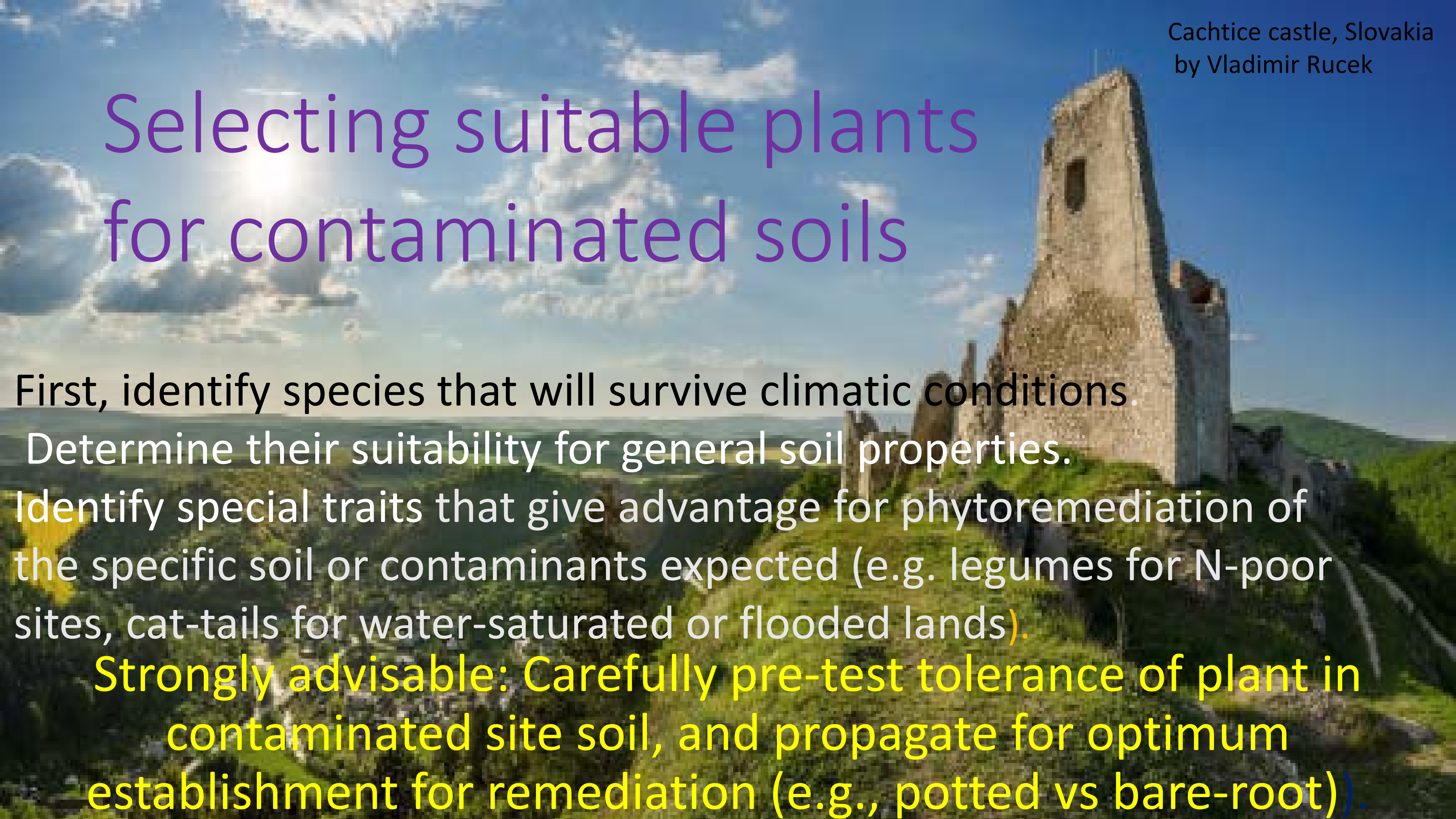
Selecting and preparing plants for contaminated soils, miscanthus as an example

Developed for Jan 9, 2018 session of Chem Engg 650



Cachtice castle, Slovakia
by Vladimir Rucek

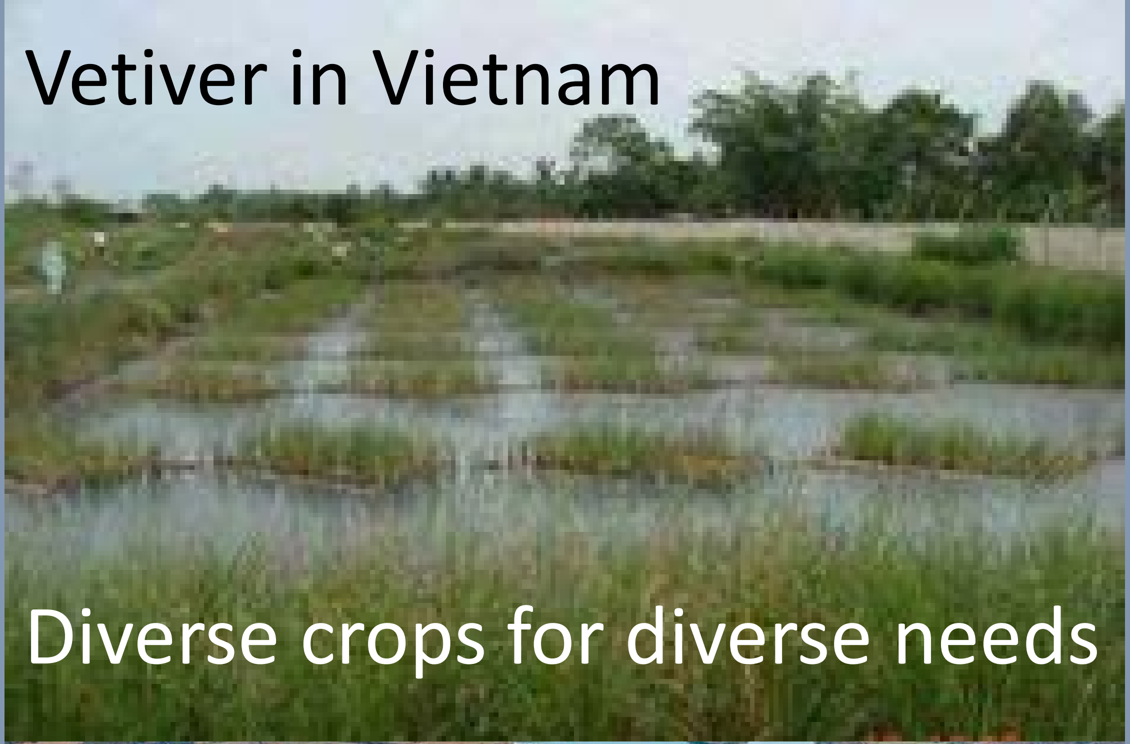
Selecting suitable plants for contaminated soils

