**How Do We Integrate 597 WTO Terms into PTO**

1. **Direction of the coloring rule**

The highlighted texts in yellow correspond to a WTO item can map into PTO.

The items highlighted in blue belong to the “environment condition”.

We want our new integrated ontologies take “environment condition” into consideration, so we plan to add the whole class into PTO. But we are not sure about whether some WTO items are suitable for PTO. So we highlight them, once we concern they are not suitable, we will delete them from the whole class.

* If there is the “【1】” attached behind the item, it means this item in PTO is described as “Wheat/Barley + item(itself)” but not include rice.
* Sometimes we apply blue highlight and yellow highlight to the same trait. It is because the PTO itself included some traits that can’t be distinguished whether they are for rice. We will delete those not for rice traits in PTO.

The grey highlighted items are traits exclusively for wheat, and discarded in our own ontology.

The green color is used to highlight those items belong to the “plant trait”. The label work of “plant trait” is different from “environment condition”. We have to judge the traits one by one to see whether they can be added to PTO.

The green highlight reveals two kinds of label conditions.

* If an item with no father node information attached, it means we are not sure if it is a trait for rice.
* If an item with a father node information attached, it means we are not sure whether we map it to the correct father node.

Other traits without highlighting are added into PTO directly.

* Whether some of the traits in the screenshot is highlighted or not depend on its father node’s color. Most traits in the same screenshot has the same property.
* The principles of adding father node information:
  + According to our own common sense and experience.
  + Or a similar trait’s father node information.
  + If a WTO father node can map into PTO, then all of its child node at least have one father node. In most condition, we will omit this father node to reduce the repeat.

We basically labeled all of the terms and show the whole structure of WTO. Just few nodes were omitted because it is not convenient to show them all. And these omitted nodes can be judged through their father nodes. If you are interested in them, you can compare our result to the WTO website. <http://agroportal.lirmm.fr/ontologies/WHEATPHENOTYPE?p=classes>

1. **Integrating WTO into PTO**
2. environmental condition WTO:0000004
   1. abiotic condition WTO:0000008
      1. abiotic stress WTO:0000062
      2. Chemical WTO:0000069
         1. Acaricide WTO:0000120
         2. Antibiotics WTO:0000124
         3. Fungicide WTO:0000139
         4. Herbicide WTO:0000154
            1. Atrazine WTO:0000207
         5. Insecticide WTO:0000156
         6. Nematicide WTO:0000166
         7. Pesticide WTO:0000176
      3. extreme temperature WTO:0000075
         1. cold WTO:0000129
         2. frost WTO:0000138
         3. heat WTO:0000152
         4. heat shock WTO:0000153
         5. hot wind WTO:0000155
      4. nutrient deficiency (TO:0000480)
      5. photoperiod WTO:0000097
      6. shade WTO:0000106
      7. soil property
         1. soil acidity WTO:0000194
         2. soil humidity WTO:0000570
         3. soil mineral WTO:0000195
            1. aluminium in the soil WTO:0000580
            2. salt in the soil WTO:0000581
         4. soil toxic component WTO:0000196
            1. aluminium in the soil WTO:0000580
            2. salt in the soil WTO:0000581
            3. toxin in the soil WTO:0000273
      8. solar radiation WTO:0000110
      9. water quantity WTO:0000117
         1. air humidity WTO:0000122
         2. excessive rain WTO:0000135
         3. flooding WTO:0000137
         4. lack of water WTO:0000157
            1. drought WTO:0000218

spring drought WTO:0000353

* + - 1. rainfall WTO:0000183
      2. soil humidity WTO:0000570
      3. water stress WTO:0000203
    1. wind speed WTO:0000119
  1. biotic condition WTO:0000010
     1. Biotic stress TO:0000179
        1. Disease WTO:0000130
           1. bacterial disease (TO:0000315)

bacterial leaf blight (TO:0000770)

bacterial stripe WTO:0000299【1】wheat and barley

basal glume rot WTO:0000300

black chaff WTO:0000303

phytoplasma disease WTO:0000337

Aster Yellows disease WTO:0000378

yellow rot WTO:0000589

* + - * 1. disease caused by nematode (TO:0000384) nematode damage resistance ?

ear cockle WTO:0000312

yellow rot WTO:0000589

* + - * 1. fungal disease (TO:0000439)

