

Index

Page numbers in *italics* refer to figures and tables

- Abutilon*, glyphosate-resistant 151
- acid rain 297
- Africa
 - agriculture
 - challenges 362, 363, 364–365
 - goals 370–371
 - labour force 364
 - biosafety 374–375
 - biotechnology 360–377
 - current status 366–370
 - development constraints 371–375
 - potential 376–377
 - products 370–371
 - brain drain 372
 - capital resources 372
 - cereal imports 362
 - crop pests/diseases 365
 - drought 364–365
 - gene transfer 375–376
 - GM crops 374
 - human resources 371–372
 - infrastructure 372
 - insect resistance to *Bt* toxins 376
 - insect-resistant maize 369
 - intellectual property rights 373
 - legislative frameworks 374, 375
 - networks 372
 - patent law 373
 - political instability 372
 - political will 374
 - production output/levels 364
 - rainfall 364–365
 - regulatory controls 374, 375
 - safety of biotechnology 375
 - scientists 371–372
- soils 365
- trade imbalances 373–374
- agricultural environment, GM crop effects 31–34
- agricultural intensification 267–268, 391
 - atmospheric effects 393
 - biodiversity impact 392
- agricultural land
 - extent 62
 - global distribution 392
- agricultural practice
 - changes 267–268
 - China 347–349
 - developing world 268
 - environmental effects 236
 - farmland bird decline 267
 - non-target arthropods 179–181
- agricultural production
 - biodiversity 31–32
 - wildlife 31–32, 33
- agricultural revolution 386–387
 - costs 390–391
 - pest adaptation 390
- agriculture
 - Africa
 - challenges 362, 363, 364–365
 - goals 370–371
 - labour force 364
 - biodiversity 31–32, 241, 242, 245–247
 - impact 392–393
 - biotechnology 361, 397–399
 - energy inputs 387
 - environmental impact 391–394
 - evolution 24–25, 51, 383–391
 - freshwater requirements 392
 - future 394–401
 - global climate change 396–397

- agriculture (*continued*)
 high-input 387
 land use 391–393
 landscape impact 392
 low-input 62
 mechanization 386
 soil impacts 393
 water quality impact 393
 agri-environment schemes (AES) 269
Agrobacterium transgenic method 5–6
Agrobacterium tumefaciens 5
 agrochemicals 387–389
 agroecosystems 242, 391–394
 agronomic practices, changes 117–128
 AIDS 42
 allergies, plant protein 50
Amaranthus, glyphosate-resistant 135, 137
Ambrosia, glyphosate-resistant 135, 137
 1-amino cyclopropane-1-carboxylate (ACC)
 synthase 12–13
 α-amylase inhibitors 166
 animal feed 279–280
 encoded protein fate 284–285
 GM ingredients 279–280
 Jatropha curcas seed cake 306–307
 processing 285
 transgenic DNA 284–285, 286
 anti-idiotype antibodies 15–16
 anti-nutritive factors (ANFs), *Jatropha curcas* 309
 antioxidants 377
 aphids 168
 Bt maize 336–337
 GNA-fed 176
 honeydew 169
Apis mellifera (honeybee) 200
 aquatic plant pests 249
 arthropods
 cotton pests 350–351
 entomophagous 168, 170, 171,
 175–176
 maize field fauna 333, 334–335, 335
 non-target 332–333, 402–404
 above-ground 165–186
 Bt maize field trials 336–339
 Bt maize toxin exposure 335–336
 see also insect(s); spiders
 assessment end points 182–183
 atmosphere, agricultural intensification
 effects 393
 atrazine
 ban 34
 maize crop use 129
 avicidin 16
 avidin 208
- Bacillus thuringiensis* 8, 44, 388
 insecticidal protein production 74–75, 166
 see also *Bt* crops; *Bt* toxins; named
 Bt crops
- bacterial blight of rice 10
 bacterial communities
 gene transfer 234–235
 soil 226–227, 228
- bacterial diseases 10
 beef cattle, production studies 283
 bees
 Bt toxin effects 201, 202
 non-*Bt* insecticidal proteins 203–205
 solitary 214
 see also bumblebees; honeybees
- bentgrass, creeping 120, 143
 betaine aldehyde dehydrogenase (BADH) 12
 biodiesel 296–317
 cetane number 301
 composition 299–300
 demand 302
 Jatropha curcas characteristics 304–306
 market demand 300
 non-edible oilseed plants 302
 petro-diesel blending 300–301
 production/consumption in EU 300
 properties 301–302
 subsidies 302
- biodiversity 240–257
 agricultural production 31–32, 241,
 242, 246–247
 agriculture impact 392–393
 centres 247
 conservation tillage for herbicide-tolerant
 crops 249–252
 crop 247
 food 54
 global distribution 245
 GRC impact 123–124
 habitat loss 248
 introduced species 248–249
 loss 54, 247–249
 need for 241, 242–243
 soil microbial community 230–232
 traditional knowledge 54
 types 243–245
- biofences 307
 biofuels 50, 296–317
 greenhouse gas impact 118
 subsidies 302
- bioinsecticides 307
- biological control
 Bt toxin safety to organisms 185–186
 natural enemies 180
- biomass energy 43
 biopesticides 307
 biosafety, Africa 374–375
 biotech crop countries 363
 biotechnology 4, 27
 African 360–377
 agricultural 361, 397–399
 biotic constraints 7–11
 biotin-binding proteins 167
 birds, farmland 35, 265–274
 agricultural practice changes 267–268
 decline in Europe 266–267, 268–269
 extinctions 268
 farm-scale evaluations 269–273
 food abundance/availability 270
 foraging behaviour 270
 GRC-based systems 124
 herbicide-tolerant crop impact 269–274
 invertebrate in diet 272