First, identify species that will survive climatic conditions.

Determine their suitability for general soil properties.

Identify special traits that give advantage for phytoremediation of the specific soil or contaminants expected (e.g. legumes for N-poor sites, cat-tails for water-saturated or flooded lands).

Strongly advisable: Carefully pre-test tolerance of plant in contaminated site soil, and propagate for optimum establishment for remediation (e.g., potted vs bare-root).


Vetiver in Vietnam
Diverse crops for diverse needs


Westar Energy, St. Mary's KS,
Coal power plant Flue Gas
Desulfurization water


Solvent remediation,
Pacific Northwest

Plant selection

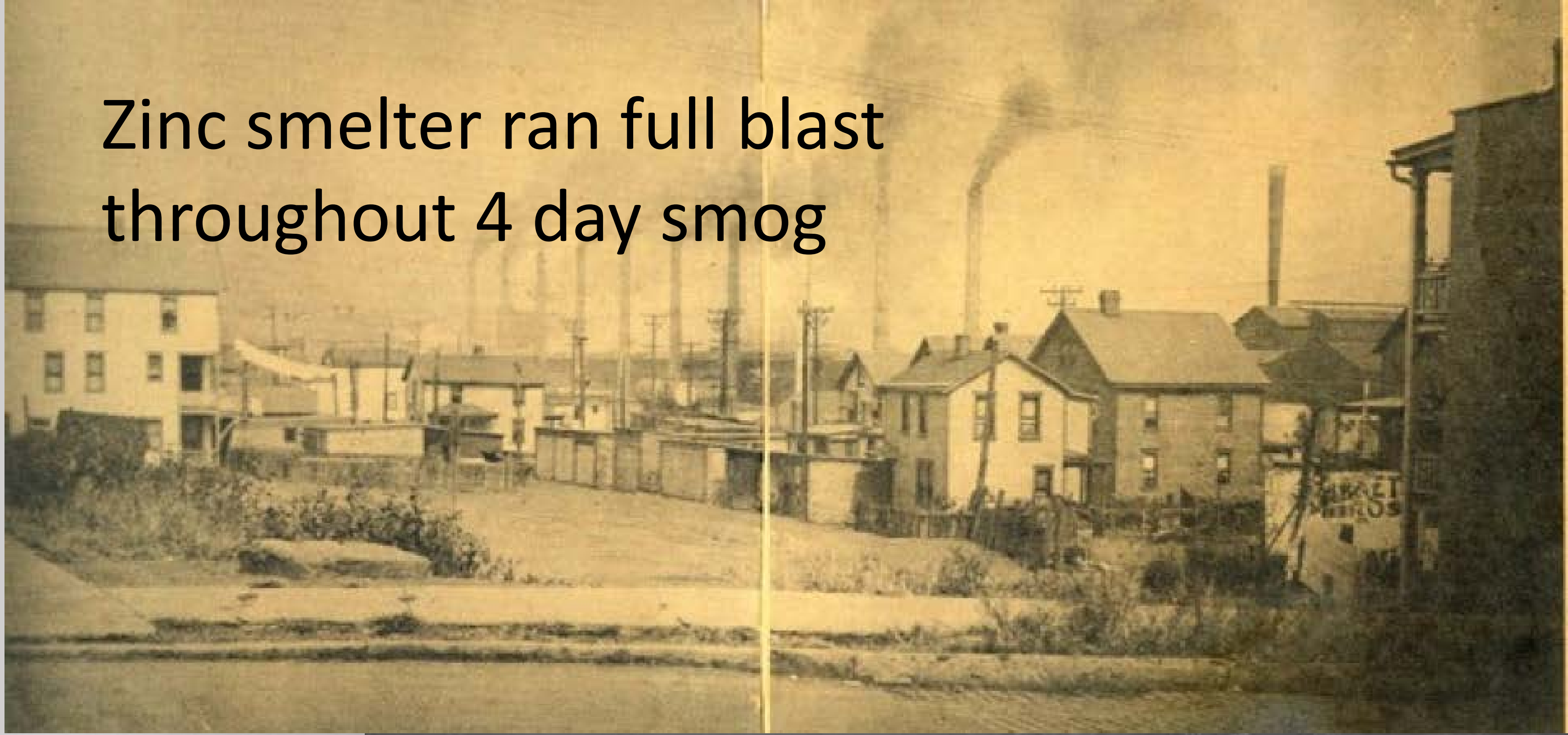
The U.S. EPA has many resources available from several decades of bioremediation. A search for Clu-in will link to databases including those describing successful use of many plant species in many settings with metals and organics. https://clu-in.org/remediation will get you there. Their site has menus for contaminants, technologies, site types, many databases.

Proper species choice may require several iterations of the selection process, including multiple factors: location, aesthetics, material availability, cost, site constraints, time frame for clean-up, intended final usage, government mandates, social factors.

Steeltown, USA at an earlier time.

Coal, limestone and Minnesota iron ore combined with river transport to make one of the most contaminated environments in the U.S.