Alternaria Leaf Blight WTO:0000276

Anthracnose WTO:0000294

Ascochyta Leaf Spot Ascochyta Leaf Spot

Black Point WTO:0000283

Bunt WTO:0000284

Common bunt WTO:0000389

Dwarf bunt WTO:0000392

Karnal bunt WTO:0000405

Cephalosporium Leaf Stripe WTO:0000287

Ergot WTO:0000313

Eyespot WTO:0000314

Fusarium head blight (TO:0000663) WTO:0000314【1】

Helminthosporium Leaf Blight WTO:0000291

Spot Blotch (TO:0020053)

Drechslera Leaf Blight WTO:0000524

tan spot WTO:0000519

mildew WTO:0000332

downy mildew WTO:0000458

powdery mildew (TO:0020061)

mold WTO:0000333

snow mold WTO:0000515

sooty molds WTO:0000516

root rot WTO:0000346

common root rot (TO:0020059)

crown rot (TO:0020058)

Fusarium root rot WTO:0000402

Pythium root rot WTO:0000426

Rhizoctonia Root Rot WTO:0000429

Rust WTO:0000347

leaf rust (TO:0020057)

stem rust WTO:0000517

stripe rust (TO:0020055)

sclerotium wilt WTO:0000348

Septoria WTO:0000349

Septoria Avenae blotch WTO:0000435

Septoria leaf blotch (TO:0020065)

Septoria nodorum blotch WTO:0000437

sharp eyespot WTO:0000350

smut (TO:0000302) obsolete/过时

flag smut WTO:0000459

loose smut WTO:0000467

snow rot WTO:0000352

take-all WTO:0000355

wheat blast WTO:0000365

* + - * 1. viral disease (TO:0000148)

American Wheat Striate Mosaic

Anthoxanthum Mosaic WTO:0000278

Chloris Striate Mosaic WTO:0000288

wheat dwarf

wheat streak mosaic

wheat yellow mosaic

* + - 1. 有害植物 noxious plant TO:0000347
         1. Noxious weed WTO:0000243

Cirsium arvense WTO:0000289

* + - 1. 害虫 pest
         1. Arthropod WTO:0000206
         2. Insect WTO:0000232

Aphid WTO:0000295

Army cutworm WTO:0000279

Euxoa auxiliaris WTO:0000394

Armyworm WTO:0000280

Billbug WTO:0000301

Cecidomyides WTO:0000285

gall midge WTO:0000460【1】

greenbug WTO:0000324

Hessian fly WTO:0000292

Khapra beetle WTO:0000584

Leafhopper WTO:0000328

Endria inimical WTO:0000393

Macrosteles fascifrons WTO:0000406

Macrosteles quadrilineatus WTO:0000407

Lepidopteran insect WTO:0000585

* + - * 1. Invertebrate WTO:0000234

Nematode WTO:0000334

Anguina tritici WTO:0000375

cereal cyst nematode WTO:0000454

root-knot nematode WTO:0000514

Meloidogyne spp. WTO:0000526

* + - * 1. Pathogen WTO:0000245

Bacteria WTO:0000297

Phytoplasma WTO:0000468

Aster yellows phytoplasma

Pseudomonas syringae pv. Atrofaciens WTO:0000417

Pseudomonas syringae pv. Syringae WTO:0000418

Rathayibacter tritici WTO:0000428

Xanthomonas campestris pv. Translucens WTO:0000593

Fungi WTO:0000593

Alternaria spp.

Alternaria triticina

Ascochyta tritici

Athelia rolfsii

Bipolaris sorokiniana

Blumeria graminis

Cephalosporium gramineum

Ceratobasidium cereale

Cladosporium spp.

Claviceps purpurea

Colletotrichum graminicola

Curvularia spicifera

Didymella exitialis

Fusarium culmorum

Fusarium graminearum

Fusarium langsethiae

Fusarium oxysporum

Fusarium pseudograminearum

Fusarium spp.

Gaeumannomyces graminis var. tritici

Magnaporthe oryzae

Microdochium majus

Microdochium nivale

Monographella nivalis

Oculimacula acuformis

Oculimacula yallundae

Parastagonospora nodorum

Puccinia graminis

Puccinia graminis f.sp. tritici

Puccinia recondita

Puccinia striiformis

Puccinia striiformis f. sp. tritici

Puccinia triticina

Pyrenophora trichostoma

Pyrenophora tritici-repentis

Pyricularia grisea

Pythium spp.

