for both compounds were suggested. The occurrence of pyrimidinyl amino acids is of chemotaxonomic significance (LAMBEIN et al. 1976).

Methylated Purines. Methylated purines, such as caffeine, theobromine, and theobromine (Fig. 1), are widely distributed in different higher plants (cf. SUZUKI and TAKAHASHI 1977). Caffeine is synthesized in the pericarp and is accumulated in leaves or seeds during fruit formation (BAUMANN and WANNER 1972). On