- mitigation of effects 35
nesting behaviour 270
population impact of GM crops 273–274
protection 268–269
seed resources 270–272
bollworm, pink 351, 352, 355
Bowman-Birk soybean trypsin inhibitor (BBI) 174, 210
Bt cotton 29–30, 75
 bee impacts 202
 China 345–346, 349
 Cry proteins 166
 full length Cry1Ac protein 78
 hybrid 207
 insect pests 207–208
 integrated resistance management implementation 354–355, 356
 land area planted 400
 pesticide use reduction 352
 refuge requirements 80–81
 resistance
 field-evolved 87–88
 monitoring 86–87, 352–354
 two-toxin 81
Bt crops 74–75
 biological control organism safety 185–186
 China
 acreage in 344–346
 resistance monitoring 344–356
 control failure absence in field populations 104
 environmental impact 180
 herbivore behaviour on 171–172
 incomplete resistance 85
 integrated resistance management implementation 354–356
 migration rates 105
 natural enemy conservation 180
 plant health improvement 181
 pollinator hazards 206–207
 predator:prey response 256
 pyramided 81, 85, 108
 refuge strategy for delaying resistance 79–85, 104, 105
 resistance
 management 101–109
 monitoring 86–87, 344–356
 refuge strategy for delaying 79–85, 104, 105
 secondary pest outbreaks 180–181
 two-toxin 81, 85
Bt genes 9, 150
 see also stacked traits
Bt maize 29, 47–48, 75
 bee impacts 201, 202
 commercial planting in EU 327–329
 detritivores 256–257
 herbivores
 populations 254–255
 predation 170
 insecticidal protein exposure to insects 169
integrated resistance management implementation 355–356
land area planted 400
natural enemy impacts 336
non-target arthropods 403–404
 field trials 336–339
 Spain 332–333
 toxin exposure 335–336
non-target organism impacts 252–257
parasitoid populations 253, 254, 255
predator populations 253, 254, 255
predator:prey ratio 256
Spain
 field trials 332–333
 growing in 327–331
 non-target arthropods 332–333
 target insect monitoring for field resistance 331–332
stacked traits 166, 400–401
toxin exposure of non-target arthropods 335–336
truncated Cry proteins 78
Bt oilseed rape 201, 202
Bt potatoes 166
 predator abundance 256
Bt toxins 8–10, 27, 388, 399–400
 bee impacts 201–202
 cadherin-based resistance 79
 direct effects 183
 exposure 185
 fate in soil 376
 gene modification for improved expression 83
 indirect effects 183
 mode of action 77–78
 non-target arthropod exposure 335–336, 404–405
 specificity 78
 weed species fitness impact 150
world use 166
 see also insect resistance to *Bt* toxins
Bt transgene 150
bumblebees
 foraging distances 214
 GM plant responses 210
 oilseed rape pollination 215
 pollen consumption 210
Burkina Faso, biotechnology 369–370

C₃ plants 13
C₄ photosynthetic pathway 13
cabbage looper control 46–47
cadherins 79
cancer-fighting tomatoes 377
canola
 gene flow
 to other crops 142
 to weeds 145
 herbicides
 resistance traits 142
 use 128–129
herbicide-tolerant 28
livestock feed 279

- canola (continued)
- trait introgression 142
 - transgene introgression 145
 - weedy relatives 138
 - wild relatives 145
 - see also* oilseed rape
- carbon, organic 229–230
- carbon dioxide 297–298
- carbon monoxide 301
- CaroRx 16
- Cartagena Protocol on Biosafety (CPB) 64
- caterpillars 54
- cattle
- Cry1Ab degradation during digestion 286–287
 - forest cover loss 391
 - production studies 283
- China
- agricultural practice 347–349
 - Bt* cotton 345–346, 349
 - insect resistance monitoring 352–354
 - Bt* crop resistance monitoring 344–356
 - cotton
 - crop pests 350–351
 - production 347–349 - integrated resistance management implementation 354–356
 - pesticide use 351–352
 - refuge strategy for delaying resistance to *Bt* crops 355
 - regulatory controls 345
 - chitinases 208
 - chloracetamide, maize crop use 129
 - Chrysoperla carnea* (green lacewing) 177, 182
 - 'clean culture' 49
 - climate change 297, 398–399
 - global 396–397
 - land availability 398
 - see also* greenhouse gases - coastal ecosystems 243
 - coccidioides vaccine 15
 - Codex process 64
 - commercialization, final authorizations 61
 - community-level physiological profiling (CLPP) 233
 - Compa maize variety 9
 - compatible solutes 11–12
 - compositional analyses of GM crops 281
 - conservation tillage, herbicide-tolerant crops 249–252
 - Conyza* glyphosate resistance 135, 136, 139
 - corn borer 9
 - control 47–48
 - European 29, 329, 331–332, 333
 - Mediterranean 328, 331–332, 333 - cotton
 - gene flow 142
 - GM 29–30, 48
 - herbicide use 129
 - herbicide-tolerant 29–30
 - planted area 118 - improved varieties 348–349
 - insecticide use reduction 180
 - insect-resistant varieties 9
 - livestock feed 279
 - nectar source 200
 - pest problems 350–351
 - pesticide use 48
 - in China 351–352 - planted area of herbicide-resistant 118
 - pollen 142
 - pollination 215
 - production in China 347–349
 - tillage methods 126
 - Vip3A crops 172
 - weed community changes 139
 - wild relatives 145
 - see also* bollworm, pink; *Bt* cotton

cotton bollworm 350–351

Bt cotton resistance

 - monitoring 352–354
 - Bt* toxin resistance 86–87
 - integrated pest management 355, 356
 - refuges 355, 356

CpTI protease inhibitor 108

creeping bentgrass

 - gene flow 143
 - glyphosate-resistant cultivars 120

crickets 54

crop(s)