Rhizoctonia solani

Sclerophthora macrospora

Sclerotium rolfsii

Stagonospora avenae

Leptosphaeria avenaria f.sp. tritici

Phaeosphaeria avenaria f. sp. tritici

Septoria avenae f.sp. tritici

Tilletia caries

Tilletia controversa

Tilletia foetida

Tilletia indica

Typhula incarnata

Typhula ishikariensis

Urocystis agropyri

Ustilago nuda f. sp. tritici

Ustilago tritici

Xanthomonas campestris pv. translucens

Zymoseptoria tritici

Virus WTO:0000362

American Wheat Striate Mosaic virus

Anthoxanthum Mosaic virus WTO:0000376

Chloris Striate Mosaic virus

Closterovirus WTO:0000455

Geminivirus WTO:0000461

Potyvirus WTO:0000469

wheat streak mosaic virus

wheat yellow mosaic virus

wheat dwarf virus

storage pest WTO:0000268

Khapra beetle WTO:0000584

Lepidopteran insect WTO:0000585

wheat moth

* 1. plant density WTO:0000047

1. plant property
   1. Phenotype /is\_a: TO:0000387 ! plant trait/
      1. ability to flower WTO:0000007
      2. awnedness WTO:0000009
      3. early beginning of anthesis WTO:00000012
      4. ealy flag leaf emergence WTO:00000013
      5. early flag leaf senescence WTO:00000014
      6. early floral initiation WTO:00000015
      7. early flowering WTO:00000016
      8. early heading WTO:00000017
      9. early maturation WTO:00000018
      10. early seedling vigour WTO:00000019
      11. free-threshing WTO:00000020
      12. hard threshing WTO:00000022
      13. high density of shoot WTO:00000023
      14. high fertility WTO:00000024
      15. high grain protein content WTO:00000025
      16. high grain specific weight WTO:00000026
      17. intermediate plant habit WTO:00000027
      18. lack of seed dormancy WTO:00000028
      19. lack of vernalization requirement WTO:00000029
      20. late beginning of anthesis WTO:00000030
      21. late flag leaf emergence WTO:00000031
      22. late floral intitation WTO:00000032
      23. late flowering WTO:00000033
      24. late heading WTO:00000034
      25. late leaf senescence WTO:00000035
      26. late maturation WTO:00000036
      27. long spike WTO:00000037
      28. long-awned WTO:00000038
      29. low density of shoot WTO:00000039
      30. low fertility WTO:00000040
      31. low grain specific weight WTO:00000041
      32. medium-awned WTO:00000042
      33. moderate response to vernalization WTO:00000043
      34. nearly-erect plant habit WTO:00000045
      35. nearly-prostrate plant habit WTO:00000046
      36. semi-erect plant habit WTO:00000051
      37. semi-prostrate plant habit WTO:00000052
      38. short spike WTO:00000053
      39. short-awned WTO:00000054
      40. shrivelled grain WTO:00000055
      41. spring growth habit WTO:00000056
      42. undersized grain WTO:00000057
      43. vernalization-responsive WTO:00000058
      44. weak response to vernalization WTO:00000059
      45. winter growth habit WTO:00000060
   2. trait
      1. development
         1. anther extrusion /is\_a: TO:1000022 {is\_inferred="true"} ! anther morphology trait /
         2. beginning of anthesis / is\_a: TO:0000933 ! plant phenological trait /
         3. ear emergence time / is\_a: TO:0000976 ! ear infructescence morphology trait /
         4. fertility (TO:0000420)
            1. percentage of florets without grain / is\_a: TO:0000420 ! fertility related trait/
         5. final leaf number / is\_a: TO:0000241 ! leaf number /
         6. flag leaf emergence time / is\_a: TO:0000832 ! flag leaf morphology trait /
         7. floral initiation / is\_a: TO:0000862 ! floral organ morphology trait /
         8. flowering duration·/ is\_a: TO:0000933 ! plant phenological trait /
         9. flowering time TO:0002616
         10. growth habit TO:0002756 【shoot growth angle/stem habit (related)|growth habit (related)|】
         11. leaf senescence time TO:0012012—— leaf senescence duration
             1. early leaf senescence / is\_a: TO: 0012012! leaf senescence time/
         12. maturity TO:0000174—— maturity trait
         13. plant habit / is\_a: TO:0000933 ! plant phenological trait/
             1. erect plant habit WTO:000000134
             2. prostrate plant habit WTO:000000182
         14. plant precocity
         15. response to vernalization
      2. growth
         1. above-ground dry matter quantity
         2. crop yield TO:0000396—— grain yield trait
            1. dry matter grain yield / is\_a: TO:0000396 ! grain yield trait /
            2. ear number per meter of row【ear infructescence number？
            3. grain number per ear / is\_a: TO:0002759 ! grain number /
            4. grain specific weight / is\_a: TO:0000919 ! grain weight /
            5. grain weight per ear / is\_a: TO:0000919 ! grain weight /
            6. harvest index TO:0000128—— harvest index
            7. number of grains per square meter /is\_a: TO:0000936 ! infructescence yield trait/
            8. number of viable seeds per meter of row / is\_a: TO:0000345 ! seed viability/
            9. thousand kernel weight / is\_a: TO:0002746 ! fruit weight /
         3. ear-bearing tiller density
            1. number of ear-bearing tillers at anthesis WTO:000000168
            2. number of ear-bearing tillers at maturity WTO:000000169
            3. number of ear-bearing tillers per meter row WTO:000000170
         4. germinative power / is\_a: TO:0000653 ! seed growth and development trait/ /is\_a: TO:0000931 ! seed quality trait /
            1. post-harvest seed dormancy / is\_a: TO:0000653 ! seed growth and development trait /
            2. seed dormancy TO:0000253—— seed dormancy
         5. Green Area Index
         6. lodging resistance / is\_a: TO:0000250 ! plant vigor trait /
         7. nutrient use efficiency
            1. macronutrient use efficiency WTO:000000159

