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[136] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-2-vein-endings-and-export-pathways>

[137] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-2-1-introduction>

[138] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-2-2-pipeline-leaf-vein-architecture>

[139] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-2-3-damage-control>

[140] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-2-4-unit-pipe-generalised-vein-structure>

[141] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-2-5-water-extraction-pipeline>

[142] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-2-6-solutes-transpiration-stream>

[143] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-2-7-solute-recycling-phloem-export>

[144] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-2-8-solute-recycling-scavenging-cells>

[145] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-2-9-solute-excretion>

[146] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-3-distribution-photoassimilates-within-plants>

[147] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-3-1-introduction>

[148] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-3-2-source-path-sink-concept>

[149] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-3-3-source-path-sink-transport-processes>

[150] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-3-4-photoassimilate-transport-and-biomass-production>

[151] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-3-5-whole-plant-distribution-photoassimilate>

[152] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-5-1-partitioning-carbon-and-nitrogen-legume>

[153] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-4-phloem-transport>

[154] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-4-1-introduction>

[155] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-4-2-characteristics-phloem-transport>

[156] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-4-3-chemical-nature-translocated-material>

[157] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-4-4-phloem-flux>

[158] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-4-5-mechanism-phloem-translocation>

[159] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-4-6-control-assimilate-transport-source-sink>

[160] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-5-phloem-loading>

[161] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-5-1-introduction>

[162] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-5-2-pathway-phloem-loading-source-leaves>

[163] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-5-3-mechanisms-phloem-loading>



- [164] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-5-4-regulation-phloem-loading>
- [165] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-5-5-sink-regulation>
- [166] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-6-phloem-unloading-and-sink-utilisation>
- [167] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-6-1-introduction>
- [168] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-6-2-cellular-pathways-phloem-unloading>
- [169] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-6-3-mechanisms-phloem-unloading>
- [170] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-6-4-sugar-metabolism-compartmentation-sinks>
- [171] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-6-5-key-transfer-events-sugar-metabolism-and-compartmentation>
- [172] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/5-6-6-sink-control-photoassimilate-partitioning>
- [173] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-1>
- [174] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/chapter-6-growth-analysis-quantitative-approach>
- [175] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/introduction-8>
- [176] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-1-concepts-and-techniques>
- [177] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-1-1-cell-populations>
- [178] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-1-2-plant-biomass>
- [179] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-1-3-leaf-area>
- [180] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-2-environmental-physiology>
- [181] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-2-1-light>
- [182] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-2-2-temperature>
- [183] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-2-3-carbon-dioxide>
- [184] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-2-4-nutrients-nitrogen-and-phosphorus>
- [185] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-2-5-light-x-nutrients>
- [186] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-2-6-co2-x-nutrients>
- [187] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-2-7-water>
- [188] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-3>

developmental-physiology

[189] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-3-1-biomass-distribution>

[190] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-3-2-size-and-ontogeny>

[191] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-3-3-reproductive-development>

[192] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-4-crop-growth-analysis>

[193] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-4-1-concepts>

[194] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-4-2-light-use-efficiency>

[195] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-4-3-potential-crop-growth-rate>

[196] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-4-4-respiratory-losses>

[197] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-5-respiratory-efficiency-and-plant-growth>

[198] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-5-1-carbon-economy-fast-versus-slow-growing-plants>

[199] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-5-2-energy-generation>

[200] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-5-3-energy-utilisation>

[201] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-5-4-methodology>

[202] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-5-5-energy-use-roots>

[203] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-5-6-growth-efficiency-and-crop-selection>

[204] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-5-7-suboptimal-environments>

[205] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/6-6-concluding-remarks>

[206] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-2>

[207] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/part-iii-coodination-growth-and-reproduction>

[208] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/chapter-7-plant-growth-and-options-reproduction>

[209] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/introduction-9>

[210] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/7-1-axial-growth-shoot-and-root-development>

[211] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/7-1-1-root-apical-meristems>

[212] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/7-1-2-shoot-apical-meristems>

[213] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/7-1-3-meristems-templates-morphogenesis>

[214] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/7-1-4-meristems-responding-their-environment>

[215] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/7-2-options-reproduction>

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[218] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/7-2-3-floral-biology-and-sexual-reproduction>

[219] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/7-2-4-sources-genetic-variation-and-restrictions-breeding>

[220] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/feature-essay-7-1-self-and-non-self-recognition-processes-flowering-plants>

[221] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-4>

[222] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/chapter-8-physical-cues-growth-and-reproduction>

[223] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/introduction-10>

[224] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-1-latent-life-dormancy>

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[226] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-1-2-seed-dormancy>

[227] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-8-1-dormancy-wheat-grains-nature-and-practical-application>

[228] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-1-3-bud-dormancy>

[229] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-1-4-physiological-control-dormancy>