 - biodiversity centres 247
 - conventional production practices 25–27
 - costs of losses to pests 46
 - damage 388
 - domestication 385
 - food species 51
 - founder 385
 - gene flow
 - to other crops 140–143
 - from weeds 147–148
 - to weeds 143–147 - genetic diversity, transgene introgression 144
 - genetic engineering 44–47
 - hybrid 386, 389
 - hybridization 62
 - with weeds 402–403 - improved varieties 4
 - improvement 62
 - landrace 386
 - losses to pests 44–47
 - near-relative wild plants 144
 - quantitative traits 389–390
 - stresses 396
 - stress-tolerant 364, 397
 - yield 13
 - lack of benefit from GM crops 48

crop breeding 386

 - environmental impact 402–403
 - modern 389–391
 - mutation 390

crop diseases 10–11

 - African 365

crop rotation

 - changes 118
 - GRCs 127–128
 - weed community impact 128

cropland, availability decline 43–44

crucifers, dead-end trap crops 109

- Cry (crystal) proteins 8, 75, 166, 399
 bee impacts 201–202
 dilution along food chain 184–185
 pyramided proteins 175
 resistance to toxins 103
 safety 375
 specificity 172, 185
 truncated 78
cry gene 399
 Cry1 family proteins 9–10
 bee impacts 201–202
 pollinator hazards 206
cry1A gene
 fusion 207
 resistance 104
 Cry1Ab 75, 76
 degradation during digestion in cattle 286–287
 green lacewing indirect effects 177
 pyramided protein 175
 with Vip3A 108
 Cry1Ac 9–10, 75, 76
 cadherin proteins 79
 full length 78
 resistance 86–87
 field-evolved 86, 87–88
 two-toxin *Bt* cotton 81
 Cry2 family proteins 206
 Cry2Ab 81
 Cry2Ab2 175
 Cry3 family proteins 206
 Cry9 family proteins 206
 cysteine protease inhibitors 204–205
- dairy cows
 production studies 283, 284
 tDNA in products 288
Danaus plexippus (Monarch butterfly) 167
 DDT 388
 deforestation 365
 desert ecosystems 243
 desertification 392
 detritivores
 Bt maize 256–257
 soil fauna 235–236
 developing world
 agricultural practice 268
 pesticide poisonings 25
 developmental regulators 14
 differential gradient gel electrophoresis (DGGE) 231, 233
- diseases
 African crops 365
 crop 10–11
 fungal of wheat 121
 human 42
 resistance 10
 disseminators, soil fauna 235–236
 diterpene phorbol esters (PE) 307
- DNA
 consumption 285
 digestion 285
 direct transfer technique 6
 free 234–235
 see also transgenic DNA (tDNA)
 DNA techniques 63
 drought 396
 Africa 364–365
 natural vegetation clearance 392
 stress 11–12
 drought tolerance 364–365
 rice 12, 377
- ecosystems
 conservation 245
 diversity 240, 241, 242, 243, 244, 245
 management 245
 natural 244
 sustainability 241
Egypt, plant biotechnology 368
 einkhorn, wild 246, 385
Eleusine indica, glyphosate-resistant 135, 136
 emmer, wild 246
 δ-endotoxins 8
 energy
 biomass 43
 expenditure 43
 inputs into agriculture 387
 resources 43
 non-renewable 297
 renewable 297–298
 solar capture by perennial crops 53
- environment
 agricultural 31–34
 agricultural practice impacts 236, 391–394
 benefits of GM crops 23–37
 gene flow impact 401–403
 herbicide resistance persistence 151
 indirect benefits of GM 34–36
 insect-resistant GM crop impact 180
 pesticide impact 26, 46, 51
 transgenic crop impact 401–405
 weed control impact 401–403
- environmental exposure concentration (EEC) 184
 environmental monitoring programmes 329
 Environmental Protection Agency (EPA) 25
 environmental risk assessment 61–70
 agricultural practices 70
 Bt maize in Spain 329
 cultivation operations 70
 data interpretation 68–70
 end points 67–68
 field testing 67, 68–69
 pesticide applications 70
 principles 64–66
 regulatory guidance 63–64
 structuring 66–67
 substantial equivalence concept 65
 tiered approach 66–67
 unintended effects 65–66
- EpCAM molecules 16
 ethanol production 50
Euphorbia heterophylla, glyphosate-resistant 135, 136