nitrogen use efficiency WTO:000000242

nitrogen harvest index WTO:000000336

phosphorus use efficiency WTO:000000248

potassium use efficiency' WTO:000000250

* + - * 1. micronutrient use efficiency WTO:000000162

boron use efficiency WTO:000000210

copper use efficiency WTO:000000213

iron use efficiency WTO:000000236

manganese use efficiency WTO:000000239

* + - 1. plant height TO:0000207—— plant height
      2. seedling vigour TO:0000280—— seedling vigor
      3. shoot density / is\_a: TO:0000654 ! shoot system growth and development trait /
         1. shoot number per m2 WTO:000000192
         2. shoot number per plant WTO:000000193
      4. water-soluble carbohydrate content / is\_a: TO:0000291 ! carbohydrate content /
    1. morphology
       1. anther color TO:0000187—— anther color
       2. awn
          1. awn color TO:0000141—— awn color
          2. awn length TO:0000072—— awn length
          3. presence of awn TO:0002734—— awn presence
       3. coleoptile length TO:0001007—— coleoptile length
       4. culm length TO:0000576—— stem length
       5. glume color TO:0000221—— glume color
       6. glume pubescence TO:0020036—— glume pubescence
       7. grain morphology TO:0001079—— caryopsis fruit morphology trait【grain morphology trait (exact)|kernel morphology trait (exact)】
          1. grain shape TO:0002730—— grain shape
          2. grain size TO:0000397—— grain size

grain length TO:0000734—— grain length

grain uniformity of size / is\_a: TO:0000397 ! grain size /

grain width TO:0000975 —— grain width

* + - 1. shatter resistance
      2. spike length TO:0000431—— ear length
      3. spike waxiness
      4. spikelet density TO:0000625—— spikelet density
         1. spikelet number TO:0000456—— spikelet number
      5. threshability
         1. glume tenacity /is\_a: TO:0000869 ! glume morphology trait/
         2. spike fragility
    1. quality
       1. fiber quality——dietary fiber related trait？
       2. food property
          1. bread making quality

bread smell

crumb colour

crumb firmness

flour colour TO:0000651—— flour color

discoloration of flour WTO:000000307

flour brightness WTO:000000316

flour whiteness WTO:000000320

yellowness of flour WTO:000000371

flour composition

crude protein content of the flour WTO:000000306

dry gluten content' WTO:000000582

flour ash content' WTO:000000315

flour crude fiber content' WTO:000000317

flour lipid content' WTO:000000318

gluten strength WTO:000000583

gliadin content WTO:000000586

glutenin content' WTO:000000587

high molecular weight glutenin subunit WTO:000000590

1.2.4.2.1.5.6.2.1.1. high-molecular WTO:000000594

swelling index of glutenin WTO:000000591

flour mechanical property

dough extensibility WTO:000000308

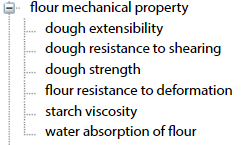
dough resistance to shearing' WTO:000000309