Donora, PA October 1948, 20 km SE from Pgh on Manongahela river “When Smoke Ran Like Water”, as described by Devra Davis.



Zinc smelter ran full blast throughout 4 day smog

No color, no sun, only the blast furnaces for light

Darkness at noon


Change can happen

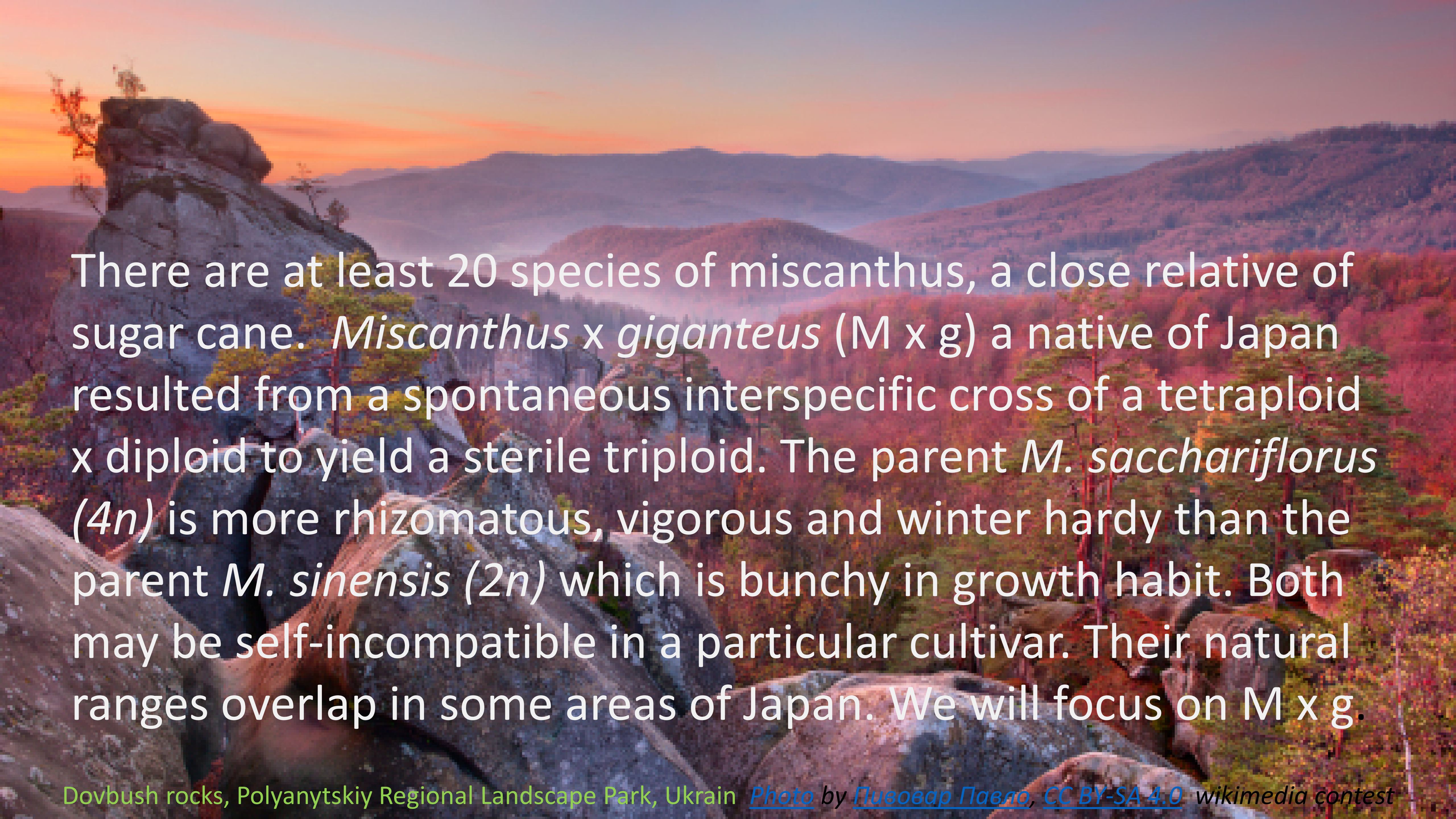
Given equivalent efficacy of plants, the choices are driven by economics

1. Crop management issues (water, soil, landscape)
2. Market value of crop ($$ per year or decade)
3. Establishment issues (labor, pests, disease)
4. Net return on investment must be positive

In the absence of either government mandates or social subsidies, neglect is usually the preferred option. Social benefits are severely undervalued in a free-market capitalist economy

Miscanthus in Croatia, courtesy V. Pidlisnyuk

There are at least 20 species of miscanthus, a close relative of sugar cane. *Miscanthus* x *giganteus* (M x g) a native of Japan resulted from a spontaneous interspecific cross of a tetraploid x diploid to yield a sterile triploid. The parent *M. sacchariflorus (4n)* is more rhizomatous, vigorous and winter hardy than the parent *M. sinensis (2n)* which is bunchy in growth habit. Both may be self-incompatible in a particular cultivar. Their natural ranges overlap in some areas of Japan. We will focus on M x g.