- Europe
 agricultural practice changes 267–268
 farmland birds 266–267
- European Food Safety Authority (EFSA) 183, 280, 330
- European Union
 agri-environment schemes 269
 biodiesel production/consumption 300
Bt maize commercial planting 327–329
 Directive 2001/18/EC 182, 329, 330
 pesticide use 30–31, 36
- exhaust gas recirculation (EGR) 301, 306
- extinctions
 birds 268
 species 247, 249
- F₁* hybrid crops 389
- farm-scale evaluations (FSEs) 31–32
 birds 269–273
- fatty acid biosynthesis (FAB) genes 316
- fatty acid methyl esters (FAMEs) 299–300, 305
- fatty acids, unsaturated 305
- Federal Insecticide, Fungicide and Rodenticide Act (FIFRA, US) 182
- Fertile Crescent 385
- fertilizers, chemical 387
 biodiversity impact 393
- field testing 67
- fish, tDNA in products 289
- fitness costs
 insect resistance to *Bt* toxins 83–85, 106–107
 refuge strategy 83–85
- flooding 396
 stress 12–13
- flood-resistant crops 377
- floral phenotypic changes 212
- food
 biodiversity 54
 use in Western countries 53
- Food and Agriculture Organization (FAO), regulatory guidance 64
- food production
 losses to pests 45
 worldwide 387
- food products, animal-derived 287, 288–289, 289
- food security 3–17, 42
 definition 4
- forests 391
 ecosystems 242
 loss 44
- fossil energy 43
- fossil fuels 297
 environmental damage 297–298
 rising prices 298
- founder crops 385
- freshwater
 agriculture requirements 392
 ecosystems 242
 resources 44
- fungal communities, soil 226–227, 228
- fungal diseases of wheat 121
- fungicides 387
- fusion genes 9–10
- Galanthus nivalis* agglutinin (GNA) 173, 208
- parasitoid/predator effects 176
- garlic leaf lectin 173
- GATEWAY vectors 6
- gene flow
 African crops 375–376
 cotton bollworm 355
 crop
 to crop 140–143
 from weed 147–148
 to weed 143–147
- environmental impact 401–403
- soil bacterial communities 234–235
- weed
 from crops 143–147
 to crops 147–148
 to weed 148–149
- gene shuffling 150
- gene transfer
 African crops 375–376
 bacterial communities 234–235
- genetic bottlenecks 385–386
- genetic diversity 243–245
Jatropha curcas 310–312
 transgene introgression 144
- genetic engineering, origins 384–385
- genetically modified herbicide-tolerant (GMHT) crops 31
see also herbicide-tolerant crops
- geranylgeranyl diphosphate (GGPP) 14
- global warming *see* climate change;
 greenhouse gases
- glufosinate 36
- canola resistance 142
- crop resistance 128–129
- rice resistance 120, 146
- glycine betaine 12
- glyphosate 7, 400
 economic importance 130–131
 fungal disease control 121
 herbicide-tolerant cotton 29–30
 herbicide-tolerant soybean 28
 maize crop use 129
 resistance 125
 canola 142
 persistence in environment 151
 transgenic 133
- selection pressure on weed
 communities 119–120
- soybean crop use 129–130
- surface runoff 36
- transgenic crop use 250–252
- glyphosate acetyltransferase 150
- glyphosate-resistant crops (GRCs) 116–117
 adoption 118–120
 rate of 122–123
- biodiversity impact 123–124
- bird populations 123
- coexistence with non-genetically modified crops 124–125

- crop rotation 127–128
 cultivars 121
 economic value 120–121
 herbicide use 128–132
 insect populations 123–124
 market share 119
 microhabitats 127
 perception of risks 122–123
 pesticide use reduction 121
 production system
 sustainability 125–128
 proportion of GM crops 119
 soil biota 124
 soybeans 251–252
 superweed influence 138–139
 technology fees 131
 tillage system changes 121, 125–126
 weed control 122
 weed population shifts 123, 125
 glyphosate-resistant weeds 133–138
 GM crops
 adoption 118–120
 Africa 374
 commercialization 397–398
 comparative safety assessment 280–284
 compositional analyses 281, 284
 economic value 120–121
 floral phenotypic changes 212
 future 399–401
 global biotech area 363
 global status 102, 361, 362
 near-relative wild plants 144
 non-target organisms 403–405
 pesticide use reduction 121
 GM higher plant (GMHP) 68
 GM traits
 movement 139–149
 see also gene flow; stacked traits
 'Golden Rice' 14
 grain
 annual production 51
 energy requirements 52
 perennial 52–53
 segregation 124–125
 use in Western countries 53
 yields 51–52
 grassland ecosystems 242
 green revolution 23–24, 25, 62, 386, 387–389
 inorganic fertilizer use 393
 greenhouse gases 297–298
 biofuel growing 118
 carbon dioxide 297–298
 carbon monoxide 301
 methane 297–298
 nitrous oxide 301, 305, 306
 sulfur dioxide 301
 groundwater, herbicide pollution 49

 habitat loss 248
 health risks 50
 pesticide use in China 351–352
Helicoverpa armigera (cotton bollworm)
 86–87, 350–351
- Heliothis zea*
 Bt toxin resistance 86, 87, 88
 non-recessive resistance 103
 hepatitis B virus, plant-derived antibody 17
 herbicides 387
 cost 131
 diversity lack 130
 increased use with GM crops 48
 losses in surface runoff 35–36
 mode of action 388
 pollution 49
 resistance 49
 multiple traits 150
 persistence in the environment 151
 superweeds 132–133
 weeds 51, 133–138
 resistance gene
 pleiotropic effects 133
 stacking 149–150
 seed resources for birds 270–272
 supplemental for weed population shifts 132
 tillage reduction 250
 use on transgenic crops 250–252
 herbicide-tolerant crops 7, 27–30, 31, 49, 361, 400
 bird impacts 269–274
 direct 269
 indirect 269–273
 chemical composition 281, 284
 conservation tillage 249–252
 pollen movement 212–213
 pollinator hazards 205–206
 herbivores
 behaviour on *Bt* crops 171–172
Bt maize
 field trials 336–337
 populations 254–255
 facultative 169
 honeydew ingestion 169
 insecticidal proteins
 exposure 168, 169
 mortality 176
 sublethal effects 176, 178–179
 maize fields 333, 336–337
 predation 170
 protease inhibitor adaptations 174
 high-dose/refuge strategy 332
 see also refuge strategy for delaying resistance to *Bt* crops
 honeybees 200
 cotton pollination 215
 foraging distances 213–214
 GM plant responses 210
 oilseed rape pollination 215
 pollen consumption 210
 soybean pollination 215
 honeydew 169–170, 176–177
 human population 26, 394–395, 396
 humans
 early 384
 health risks 50
 pesticide use in China 351–352