dough strength WTO:000000310

flour resistance to deformation WTO:000000319

starch viscosity WTO:000000354

water absorption of flour WTO:000000364



seed colour TO:0000486 ——seed color

yellow pigment content of seed

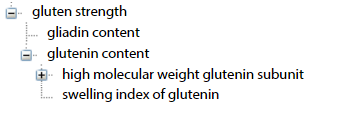
* + - * 1. semolina characteristic

semolina color

* + - 1. grain composition
         1. grain gluten content

dry gluten content

* + - * 1. grain nitrogen content
        2. grain protein content



* + - * 1. grain starch content
        2. polyphenol content
      1. grain quality TO:0000162—— grain quality trait
         1. grain color trait TO:0001109——grain color trait

grain bright color / is\_a: TO:0001109 ! grain color trait /

* + - * 1. grain hardness / is\_a: TO:0000162 ! grain quality trait /

endosperm texture？/ is\_a: TO:0000587 ! endosperm quality /

grain softness / is\_a: TO:0000162 ! grain quality trait /

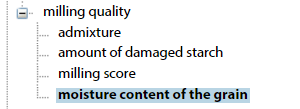
hard grain texture / is\_a: TO:0000162 ! grain quality trait /

level of starch-surface friabilin / is\_a: TO:0000162 ! grain quality trait /

quantity of hard starch granule / is\_a: TO:0000162 ! grain quality trait /

single-kernel hardness / is\_a: TO:0000162 ! grain quality trait /

soft grain texture / is\_a: TO:0000162 ! grain quality trait /

* + - * 1. grain specific weight
        2. mottled grain
        3. presence of black points
      1. milling quality
         1. 
    1. 生殖 reproduction
       1. Sterility
          1. female sterility TO:0000358——female sterility
          2. male sterility TO:0000437——male sterility

cytoplasmic male sterility TO:0000580——cytoplasmic male sterility

nuclear male sterility / is\_a: TO:0000437 ! male sterility /

* + 1. 对环境条件的反应 response to environmental condition
       1. response to abiotic stress TO:0000168—— abiotic stress trait
          1. 化学敏感性 chemosensitivity TO:0000482 —— chemical stress sensitivity

resistance to chemicals

resistance to herbicides TO:0000058——herbicide sensitivity

resistance to atrazine

resistance to chlorsulfuron

resistance to imidazolinone / is\_a: TO:0000058 ! herbicide sensitivity /

toxin resistance / is\_a: TO:0000482 ! chemical stress sensitivity /

toxin sensitivity / is\_a: TO:0000482 ! chemical stress sensitivity /

* + - * 1. 光敏性 photosensitivity / is\_a: TO:0000168 ! abiotic stress trait /

sensitivity to photoperiod TO:0000229——photoperiod sensitivity trait

shade tolerance / is\_a: TO:0000075 ! light sensitivity /

* + - * 1. response to nutrient deficiency TO:0000480 ——nutrient sensitivity

response to potassium limitation / is\_a: TO:0000480 ! nutrient sensitivity /

primary nutrient deficiency / is\_a: TO:0000480 ! nutrient sensitivity /

tolerance to micronutrient deficiency TO:0000080——micronutrient sensitivity

* + - * 1. response to stress from soil

aluminium resistance TO:0000354——aluminum sensitivity

response to soil acidity TO:0000003 alkali soil sensitivity



Rhizotoxicity

metal toxicity / is\_a: TO:0000247 ! other nutrient sensitivity /

aluminium toxicity TO:0000354——aluminum sensitivity

heavy metal toxicity

cadmium toxicity

chrome toxicity TO:0000034——chromium sensitivity

cobalt toxicity TO:0000016——cobalt sensitivity

copper toxicity TO:0000021——copper sensitivity

lead toxicity

manganese toxicity TO:0000073——manganese sensitivity

mercury toxicity

nickel toxicity

zinc toxicity

metalloid toxicity / is\_a: TO:0000247 ! other nutrient sensitivity /

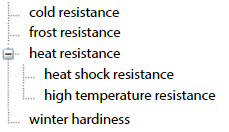
arsenic toxicity

boron toxicity TO:0000018 ——boron sensitivity

salt resistance TO:0006001 —— salt tolerance

* + - * 1. response to temperature TO:0000432——temperature response trait

Extreme temperature resistance



Tolerance to extreme temperature / is\_a: TO:0000432——temperature response trait /