Dovbush rocks, Polyanytskiy Regional Landscape Park, Ukrain *Photo by Пивовар Павло, CC BY-SA 4.0 wikimedia contest*

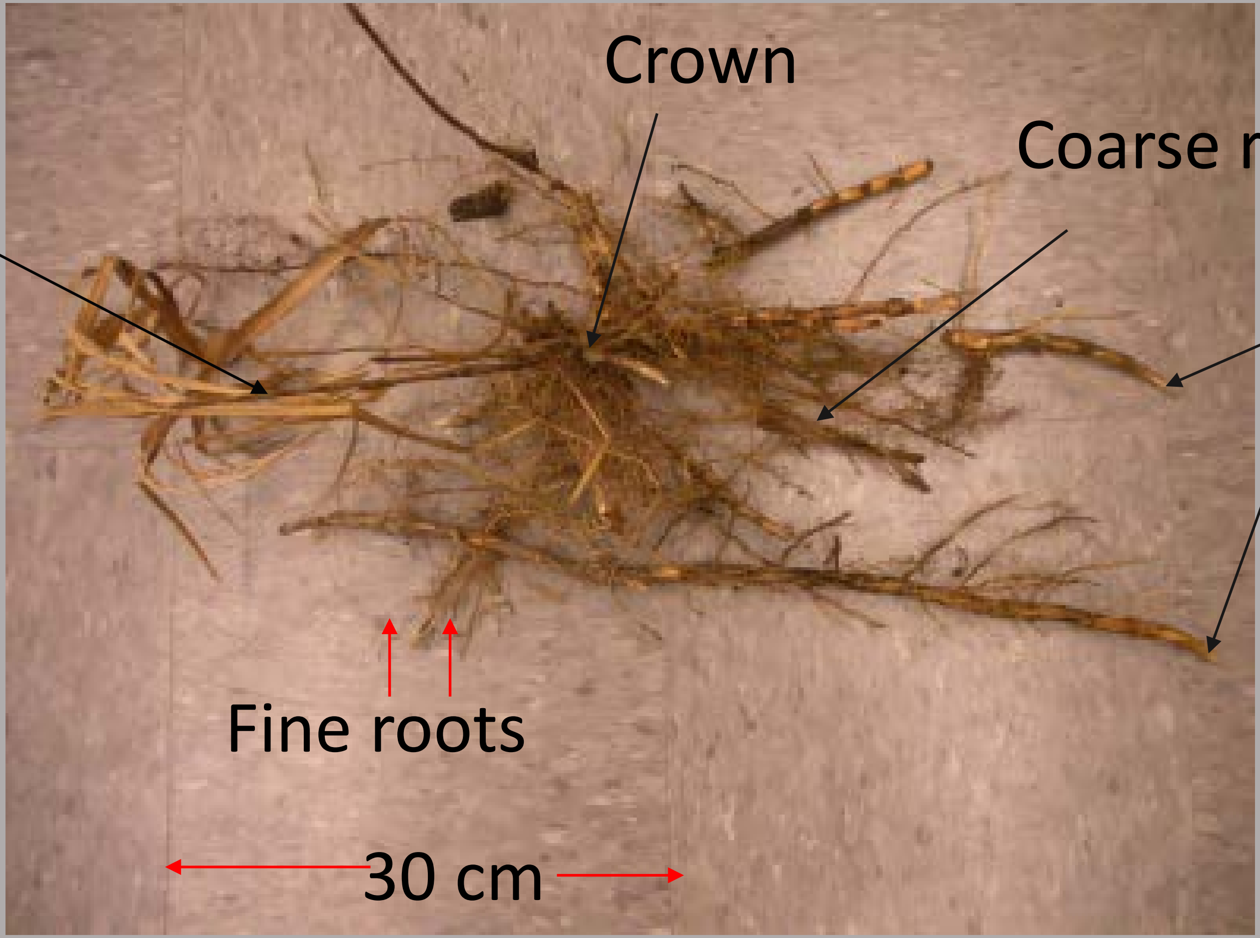
Miscanthus x giganteus, a sterile triploid hybrid of: *Miscanthus sinensis* , diploid called Chinese silvergrass, Maidengrass (invasive U.S. south) and *Miscanthus sacchariflorus*, tetraploid often called Amur silvergrass, (invasive weed in Minnesota)

Silvergrass, photo by University of Minnesota horticulture dept.

Photo credit: Ann Gibson, Vancouver BC

Here is an example of a 1 year old miscanthus plant

Leaves and stalk



Rhizome with large terminal bud and many potential laterals

Plant grown on fine sandy soil, partial shade, supplemental water

So, how do we efficiently prepare suitable material for planting to contaminated sites?