[230] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-2-plant-and-organ-orientation>

[231] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-2-1-gravitropism>

[232] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-2-2-thigmotropism>

[233] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-2-3-phototropism>

[234] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-2-4-overall-models-control-tropisms>

[235] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-2-5-nastic-movements>

[236] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-3-reproduction>

[237] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-3-1-time-flower>

[238] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-3-2-processes-floral-induction-and-initiation>

[239] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-4-photoreceptors-and-light-cues>

[240] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-4-1-phytochromes-multi-functional-light-sensors>

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[242] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-4-3-phytochrome-operation-and-light-quantity>

[243] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-4-4-phy-mutants>

[244] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-4-5-blue-light-receptors-and-responses>

[245] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/8-4-6-conclusion>

[246] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-8>

[247] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/chapter-9-plant-hormones-chemical-signalling-plant-development>

[248] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/introduction-11>

[249] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/9-1-basis-chemical-control-plant-development>

[250] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/9-1-1-signal-sources-which-tissues-make-hormones-how-are-hormones-synthesised>

[251] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/9-1-2-how-mobile-are-plant-hormones>

[252] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/9-2-physiology-hormone-action>

[253] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/9-2-1-signal-targets-perception-and-signal-transduction>

[254] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/9-2-2-diverse-roles-plant-hormones>

[255] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/9-2-3-direct-effects-cellular-processes>

[256] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-9-1-models-control-shoot-branching-more-just-auxin-and-cytokinin>

[257] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/9-2-4-modified-gene-expression>

[258] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/9-3-harnessing-hormones-making-use-chemical-signals>

- [259] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/9-3-1-manipulating-growth-and-development-applied-plant-growth-regulators>
- [260] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/9-3-2-control-through-genetic-alterations>
- [261] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/9-4-concluding-remarks>
- [262] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-3>
- [263] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/chapter-10-differentiation-and-gene-expression>
- [264] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/introduction-2>
- [265] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/10-1-cellular-development-and-coordination>
- [266] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/10-1-1-generating-cells-and-organelles-control-division-processes>
- [267] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/10-1-2-cellular-integration>
- [268] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/feature-essay-10-1-communication-between-plant-cells>
- [269] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/10-2-options-differentiation>
- [270] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/10-2-1-concept-totipotency>
- [271] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/10-2-2-types-differentiation>
- [272] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/10-3-gene-expression>
- [273] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/10-3-1-gene-expression-and-protein-synthesis>
- [274] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/10-3-2-genome-interactions>
- [275] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/10-3-3-gene-regulation-during-development>
- [276] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/10-3-4-gene-expression-modified-external-factors>
- [277] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-10-1-plant-pathogen-interactions-pathogens-biotic-stress-factors>
- [278] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/10-4-modified-genomes-genetic-engineering>
- [279] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/10-4-1-transformation-systems>
- [280] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/10-4-2-transgenic-plants>
- [281] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-5>
- [282] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/chapter-11-fruit->

growth-and-postharvest-physiology

[283] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/introduction-3>

[284] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-1-onset-fruit-growth>

[285] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-1-1-early-events>

[286] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-1-2-origin-fruit-tissues>

[287] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-1-3-fruit-set>

[288] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-2-dynamics-fruit-growth>

[289] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-2-1-time-course>

[290] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-2-2-cell-division-and-enlargement>

[291] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-2-3-cell-differentiation>

[292] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-2-4-kiwifruit-development-case-study>

[293] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-2-5-seed-development-and-fruit-growth>

[294] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-3-resources-fruit-growth>

[295] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-3-1-carbohydrate-economy>

[296] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-3-2-photoassimilate-distribution>

[297] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-3-3-composition-photoassimilates>

[298] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-3-4-fruit-composition-and-sensory-attributes>

[299] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-3-5-mineral-nutrients>

[300] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-4-maturation-and-ripening>

[301] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-4-1-carbon-accumulation>

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[304] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-5-respiration-climacteric-and-edibility>

[305] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-5-1-ripening->

indicators

[306] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-5-2-climacteric-behaviour>

[307] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-5-3-ripening-triggers>

[308] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-5-4-texture-and-softening>

[309] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-5-5-colour-and-flavour>

[310] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-5-6-ethylene>

[311] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/feature-essay-11-1-century-ethylene-research>

[312] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-6-extending-storage-life>

[313] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-6-1-temperature>

[314] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-6-2-relative-humidity>

[315] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-6-3-modified-and-controlled-atmospheres>

[316] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-6-4-physiology-controlled-atmosphere-storage>

[317] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-6-5-storage-disorders>

[318] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-7-future-technologies>

[319] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/11-8-concluding-remarks>

[320] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-6>

[321] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/part-iv-ecophysiology-natural-and-managed-communities>