- hybridization 386, 389
crop plants 62
with weeds 402–403
- hypoxia, flooding stress 12–13
- identity preservation 124–125
- insect(s)
bird diet 272
foraging distances 213–214
maize crops 34
maize fields 333
oilseed rape crops 33
pollination of GM crops 214–215
soybean crops 123–124
sugarbeet crops 33–34
see also arthropods
- insect pathogens, GM crop combination 107
- insect pests 8–10
Africa 365
Bt cotton 207–208
cotton crops 350–351
field resistance monitoring 331–332
fitness 106–107
herbicide impacts 49–50
plant damage prevention 181
region-wide suppression 175–176
secondary outbreaks 180–181,
185–186
- insect resistance to *Bt* toxins 75, 76–77, 150,
399–400
Africa 376
dominance 82–83, 87, 89
environmental impact 401
field monitoring 87
field-evolved 87–88
fitness costs 83–85, 106–107
genetics 78–79
incomplete 85
mode 1 78–79
refuge strategy for delaying 79–85, 104
population-level
processes 105–106
refuge theory 87
- insect resistance to GM crops 74–90,
399–400
environmental impact 401
evolution 75
management 101–109
- insecticidal proteins
behavioural response to plant 170–172
direct toxicity 167–172
exposure
routes 167–168
through plant feeding 168–169
- highest mean concentration 184
honeydew exposure 169–170
indirect effects 175–179
- Lepidoptera larvae hazards 174–175
molecules 47–48
mortality of herbivores 176
non-*Bt* effects on bees 203–205
non-target effects 167–179
parasitization exposure 170
- plant feeding exposure 168–169
predation exposure 170
sublethal effects on herbivores 176
- insecticide-resistant (IR) GM crops 101–109
insecticides 387
broad-spectrum spray damage 181
cotton crop use 180
maize crop use 46, 179
reduction in use 180
terpenoids 307
- insect-resistance genes 8
insect-resistant transgenic crops 361,
399–400
above-ground non-target arthropod
impact 165–186
- agricultural practice changes 179–181
chemical composition 281
direct toxic effects 167–172
environmental impact 180, 404
exposure routes 167–168
natural enemy hazards 172–174
regulatory risk assessment 181–186
risk assessment 181–186
- integrated pest management (IPM) 167
- integrated resistance management (IRM) 109
Chinese implementation 354–356
- integrated weed management (IWM)
117, 131
- intellectual property rights, Africa 373
- Intergovernmental Panel on Climate Change
(UN) 397
- introduced genes, pest potential 50
- invertebrate populations
biomass 273
farmland bird diet 272
- irrigation 392
- Jatropha curcas*
accessions 310–312, 315
agronomic requirements 315
biodiesel 296–297, 303–317
biotic stress 314–315
co-carcinogens 307, 309–310
co-products 306–307
diseases 314–315
economic factors 308
fatty acid ethyl esters 305
fatty acid methyl esters 305
flowering 312
fuel production 308
gene expression analysis 315–316
gene mining 315–316
generative propagation 314
genetic variability limitations 310–312
phorbol esters 307, 309–310
plant biology 303–304
pollination 313
propagation 312, 314
reproduction 313
seed cake 306–307
seed germination 312
seed oil characteristics 304–306
seedlings 314
socio-economic development 308

- toxins 306–307, 309–310
traditional uses 307
uses 304, 307
vegetative propagation 314
waste processing 306
wasteland reclamation 308
jatropholones 307
- Kenya, plant biotechnology 368–369
- lacewing, green 177, 182
land use, agricultural 391–393
landscape, agriculture impact 392
lectins 167, 173
 pollinator effects 208, 212
legislative frameworks in Africa 374, 375
Lepidoptera
 Bt toxins 166
 resistance 78–79, 103–104
 insecticidal protein hazards to
 larvae 174–175
 non-target species 167, 403–404
 Red List species 167
- lignin, reduction in plants 50
- linoleic acid 305
- livestock 53
 diseases 369
 feed
 encoded protein fate 284–285
 GM ingredients 279–280
 Jatropha curcas seed
 cake 306–307
 processing 285
 transgenic DNA 284–285, 286
 monogastric 282–283
 nutrient bioavailability 282
 nutritional assessment of GM
 crops 281–284
 production studies 282–284
 ruminant 283
 tDNA detection 285–287
- living modified organisms (LMOs) 64
- Lolium*, glyphosate-resistant 135,
 137–138
- lucerne
 gene flow 143
 glyphosate-resistant cultivars 120
- lycopene 377
- maize
 arthropod fauna 333, 334–335, 335
 chemical composition 284
 corn borer control 47–48
 domestication 385
 gene flow
 to other crops 141
 to weeds 144
 glyphosate-resistant 119, 150
 GM 28–29
 herbicide use 129
 herbicide-tolerant 34, 118
 insecticide use 46, 179
 insect-resistant variety 9, 369
 livestock feed 279, 280
 losses to pests 46
 natural enemy abundance 179
 planted area of herbicide-resistant 118
 pollen
 insecticidal proteins 175
 monarch butterfly long-term
 exposure 185
 movement 124–125, 141
 pollination 214
 silage chemical composition 284
 spontaneous hybridization 144
 transgenes introgression 141, 144
 Vip3A 172
 weeds
 abundance 272
 community changes 139
 yield enhancement 13
 see also *Bt* maize
- maize stem borer control 179
- malaria 42
- malnutrition 42
- Malthusian cycles 394–395
- managed ecosystems 244
- marine ecosystems 243
- marker genes 5
- metabolically engineered plants 209
 pollinator impact 200, 202, 209
- metapopulations, evolution of
 resistance 105
- methane 297–298
- microbial communities, soil 230–232
- Millennium Ecosystem Assessment 394
- minilivestock 53–54
- molecular biology 62
- molecular pharming 14–17
- monarch butterfly 48, 403–404
 broad-spectrum spray insecticide
 damage 181
 herbicide-tolerant crop impact 269
 insecticidal proteins in pollen 175
 long-term exposure to maize pollen 185
 pollen passive ingestion 169
 Red List species 167
- monocultures
 biodiversity impact 392
 F₁ hybrids 389
 natural 246
- Monsanto, market share of GRCs 119
- moths, foraging distances 214
- N-acetyltransferase 150
- native organisms, genetically engineered 50
- natural ecosystems 244
- natural enemies
 abundance
 Bt maize varieties 179
 Bt potato cultivars 179–180
 biological control function 178
 Bt maize 179, 336
 conservation with *Bt* crops 180
 GM crop combination 107
 hazards 172–174