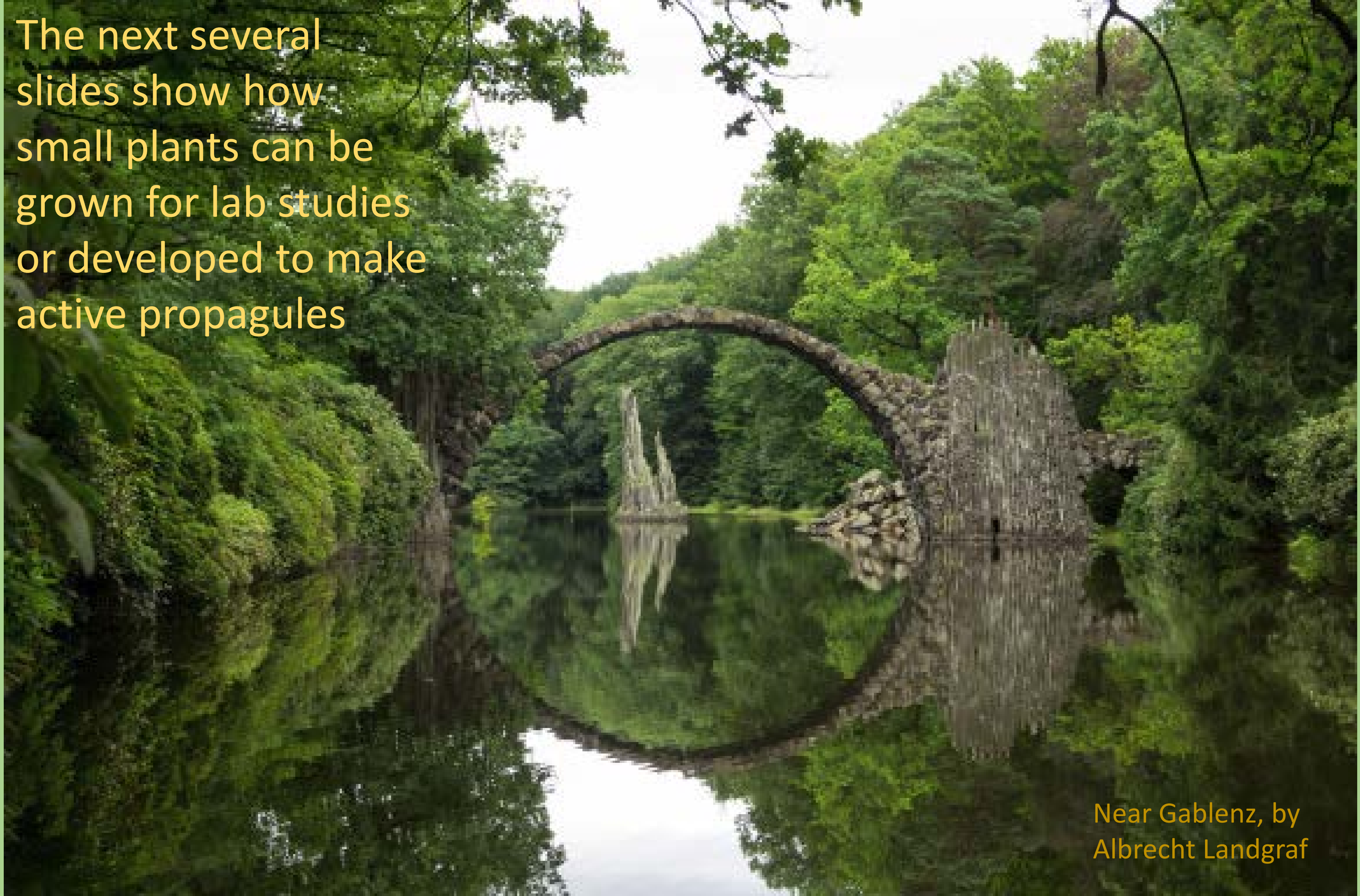
Either: 1. collect a large amount of rhizome material ready to plant directly, or 2. propagate from smaller pieces and plant actively growing material

Today I will show you examples of both approaches,
based on our experiences in 2014-2017

Starting with small pieces assumes suitable greenhouse or growth room facilities, and a good amount of lead time. Advantage, no big growth delay at planting, economical of limited starting material.

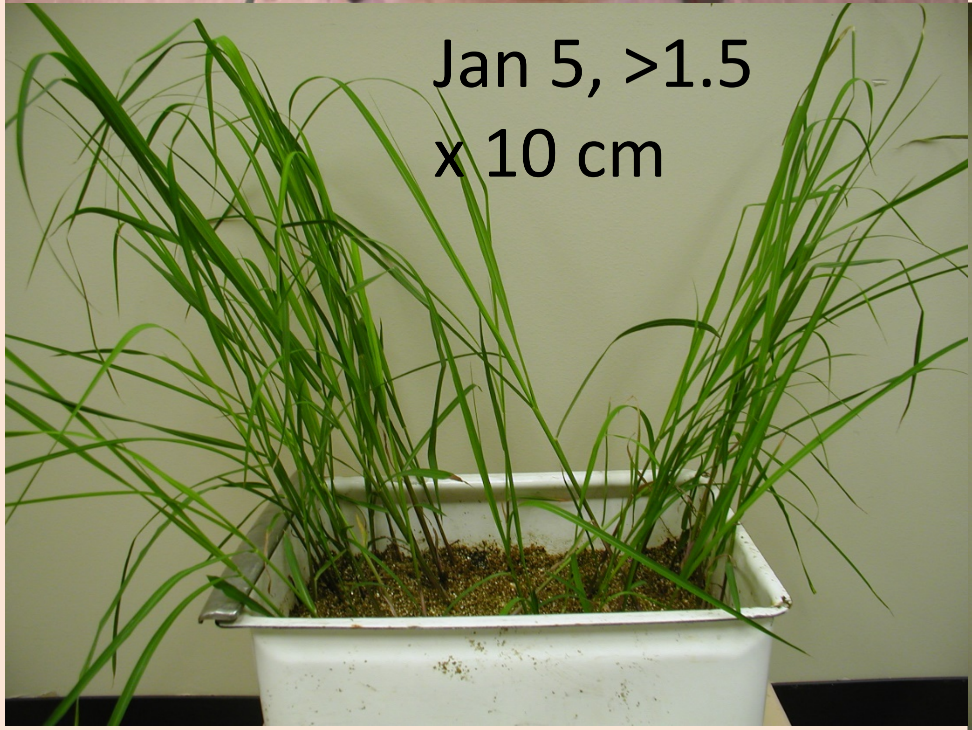
Oskaloosa sunset, courtesy of Cynthia Annett

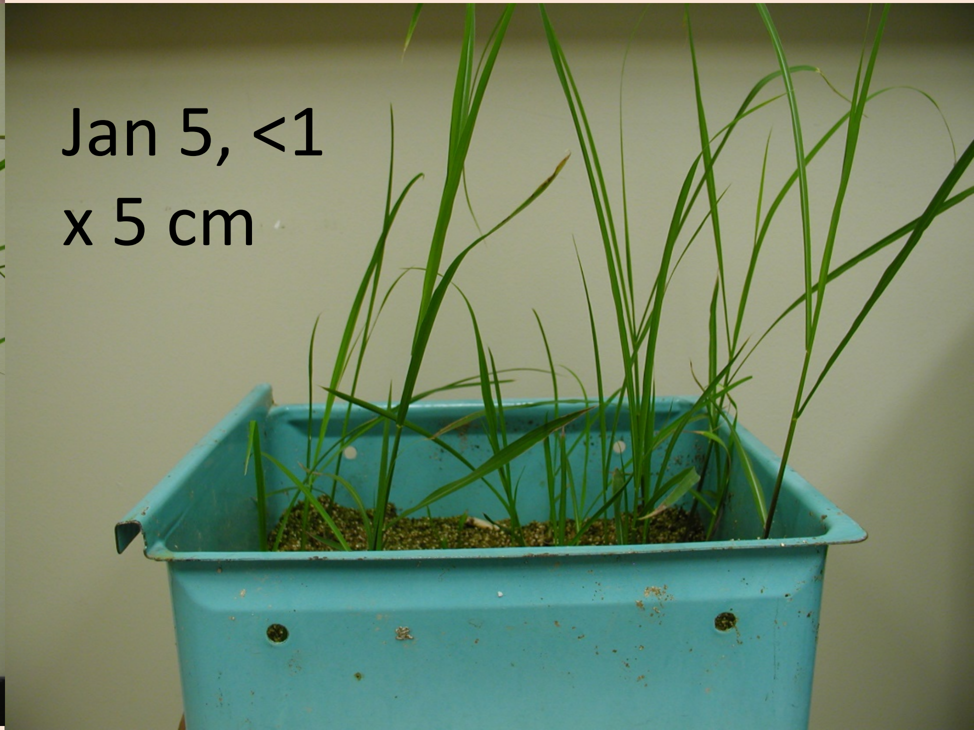
The next several slides show how small plants can be grown for lab studies or developed to make active propagules

