

Table 2. Activity and location of C₄ pathway enzymes in sub-groups of C₄ species^a. Activity unit=1 μmol/min. Abbreviations: M, mesophyll cell; BS, bundle sheath cell; cyto, cytoplasm; chloro, chloroplast; mito, mitochondria

Enzymes with similar activities in all C₄ species

Enzymes	Activity (units/mg chl.)	Location		Activity in C ₃ species (units/mg chl.)	References to identification activity, properties and location ^b
		Cell type	Within cell		
PEP carboxylase	15-40	M	cyto	0.4-1.5	1, 2, 3, 4, 5, 6, 7
Pyruvate, Pi dikinase	3-10	M	chloro	0	8, 9, 10, 7, 11, 12, 28
Adenylate kinase	17-45	>M	chloro in M	0.5-1.0	13, 10, 7
Pyrophosphatase	20-60	>M	chloro in M	2-4	13, 10, 7
3-PGA to triose-P enzyme	similar to C ₃	both	chloro	—	10, 14, 22, 7, 11
Other PCR cycle enzymes	similar to C ₃	BS	chloro	—	10, 2, 14, 22, 7, 4, 6

Enzymes with varying activity in sub-groups of C₄ species^c

Enzymes	'NADP-ME-type' species			'PCK-type' species			'NAD-ME-type' species			Activity in C ₃ species (units/mg chl.)	References to identification activity, properties and localisation ^b
	Activ-ity (units/mg chl.)	Location Cell type	Within cell	Activ-ity (units/mg chl.)	Location Cell type	Within cell	Activ-ity (units/mg chl.)	Location Cell type	Within cell		
NADP malate dehydrogenase	10-17	M	chloro	1-3	—	—	1-2	both	chloro	0.5-1.2	15, 10, 16, 7, 11, 19
NADP malic enzyme	9-14	BS	chloro	0.3-0.4	—	—	0.2-0.8	—	—	0.1-0.8	1, 10, 17, 16, 18, 4, 19
PEP carboxykinase	<0.2	—	—	10-14	BS	?	<0.2	—	—	<0.2	21, 22, 6, 19, 23, 12
NAD malic enzyme	0.2-0.4	—	—	0.2-0.5	—	—	5-9	BS	mito	0.05-0.1	24, 25, 26, 12, 23, 27
Aspartate aminotransferase	5-7	>M	chloro	45-60	both	cyto?	25-45	M	cyto	1-2.4	10, 18, 20, 12, 19
								BS	mito		
Alanine aminotransferase	2-4	—	—	38-45	both	cyto?	30-60	both	cyto	2-3	18, 20, 12, 19

For footnotes see opposite page.

^a For the enzymes common to all C₄ species the ranges of activity are for a large selection of species. Ranges of activity are also shown for 'NADP-ME-type' C₄ species (*Z. mays*, *Sorghum sudanense*, *Pennisetum typhoides*, *D. sanguinalis* and *Saccharum officinarum*), 'PCK-type' C₄ species (*P. maximum*, *Sporobolus fimbriatus*, *Chloris gayana*), 'NAD-ME-type' C₄ species (*A. spongiosa*, *Portulaca oleracea*, *A. edulis*, *P. mil-taceum*, *Eragrostis curvula*), and C₃ plants (wheat, spinach, pea, soybean and *Atriplex patula*). In some instances low values reported in the literature have been excluded, where higher activities have been reported elsewhere for the same species. For comparison, maximum photosynthesis rates for C₄ species range between 3 and 5 μmol/min/mg chlorophyll. The prefix (>) indicates the predominant location, 'Both' indicates approximately equal distribution between two cell types (see text).

^b References in Table are: (1) SLACK and HATCH (1967); (2) BJÖRKMÄN and GAUHL (1969); (3) EDWARDS and BLACK (1971); (4) CHEN et al. (1973); (5) TING and OSMOND (1973); (6) GUTIERREZ et al. (1974b); (7) HATCH and KAGAWA (1973); (8) HATCH and SLACK (1968); (9) ANDREWS and HATCH (1969); (10) SLACK et al. (1969); (11) KAGAWA and HATCH (1974a); (12) HATCH et al. (1975); (13) HATCH et al. (1969); (14) see HATCH and SLACK (1970); (15) HATCH and SLACK (1969b); (16) JOHNSON and HATCH (1970); (17) BERRY et al. (1970); (18) ANDREWS et al. (1971); (19) GUTIERREZ et al. (1975); (20) HATCH and MAU (1973); HATCH (1973); (21) EDWARDS et al. (1971); (22) KANAI and BLACK (1972); (23) GUTIERREZ et al. (1974a); (24) HATCH and KAGAWA (1974a); (25) HATCH and KAGAWA (1974b); (26) HATCH et al. (1974); (27) KAGAWA and HATCH (1975); (28) SUGIYAMA (1973).

^c See HATCH et al. (1975) for the sub-grouping terminology used.