- natural enemies (continued)
 insect pest region-wide suppression 176
 insecticidal proteins
 herbivores affected by 178–179
 transfer 167–168
 insect-resistant transgenic crops 404
 natural gas 299
 natural vegetation, clearance 391–392
 nectar
 protein content 210
 sources 200
 nematodes 107
 New Rice for Africa (NERICA) 371
 nitrate leaching 393
 nitrogen cycle 229
 nitrogen-fixing organisms 229
 nitrous oxide 301, 305, 306
 non-Bt toxins 108
 non-genetically modified crops, GRC
 coexistence 124–125
 non-Hodgkin's lymphoma vaccines 15–16
 no-tillage systems 126
 no-till conservation 49
 nuclear polyhedrosis virus (NPV) 46–47, 107
 nut allergies, health risks 50
 nutrients
 bioavailability 282
 cycling in soil 228–229
 nutritional assessment of GM crops 281–283
 nutritional improvement 13–14
- oil palm, forest cover loss 391
 oil prices 298
 oilseed plants, non-edible 302–303
 oilseed rape
 Bt crops 201, 202
 cross-pollination 215
 herbicide-tolerant 28
 spring-sown 32–33
 winter-sown 32
 nectar source 200
 pollination 215
 volunteer weeds 403
 weed seeds 271–272
 see also canola
 oleic acid 305
 organic matter, soil inputs 229–230
 Organization for Economic Cooperation and Development (OECD) 183
 safety assessment 281
 oxygen deficit, flooding stress 12–13
- palmworms 54
 panleukopenia vaccine 16
Papilio polyxenes (black swallowtail) 403
 parasitic wasps 171, 176–177
 parasitism 7
 parasitization, insecticidal protein
 exposure 170
 parasitoids
 Bt maize field trials 339
 honeydew ingestion 169
- hymenopteran 171
 insecticidal proteins
 exposure 169
 indirect effects 177–178
 transfer 167–168
 insect-resistant transgenic crops 404
 populations in Bt maize 253, 254, 255
 protease inhibitor actions 174
 particle bombardment 6
 PAT gene 150
 patent law, Africa 373
 pathogen-derived resistance 11
 perennialism 52
 cropping benefits 52–53
 pest(s)
 adaptation 390
 African crops 365
 control 8–10, 45–46
 crop losses 44–47
 see also insect pests
 pesticides 387–389
 biodiversity impact 393
 contact non-persistent 27
 costs of use worldwide 46
 cotton crops in China 351–352
 environmental impact 26, 46, 51
 EU usage 30–31, 36
 GM crop impact 27–30
 poisoning 25, 46
 pollution 393
 public health impact 25, 46
 resistance 51
 synthetic 25
 terpenoids 307
 use
 with GM cotton 48
 reduction 121
 transgenic crops 250–252
- petro-diesel 300–301
 properties 301–302
 petroleum 299
 pGreen vectors 5
 phorbol esters 307, 309–310
 phosphoenolpyruvate carboxylase (PEPC) 13
 phospholipid fatty acid profiles (PFLA) 233
 phytoene 14
 phytoremediation 35
 pigs
 production studies 282–283
 tDNA in products 288–289
- plant(s)
 domestication 385
 improved varieties 4
 transgenic
 methodology 5–6
 triple 9
 plant diseases, African crops 365
 plant feeding, exposure to insecticidal proteins 168–169
 plant pathogens, herbicide impacts 49–50
 plant protein allergies 50
 plant-derived antibodies 16–17
 plant-made industrial proteins (PMIs) 14
 plant-made pharmaceuticals (PMPs) 14

- pleiotropy
herbicide-resistance gene 133
refuge strategy for delaying resistance to
Bt crops 84
- poisonings, human with pesticides 25, 46
- policies on biotechnology 374
- pollen
agricultural 393
cotton gene flow 142
dispersal patterns 213
drift 47
GM trait movement into non-GM crops/
weeds 123, 124–125
insect food source 169
insecticidal protein exposure 169
- maize
gene flow 124–125, 141
insecticidal proteins 175
monarch butterfly long-term
exposure 185
- movement 212–213
- novel protein expression 210, 211, 212
- passive ingestion 169
- pollinator transport between
GM/non-GM plants 205
- rice gene flow 142–143
- soybean gene flow 142
- transgene expression 210, 211, 212
- pollination
cotton 215
insect 214–215
Jatropha curcas 313
maize 214
oilseed rape 215
open 125
patterns 213
soybean 215
wind 214
- pollinators 199–216
abundance variation 213
alternative 200
exposure routes 209–210, 211, 212
foraging distances 213–214
GM plant responses 210
honeydew ingestion 169
insect-resistant transgenic crops 404
metabolically engineered plant
impact 200, 202
- pollen transport between GM/non-GM
plants 205
- potential hazards from GM
plants 205–209
- potential impacts of GM crops 200
- toxicity risk from GM plants 205
- transgene flow 212–215
- worldwide decline 199–200
- pollution
fertilizers 393
herbicides 49
pesticides 393
use in China 351–352
- Pongamia pinnata* 303
- population dynamics 394–397
evolution of resistance 104–105
- potato
Bt 166, 256
herbicide-tolerant 30
insect-resistant 166
natural enemy abundance 179–180
nutritional improvement 14
predator abundance 256
- poultry
production studies 282
tDNA in products 288
- predation, insecticidal protein exposure 170
- predators
Bt maize
field trials 337–339
populations 253, 254, 255
detritivore relationships 256–257
honeydew ingestion 169
insecticidal proteins
exposure 169
transfer 167–168
- insect-resistant transgenic crops 404
- maize fields 333
- potato crop abundance 256
- prey range 176
- protease inhibitor adaptations 174
- response to herbivore behaviour on *Bt*
crops 171–172
- primary transformant 5
- protease inhibitors 166, 173–174
- pollinator effects 208
- proteins, novel, presence in animal-derived
food products 287
- public concerns over GM trait
movement 140
- public health
herbicide pollution 49
pesticide impact 25, 46
- pyrethroids, synthetic 388
- pyruvate orthophosphate dikinase (PPDK) 13
- quantitative traits 389–390
- rabies vaccine 16
- rainfall in Africa 364–365
- refuge strategy for delaying resistance to *Bt*
crops 79–85, 104
- Bt* maize pests 332
- China 355, 356
- cotton bollworm 355, 356
- dominance of resistance 82–83
- versus field monitoring evidence 87
- fitness costs 83–85
- high-dose 82
- incomplete resistance 85
- insect gene flow 81–82
- integrated approach to resistance
management 109
- non-random mating 105
- pleiotropic effects 84
- population-level processes 105–106
- random mating of insects 81–82
- refuge size/composition 80–81