Cold tolerance TO:0000303——Cold tolerance

Frost tolerance

Heat tolerance TO:0000259——Heat tolerance

* + - * 1. response to water stress TO:0000237——water stress trait

Flooding tolerance TO:0000114——flooding related trait

Moisture tolerance

Response to water deficiency

drought tolerance TO:0000276——drought tolerance

Tolerance to water stress TO:0000237——water stress trait

* + - * 1. wind resistance
      1. Response to biotic stress
         1. Pest resistance / is\_a: TO:0000054 ! animal damage resistance /

insect resistance insect TO:0000261—— damage resistance

aphid resistance

Russian wheat aphid resistance

Armyworm resistance



billbug resistance / is\_a: TO:0000261 ! insect damage resistance/

Cecidomyides resistance / is\_a: TO:0000261 ! insect damage resistance/

resistance to gall midge TO:0000423——gall midge resistance

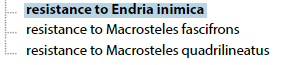
resistance to orange wheat blossom midge

wheat midge resistance

greenbug resistance / is\_a: TO:0000261 ! insect damage resistance/

Hessian fly resistance / is\_a: TO:0000261 ! insect damage resistance/

leafhopper resistance ? TO:0000082——zigzag leafhopper resistance / is\_a: TO:0000261 ! insect damage resistance/



resistance to Army Cutworm ? TO:0000317\_cutworm resistance / is\_a: TO:0000261 ! insect damage resistance/

resistance to Euxoa auxiliaris / is\_a: TO:0000261 ! insect damage resistance/

resistance to Khapra beetle / is\_a: TO:0000261 ! insect damage resistance/

pathogen resistance

resistance to a fungal pathogen TO:0000439——fungal disease resistance

late blight resistance /is\_a: TO:0000664 ! fungal blight disease resistance/

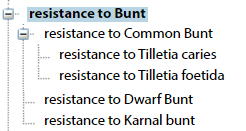
resistance to Alternaria Leaf Blight /is\_a: TO:0000664 ! fungal blight disease resistance/

resistance to Anthracnose

resistance to Ascochyta Leaf Spot

resistance to Black Point

resistance to Bunt



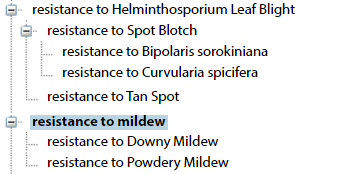
resistance to Cephalosporium Leaf Stripe

resistance to Ergot

resistance to Eyespot

resistance to Fusarium head blight ？[barley wheat]

resistance to Helminthosporium Leaf Blight ?[barley wheat]



resistance to mildew ？[barley wheat]



resistance to Mold

resistance to root rot ？[barley wheat]

resistance to rust ？[barley wheat]

resistance to Sclerotium Wilt

resistance to septoria ？[barley wheat]

resistance to Sharp Eyespot

resistance to smut

resistance to Take-All

resistance to wheat blast

resistance to bacterial disease TO:0000315——bacterial disease resistance

bacterial leaf blight resistance /is\_a: TO:0000770 ! bacterial blight disease resistance/

resistance to bacterial stripe

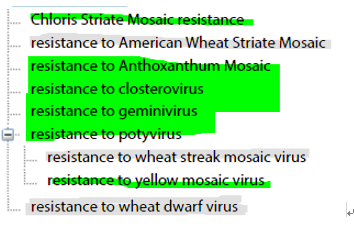
resistance to basal glume rot

resistance to black chaff

resistance to phytoplasma ？TO:0000013 ——resistance to disease by mycoplasma-like organism

resistance to yellow rot

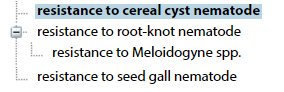
virus resistance TO:0000148 —— viral disease resistance



resistance to arthropod / is\_a: TO:0000054 ! animal damage resistance/

resistance to invertebrate pest / is\_a: TO:0000054 ! animal damage resistance/

nematode resistance TO:0000384——nematode damage resistance/



storage pest resistance / is\_a: TO:0000054 ! animal damage resistance/

resistance to Khapra beetle

resistance to Lepidopteran insect

wheat moth resistance

* + - * 1. Resistance to noxious weed / is\_a: TO:0000179 ! biotic stress trait /

resistance to Cirsium arvense

* + - 1. Response to plant density / is\_a: TO:0000164 ! stress trait /
      2. Sprouting tolerance / is\_a: TO:0000164 ! stress trait /
         1. pre-harvest sprouting tolerance