[322] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/chapter-12-sunlight-all-pervasive-source-energy>

[323] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/introduction-4>

[324] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-1-photosynthesis-sun-and-shade>

[325] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-1-1-light-interception-and-utilisation>

[326] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-1-2-photoinhibition-and-photoprotection>

[327] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/feature-essay-12-1-perspectives-photoinhibition>

[328] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-1-3-sunshade-acclimation-and-rainforest-gaps>

- [329] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-12-1-interaction-light-and-nutrients-rainforest-seedlings>
- [330] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-1-4-sunflecks>
- [331] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-2-ultraviolet-radiation>
- [332] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-2-1-ultraviolet-radiation-ancient-earth>
- [333] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-2-2-ultraviolet-attenuation-modern-earth>
- [334] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-2-3-ultraviolet-radiation-and-plant-biology>
- [335] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-3-agricultural-production>
- [336] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-3-1-par-and-yield>
- [337] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-3-2-leaf-area-index-and-canopy-light-climate>
- [338] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-3-3-light-use-efficiency>
- [339] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-4-forest-production>
- [340] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-4-1-canopy-architecture>
- [341] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-4-2-canopy-productivity>
- [342] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-12-2-pine-forest-canopies-and-biomass-production>
- [343] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-5-horticultural-production>
- [344] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-5-1-sunlight-interception>
- [345] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-5-2-light-climate-and-fruit-quality>
- [346] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-5-3-flower-bud-differentiation-and-fruit-set>
- [347] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-5-4-orchard-design-and-canopy-management>
- [348] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/12-6-concluding-remarks>
- [349] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-7>
- [350] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/chapter-13-carbon-dioxide-universal-substrate>
- [351] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/introduction-6>
- [352] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-1-dynamics->



atmospheric-co2

[353] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-1-1-global-carbon-cycle>

[354] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-1-2-small-scale-variation-co2>

[355] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-2-leaf-adjustments-under-co2-enrichment>

[356] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-2-1-c3-plants-versus-c4-plants>

[357] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-2-2-stomatal-conductance>

[358] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-2-3-respiratory-adjustments>

[359] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-2-4-ontogeny-and-duration-co2-enrichment>

[360] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-2-5-photosynthetic-acclimation>

[361] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-2-6-carbon-partitioning>

[362] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-3-factor-interaction-and-co2-enrichment>

[363] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-3-1-light>

[364] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-3-2-sink-strength>

[365] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-3-3-temperature>

[366] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-3-4-phenology-temperature-and-co2>

[367] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-3-5-drought>

[368] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-3-6-concluding-remarks>

[369] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-13-1-co2-cyanide-and-plant-defence>

[370] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-4-horticultural-applications-co2-enrichment>

[371] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-4-1-greenhouse-cropping>

[372] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-4-2-vegetables-and-fruit-crops>

[373] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-4-3-ornamentals-and-nursery-stock>

[374] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-4-4-vegetative-propagation>

[375] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-5-tropical->

trees-and-co2-enrichment

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[377] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-5-2-leaf-gas-exchange>

[378] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-5-3-temperature-x-co2>

[379] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-5-4-water-x-co2>

[380] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-5-5-growth-competition-and-ecosystem-structure>

[381] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-13-2-heat-therapy-and-co2>

[382] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/13-6-concluding-remarks>

[383] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-11>

[384] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/chapter-14-temperature-driving-variable-plant-growth-and-development>

[385] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/introduction-13>

[386] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-1-thermal-environment-and-growth-responses>

[387] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-1-1-temperature-means-and-extremes>

[388] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-1-2-plant-temperatures>

[389] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-1-3-variation-sensitivity>

[390] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-1-4-biochemistry-and-basic-concepts>

[391] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-2-plant-coordination>

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[395] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-2-4-growth-and-development>

[396] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-2-5-plant-form>

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[398] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-3-1-daynight-temperature-differential>

[399] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-3-2-thermal-time>

[400] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-3-3-response-integration>

[401] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-4-chilling-injury>

[402] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-4-1-quantifying-chilling-injury>

[403] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-4-2-ranges-chilling-tolerance>

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[406] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-5-plant-heat-budgets>

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[409] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-5-3-sensible-heat-exchange>

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[415] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/14-7-concluding-remarks>

[416] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-12>

[417] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/chapter-15-water-limiting-factor>

[418] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/introduction-14>

[419] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/15-1-soil-plant-atmosphere-continuum>

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[421] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-15-1-water-repellent-sands>

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[423] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/15-1-3-soil-plant-hydraulic-conductivity>

[424] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/15-1-4-hydraulic-lift>

[425] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-15-2-pressure-volume-curves>

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[427] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/15-2-1-stomatal-structure-and-function>

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[429] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/15-2-3-light-co2-and-stomatal-aperture>