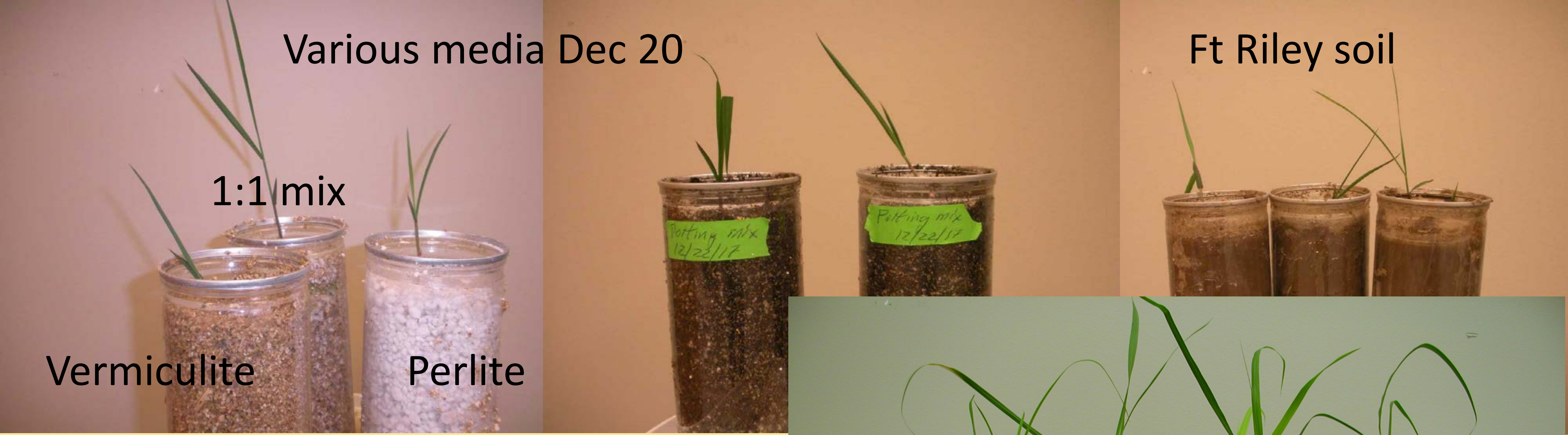


Near Gablenz, by Albrecht Landgraf

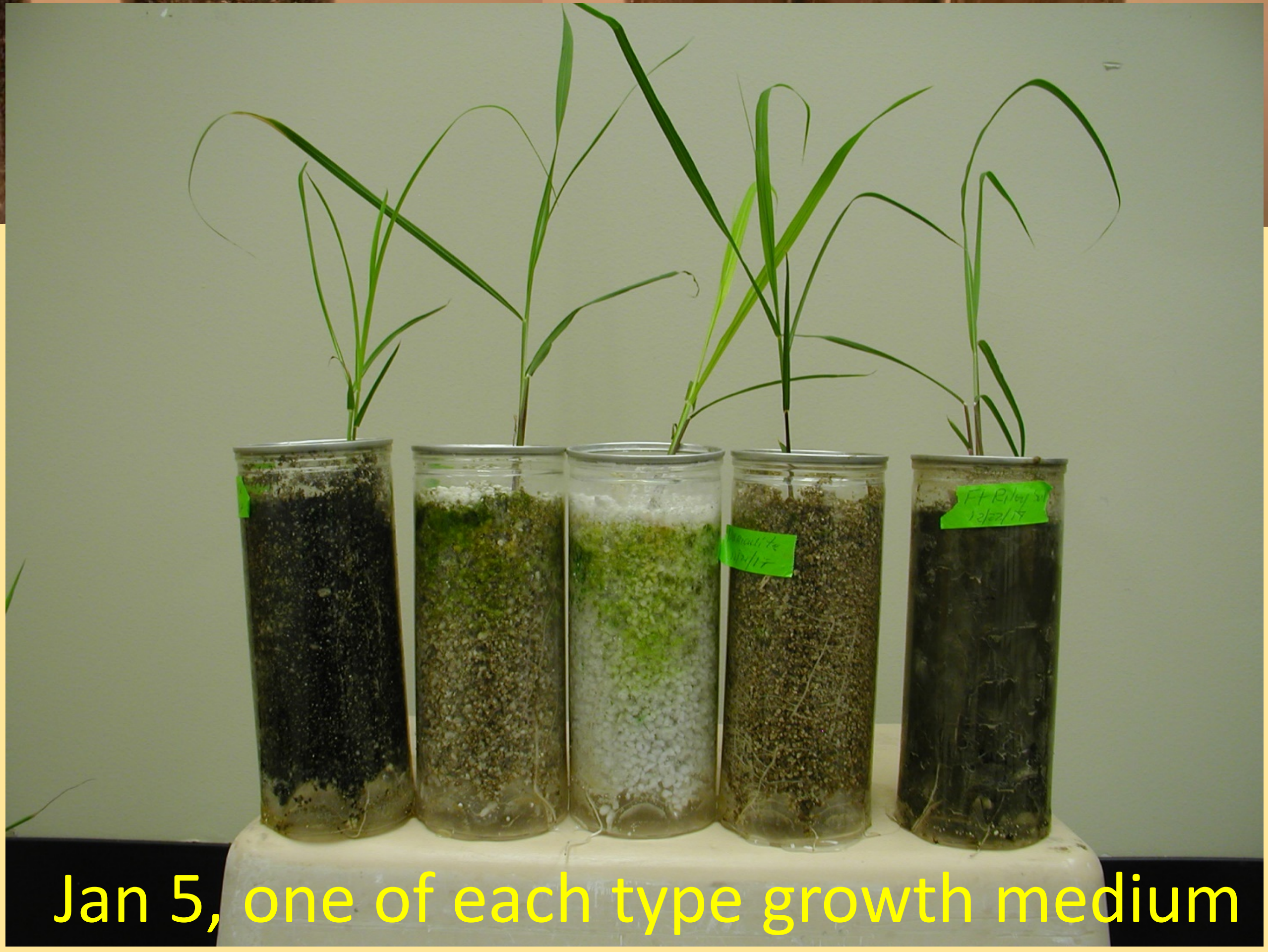
Large and small miscanthus stored rhizomes (from April 2017 at 4 C) kept under lights at ~25 C from early Dec to Dec 20 and Jan 5, ½ strength Hoagland's soln for nutrition. Growth is rapid. Larger are more vigorous