- regulatory controls
 - Africa 374, 375
 - China 345
 - South Africa 366
- regulatory risk assessment 181–186
 - assessment end points 182–183
 - environmental exposure
 - concentration 184
 - risk hypotheses 183–185
- reindeer population 395–396
- resistance
 - evolution 104–108
 - bottom-up impacts 106–107
 - population-level processes 105–106
 - top-down impacts 107–108
 - non-recessive 103
- resistance genes, ecological factors 104–105
- resistance management of herbicide-tolerant crops 115–152
- resistance management of insecticide-resistant crops 101–109
 - genetic methods 108–109
 - insect pathogen use 107–108
 - integrated methods 109
 - natural enemy use 107–108
 - pyramided *Bt* crops 108
 - resistance evolution 104–108
- rhizosphere, soil 228
- rice
 - bacterial blight 10
 - disease resistance gene complex 10
 - drought tolerance 12, 377
 - flood-resistance 377
 - gene flow
 - to other crops 142–143
 - to weeds 145–146
 - glufosinate-resistant 120, 146
 - insect-resistant varieties 9
 - New Rice for Africa 371
 - non-shattering cultivars 143
 - nutritional improvement 14
 - pollen 146
 - transgene introgression 146
 - wild relatives 145–146
 - yield enhancement 13
- Rice Hoja Blanca Virus (RHBV) 11
- Rice Tungro Bacilliform Virus (RTBV) 11
- Rice Tungro Spherical Virus (RTSV) 11
- Rice Yellow Mottle Virus (RYMV) 11
- RIDL dominant lethal gene 109
- risk assessment 63
 - GM trait movement 140
 - see also* environmental risk assessment
- risk hypotheses 183–184
- RNA interference, insect gene silencing 74–75
- rodenticides 387
- Roundup *see* glyphosate
- safety
 - African biotechnology 375
- agronomic assessment 280–281
- biological control organism 185–186
- biosafety in Africa 374–375
- comparative assessment of GM crops 280–284
- compositional assessment 280–281
- Cry proteins 375
- human consumption 278–289
- phenotypic assessment 280–281
- St Matthew Island (Bering Sea) 395–396
- salinity, stress 11–12
- salinization 43, 392
- scFv molecules 16
- schistosomiasis 42
- seed(s)
 - resources for birds 270–272
 - weed 271–272
- seed oil
 - Jatropha curcas*
 - characteristics 304–306
 - potential 306
 - see also* oilseed plants, non-edible; oilseed rape
- seed storage proteins 13–14
- semi-natural ecosystems 244
- serine protease inhibitors 203–204
 - pollinator effects 208, 212
- Sesamia nonagrioides* (corn borer) 9
- shikimate biosynthetic pathway 121
- snowdrop lectin 173, 176, 208
- socio-economic development, *Jatropha curcas* use 308
- soil
 - African 365
 - agricultural impact 393
 - assessment of GM crop impact 233–236
 - bacterial communities 226–227, 228
 - Bt* proteins fate 376
 - carbon content 229–230
 - ecology impact of GM crops 225–236
 - ecosystems 226–228, 232
 - fauna 226–227, 235–236, 404–405
 - food web 227–228, 236
 - free DNA 234–235
 - functional assays 233
 - functional dynamics 232
 - fungal communities 226–227, 228
 - hand tilling 52
 - microbial diversity 230–232
 - nutrient cycling 228–229
 - nutrient deficient 393
 - organic matter inputs 229–230
 - physical conditions 226
 - plant inputs 228
 - processes 232–233
 - rhizosphere 228
 - salination 392
 - topsoil loss 44, 53
 - trophic levels 227
- soil biota 226–228
 - GRC effects 124
- soil conservation 35
 - perennial grain growing 53
- soil erosion 44, 49, 53, 384