[430] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/15-2-4-leaf-air-vapour-pressure-difference>

[431] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/15-3-water-use-managed-plant-communities>

[432] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/15-3-1-water-use-ef-ciency-crops>

[433] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/15-3-2-crop-water-use-and-irrigation>

[434] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-15-3-more-plant-less-water>

[435] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/15-3-3-phenology-drought-and-yield>

[436] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/15-3-4-regulated-de-cits-and-fruit-yield>

[437] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/15-3-5-drought-stress-and-adaptive-responses>

[438] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/feature-essay-15-1-resurrection-plants>

[439] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/15-4-water-use-natural-plant-communities>

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[443] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/15-4-3-epiphytes>

[444] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/15-5-concluding-remarks>

[445] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-13>

[446] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/chapter-16-nutrients-sparse-resource>

[447] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/introduction-12>

[448] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/16-1-soil-formation>

[449] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/feature-essay-16-1-brief-history-plant-nutrition>

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[455] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-16-2-nutrient-response-eucalyptus-grandis>

[456] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/16-3-3-deficiencies-and-responses>

[457] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/feature-essay-16-2-sodium-c4-photosynthesis>

[458] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/16-3-4-diagnosis-deficiencies>

[459] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/16-3-5-nutrient-interactions>

[460] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/16-4-adaptation-low-availability-nutrients>

[461] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/16-4-1-symbiotic-associations>

[462] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-16-3-rainforest-succession-and-nitrogen-nutrition>

[463] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/16-4-2-parasitic-plants-and-carnivorous-plants>

[464] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/16-5-soil-acidity-and-toxicities>

[465] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/16-5-1-soil-acidification>

[466] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/16-5-2-aluminium-and-manganese-toxicities>

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[468] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/16-6-concluding-remarks>

[469] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-14>

[470] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/chapter-17-salt-environmental-stress>

[471] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/introduction-15>

[472] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/17-1-perspectives-salinity>

[473] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/17-1-1-geographic-extent>

[474] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/17-1-2-sodic-soils>

[475] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/17-1-3-solutes-and-osmotic-pressure>

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[478] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/17-2-2-perennial-plants>

[479] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/17-2-3-heritability-salt-tolerance>

[480] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/17-3-halophytes-and-adaptation-salt>

[481] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-17-1-mangroves-and-saltmarsh-communities>

[482] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/17-3-1-devices-manage-leaf-salt>

[483] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/17-3-2-turgor-maintenance>

[484] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/17-3-3-organic-solutes-metabolic-protectants>

[485] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-17-2-aquatic-organisms-and-compatible-solutes>

[486] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/17-4-salt-affected-land-utilisation-and-reclamation>

[487] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-15>

[488] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/chapter-18->

waterlogging-and-submergence-surviving-poor-aeration

[489] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/introduction-16>

[490] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/18-1->

waterlogging-and-submergence-terrestrial-plants

[491] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/18-1-1-root-zone-aeration>

[492] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/18-1-2-adaptive-responses-waterlogging>

[493] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-18-1-soybean-unsuspected-paludophyte>

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[495] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/18-2-seagrasses-angiosperms-adapted-sea-floors>

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[498] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/case-study-18-3-seagrasses-successful-marine-macrophytes>

[499] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-16>

[500] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/chapter-19-fire-ecosystem-sculpture>

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[511] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/19-3-strategies-surviving-re-prone-environments-seeders-and-resprouters>

[512] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/19-3-1->

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[513] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/19-3-2-fire-ephemerals-plants-grow-seed-banks>

[514] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/19-3-3-cryptophytes-geophytes-plants-grow-storage-organs>

[515] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/19-3-4-obligate-seeders-and-resprouters-perennial-plants-seed-or-resprout-after-re>

[516] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/19-4-impact-climate-change-and-burning-practices-vegetation>

[517] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/19-4-1-introduction>

[518] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/19-4-2-pollen-evidence-indicating-changes-vegetation>

[519] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/19-4-3-fire-ecosystem-sculptor>

[520] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-17>

[521] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/chapter-20-herbicide-resistance-case-rapid-evolution>

[522] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/introduction-18>

[523] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/20-1-acquiring-resistance-herbicides>

[524] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/20-1-1-lolium-rigidum-australia-very-resistance-prone-weed>

[525] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/20-1-2-rapid-development-resistance>

[526] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/20-2-biochemistry-herbicide-resistance>

[527] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/20-2-1-target-site-resistance>

[528] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/20-2-2-non-target-site-resistance-mechanisms>

[529] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/20-2-3-cross-resistance>

[530] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/20-2-4-multiple-resistance>

[531] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/20-2-5-lessons-be-learnt-herbicide-resistance>

[532] <http://plantsinaction.science.uq.edu.au/edition1/?q=content/further-reading-18>