All plants grew. Perlite needed daily watering 1 wk, gets blue-green algae a lot. All plants have roots extending out bottom of container into shallow standing water in tray by 10 days. New basal shoots will emerge within 6 wk; can transplant outside by 3 mo.



From the larger rhizomes Jan 5, shoots were selected and severed from the rhizome. Each has a good lot of coarse roots. The 5 shown were transferred into ½ strength Hoagland's and tops cut back. The rhizomes + small shoots were returned to large container to grow bigger and new shoots

Single shoots in hydroponic culture Jan 5, 2018. These can be transferred to larger containers to test specific contaminants, or to produce more basal shoots for transfer to growth media

Small rhizomes shown to scale, as used for planting Dec 20, but maintained in bulk until Jan 5. Roots have elongated in that time and shoots grown longer

15 cm pot suitable for short duration testing of contaminants or to prepare transplants for rapid establishment in a field setting, if water is available during weeks following transplantation. Soil from intended planting site would be preferred medium to avoid diluting actual site contaminants

Severely pot-bound after months of growth in greenhouse. Optimum transplants should not be so tightly wound up in the pot

10 kg Ft. Riley soil, by Zafer Alasmary

Miscanthus tolerance of metals and salt in lab

Hydroponic water use by M x g is half that of sunflower for same biomass, ~175 mL/g , vs 350 mL/g. Field values would show less efficient because belowground biomass is not counted in usual field studies. Less tolerant of salts than sunflower in extensive hydroponic studies.

Miscanthus grows well in good soil with total Pb = 700-1500 mg/kg, poorly with high Zn + Pb chat material even when supplemented with 10 % by wt of composted cattle manure. Chat has total Zn > 4000 mg/kg, total Pb> 2000 mg/kg. Extractable metals expected to be ~ 20 x lower with compost treatment. In earlier field studies Zn toxicity was limiting for growth of other grass crops. Studies below are 2014 to 2015, before field work began. Some of these plants used for establishment of 2015 Ft. Riley site.

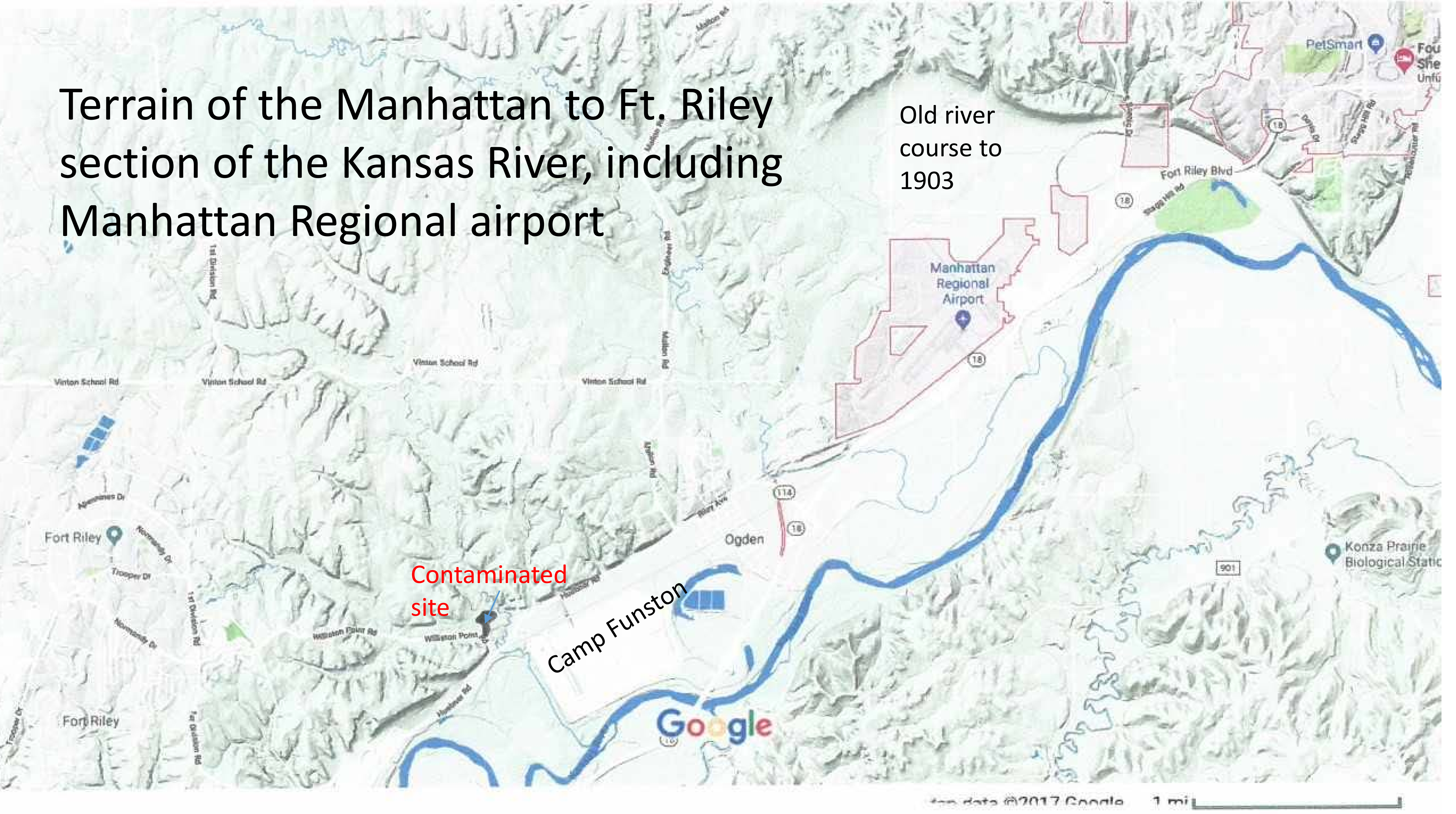
~1000 mg/kg total Pb aged in good soil at Ft. Riley, KS