- conservation tillage systems 126
- Jatropha curcas* use 307
- natural vegetation clearance 392
- soil microorganisms 226–228
 - diversity 230–232
 - GRC effects 124
 - response to GM plants 233–234
- solar energy, capture by perennial crops 53
- solitary bees, foraging distances 214
- sorghum, fortified 370
- Sorghum halepense*, glyphosate-resistant 135, 137
- South Africa
 - commercial use of transgenic crops 361
 - plant biotechnology 366–368
 - regulatory controls 366
- soybean
 - biodiversity preservation 145
 - forest cover loss 391
 - gene flow
 - to other crops 142
 - to weeds 144–145
 - glyphosate-resistant 119, 150
 - glyphosate-resistant weeds 252
 - herbicide use 129–130
 - herbicide-tolerant 27–28, 36, 118
 - livestock feed 279, 280
 - nectar source 200
 - planted area of herbicide-resistant 118
 - pollen 142
 - pollination 215
 - tillage systems 250–252
 - weed community changes 139
 - wild relatives 144–145
- Soybean Bowman-Birk inhibitor (SBBI) 174, 210
- Spain
 - Bt maize commercial planting 327–329
 - field trials 332–333
 - post-market monitoring of GM maize 329–331
 - target insect monitoring for field resistance 331–332
- species
 - diversity 244
 - extinctions 247, 249
 - introductions 248–249
- spermidine 12
- spermine 12
- spiders
 - bird diet 272
 - maize fields 335
 - oilseed rape crops 33
 - pollen passive ingestion 169
- Spodoptera litura* (insect pest) 9–10
- springtails, GR soybean crops 123–124
- stacked traits 166, 400–401
 - herbicide resistance gene 149–150
 - pyramided Cry proteins 175
 - two-toxin Bt crops 81, 85, 108
- streptavidin 208
- Streptococcus mutans* adhesin antibody 16–17
- stress resistance 11–13
- stress tolerance 364
- Striga* control 7–8, 369
- substantial equivalence concept 65
- sugarbeet
 - gene flow
 - to other crops 143
 - to weeds 146
 - glyphosate-resistant 120
 - herbicide-tolerant 33–34, 35
 - transgene introgression 146
 - weed seeds 271–272
 - weedy beets 403
 - wild relatives 146
- sulfur dioxide 301
- sunflower
 - gene flow 143, 146–147, 148
 - volunteer 148
- superweeds 132–139, 401
 - concept 132–133
 - herbicide-resistant GM crop influence 138–139
- surface runoff, herbicide losses 35–36
- surface water, herbicide pollution 49
- sustainable agriculture 3–17, 26–27, 62
- swallowtail, black 403
- sweet potato, disease-resistant 376–377
- temperature gradient gel electrophoresis (TGGE) 231, 233
- teosintes, maize spontaneous hybridization 144
- terpenoids 307
- tillage systems
 - changes 121, 125–126
 - conservation 126, 249–252
 - crop residues 249, 250
 - reduction with herbicide-tolerant crops 250
 - soybean crops 250–252
 - weed community composition 127
 - weed control 249–250
- tobacco, transgenic 344–345
- tomatoes
 - ACC deaminase expression 12–13
 - cancer-fighting 377
 - tastier 377
- topsoil loss 44, 53
- trade, imbalance in Africa 373–374
- Trade Related Aspects of Intellectual Property Rights 373
- traditional knowledge, biodiversity 54
- transferred DNA (T-DNA) 5
- transformation, in *planta* 5
- transgenes 5
 - DNA 6
 - introgression 141, 142, 144
 - non-target species impact 236
- transgenic DNA (tDNA)
 - consumption 285
 - detection in livestock 285–287
 - fragmentation 285, 286
 - presence in animal-derived food products 287, 288–289, 289

- transgenic plants
methodology 5–6
triple 9
- transgenic traits
movement 139–149
see also stacked traits
- Transmissible Gastroenteritis Virus (TGEV)
vaccine 15
- transport sector, fuels 299–302
- trap crops, dead-end 109
- Triticum* wild species 246, 385
- tropical forests 391
- tuberculosis 42
- tumour-inducing (Ti) plasmid 5
- tungro 11
- unintended effects 65–66
- United Nations
Intergovernmental Panel on Climate Change 397
millennium development goals 398–399
- United States, biodiesel
production/consumption 300
- urban ecosystems 243
- urbanization 54
- vaccines, plant-derived 14–15
- vegetable oils, trans-esterification 299
- vegetation, monodominant 246
- vegetative cover, overexploitation 365
- vegetative insecticidal proteins (VIPs)
pollinator hazards 201, 207
Vip3A 108, 172
- VipCot cotton 108
- viral diseases 10–11
- vitamin A deficiency 14
- wasps, parasitic 171, 176–177
- wasteland reclamation, *Jatropha curcas* use 308
- water
pollution 49
quality impact of agriculture 393
shortages 44
see also freshwater
- waterlogging resistance 377
- weather, unpredictability 398–399
- weed(s) 7–8
Africa 365
aquatic 249
Bt toxin impact 150
community composition 127, 130
management 132
- crop plant hybridization 402–403
- crop rotation impact on
communities 128
- fitness 133
Bt toxin impact 150
- gene flow
- to crops 147–148
to other weeds 148–149
- glyphosate-resistant 116–117, 126,
133–139
evolution rate 135–136
persistence 151
soybean crops 252
- GM trait movement into via pollen
123
- herbicide resistance 51, 133–138
- interspecific hybridization 148–149
- maize crops 272
community changes 139
- oilseed rape crops 32–33
- pests 50–51
- population shifts with GRCs 123, 134,
138–139
- recombinant DNA transfer 236
- seedbank characteristics 126–127
cropping sequence 128
- seeds 271–272
germination 126–127
- selection pressure of glyphosate
application 119–120, 125
- sugarbeet crops 33–34
- transgenic glyphosate resistance 133,
148–149
- weed control 7, 117, 388, 400
environmental impact 401–403
glyphosate-resistant crops 122, 123
simplification 121
tillage systems 249–250
- 'weed free' management 35
- weed management 117, 121
augmentation alternatives 131–132
insect populations 123–124
weed population changes 130, 139
- wheat
fungal disease control 121
gene flow 143, 147
glyphosate-resistant cultivars 120
fungal disease control 121
nutritional improvement 14
wild relatives 147, 246
- wildlife, agricultural production 31–32, 33
- witchweed *see* *Striga* control
- world food production 25
- World Health Organization (WHO), regulatory guidance 64
- world population 26–27, 42
- Xa21* gene 10
- Xanthomonas oryzae* (bacterial blight of rice) 10
- yield ceiling 13
- yield gap 13
- Zimbabwe, plant biotechnology 369–370