S.E. KS mine waste chat, + 10 % compost, 1 % straw

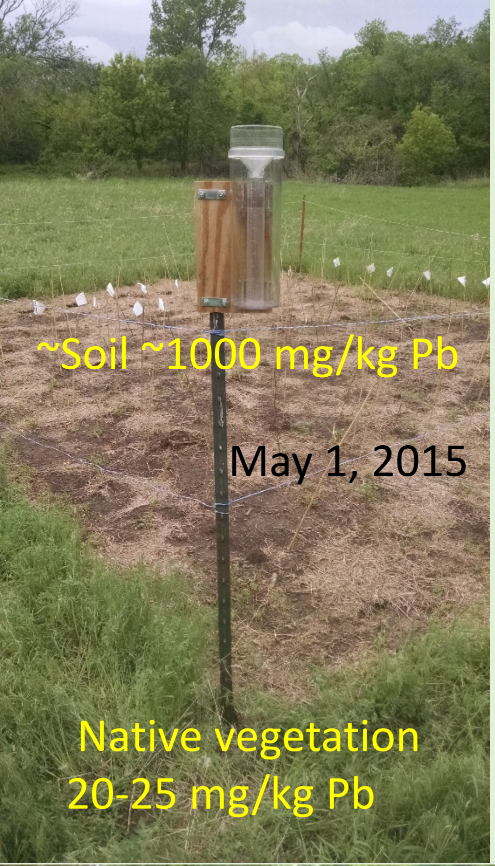
Hydroponic, perlite, + Hoagland’s complete nutrient solution

~1000 mg/kg total Pb in Ft. Riley soil, second test series

Terrain of the Manhattan to Ft. Riley section of the Kansas River, including Manhattan Regional airport

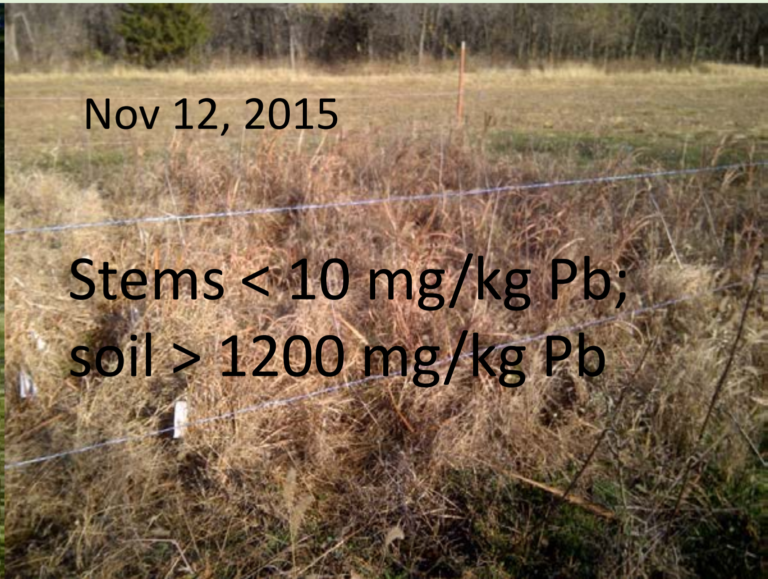


Preliminary studies at Ft Riley



Lab tests: ~ 30 mg/kg Pb in plants from ~1000 /mg/kg Pb in soil

Plants successfully established (no-till) in 2015 using several propagation methods. Best results obtained with larger rhizomes rather than lab-grown smaller branched plants. Rhizomes were successfully stored at 4 C for up to two years before planting. With watering, actively growing plants can be transplanted (in gardens) even during summer months.



Contrasting soil types

Unlike many genera, miscanthus species are able to grow on relatively low nutrient soils as seen at Mimon, CZ or as seen here at Dolyna, Ukraine with other competitors, and in our 2015 Ft. Riley plot, which yielded 10 tons/ha in its 2nd season when planted directly (as trees would be) into untilled unfertilized soils. Legumes might do better in very N-poor soils but few temperate zone perennial legumes are high yielding or high value timber or biomass producers.

Thank you,
time for questions

Photo by Cynthia Annett

Enjoy the winter snow