DESIGNING AND INSTALLING AN AGRICULTURAL HEDGEROW TO RESTORE NATIVE POLLINATOR HABITAT

A project in partial fulfillment of the requirements for the degree of Master of Environmental Horticulture

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Introduction

Pollinator Services

Pollinators, particularly domesticated and wild bees, have become the subject of increasing study and attention over the past few decades. At least 85% of angiosperms in the world require pollination in order to produce seeds and thus reproduce (Moldenke 1976, Simpson 1977); furthermore, 75% of food crops grown in agricultural settings require pollination to produce fruits, vegetables and nuts to feed the world's growing population (Klein 2007). The majority of this commercial pollination is carried out by the European honey bee (*Apis mellifera*), but the number of these honey bee colonies declined by 59% from 1947 to 2005 (National Research Council 2006). At the same time, the amount of pollinator-dependent agriculture required to meet the food needs of our planet has increased by 300% (Aizen and Harder 2009); this discord suggests significant problems for food security if alternative measures are not implemented to increase pollination efficiency.

Although honey bees have been the subject of much of the recent study, many species of native, wild bees live all over the world and they are quite capable of pollinating agricultural crops. Native pollinators can meet pollination requirements of a large number of crop types (Kremen 2004); in fact, 90% of tested farms' native bees were able to provide sufficient pollination (Winfree 2007), or even exceed the efficiency of honey bee monocultures (Garibaldi 2013). Unfortunately, wild bee diversity is also decreasing, particularly those species that are floral specialists and those that are relatively sedentary (Potts 2010). A recent analysis of plant-pollinator networks over the past 120 years found that pollinator species' vulnerability to land-use change and climate change strongly correlated with a non-random extirpation of those same species. Even if resilient bee populations survive environmental fluctuations, the changes result in a mismatch of phenology between the bloom times of bees' historical nectar sources and bee emergence and feeding habits. Plant-pollinator network linkages and interactions are disappearing, and this loss of redundancy weakens ecosystems globally (Burkle 2013). The crisis of pollinator decline even prompted the President of the United States to issue a memorandum to preserve pollinator health, and to release the "Pollinator Research Action Plan" to bolster surviving populations (White House 2014).

In order to prevent further decline and promote population regrowth, pollinator habitat and food sources (flowering plants) must be restored. These restoration efforts provide the most benefit to generalist pollinators, as they can obtain resources from a variety of different flowers, even introduced agricultural crops (Waser 1996). An additional advantage of habitat restoration is the demonstrated overlap in native plant use by both pollinators and beneficial predatory insects (Tuell 2008). Enhancing resources for wild pollinators is also advantageous for managed colony species, primarily honey bees, which feed on the same floral nectar sources as the majority of generalists (Garibaldi 2014). Dixon (2009) has called for habitat restoration efforts to focus on planting "framework, bridging, and magnet species for pollinators", species that draw pollinators to an area, and provide adequate food, resources, and habitat to sustain the population through to the next season. In order to support a diversity of pollinators with a wide range of mouthparts, body sizes, temporal variation feeding time, and responses to climate change, a large array of flowering plants are needed in any given habitat (Garibaldi 2014).

This project of researching, designing, and ultimately planting a native plant agricultural hedgerow was carried out in collaboration with Sarah Geurkink of the University of Washington (UW) Farm at the Center for Urban Horticulture (CUH). The hedgerow is located just south of the farm, and it will provide forage and habitat for native pollinators, including bees, flies, butterflies, and hummingbirds. Additionally, the hedgerow will function as a visual barrier to separate the farm from Wahkiakum Lane, as well as a windbreak. Educational opportunities related to pollinators and native plant restoration will exist for farm interns, Seattle Youth Garden Works, and the future Children's Garden. This agricultural hedgerow will be able to serve as a model for future hedgerows at similar Puget Sound area farms, and will ultimately benefit the farm at CUH by increasing the diversity and abundance of native pollinators, with the ultimate goal of higher crop yields and more efficient farming practice.

Bees of the Pacific Northwest

Wild bees can be broken into two groups based on proboscis length: long tongued bees forage for nectar in long, tubular flowers, and short tongued bees are limited to open-faced flowers for their resources (Moisset 2011). However, flower shape is only one aspect to consider in pollinator habitat. Bees and other pollinators, such as butterflies, moths, and syrphid flies, require appropriate nesting habitat for both daily activities and their overwintering stage. Many female solitary bees practice "mass provisioning", or providing all food for developing larvae in one cell or nesting site. These nests are located underground, in beetle holes, or in the hollows of pithy stems (Moisset 2011).

Behind honey bees, the most recognized group of bee pollinators are the bumble bees of the genus *Bombus*. The common bumble bee (*Bombus impatiens*) is used commercially to pollinate tomatoes and other Solanaceae. These, and about 70 other families of plants, require a particular method of pollination known as buzz pollination. Flowers in these particular families have small pores on the tip or side of the anthers (poricidal anthers) from which pollen can emerge. Bumble bees grasp the anthers with their legs & mouthparts and vibrate their bodies at high frequencies to shake the pollen loose; this muscle vibration is what causes the audible buzzing noise of a bumble bee on a flower. Occasionally, the bees have to use their mandibles to grasp the anther cone to avoid being shaken off; commercial tomato growers can check the number of marks on the cone to see how effective buzz pollination has been (Willmer 2011). The common bumble bee is only native to the eastern United States, however, and as such there are efforts to keep it localized (Buchmann 2011). Western bumble bee (*Bombus occidentalis*) populations have declined over the years, but alternative species in the western United States that could perform the same buzz pollination function as the commercially raised bumble bee include the yellow-faced bumble bee (*Bombus vosnesenskii)* or the Morrison bumble bee (*Bombus morrisoni)* (Buchmann 2011). Bumble bees are particularly vulnerable to land-use change and climate change, and are usually the first species to be locally extirpated after urbanization (Larsen 2005). Bumble bee habitat requirements include bare ground for nesting sites, and flowers that bloom quite early in the spring and later in the fall, to sufficiently feed the colony queen when she emerges, as well as when she nests and hibernates at season's end (Moisset 2011).

A second group of native bees important to the Pacific Northwest region are the Megachile family, which include mason bees and leafcutter bees. Blue orchard bees (*Osmia lignaria*), a local species of mason bee, are highly efficient pollinators of fruit trees: cherries, apples, and various other stone fruit crops grown in orchards (Moisset 2011). Mason bees lay their eggs in existing beetle holes or in the brittle stems or limbs of dead trees. To artificially mimic these nesting sites, 7-8mm holes can be drilled into a block of wood (Buchmann 2011). While mason bees plug those holes with mud, leafcutter bees (Megachile spp) use leafy material to seal off their nests; this material is often cut from rosebushes (*Rosa* spp) and the removal only causes minor cosmetic damage, leaving no lasting harm to the plant (Mader 2011).

Other wild bees found in the region include squash bees (genera *Peponapis & Xenoglossa*). They only feed on cucurbit flowers at or before dawn, and they nest underground right beneath the plants they pollinate (Moisset 2011). Sweat bees, belonging to Halictidae, are a bright metallic blue or green color. They nest in the ground and are usually generalist pollinators. The two most common genera of sweat bees in the western United States are *Lasioglossum* and *Agapostemon*. The latter is a short tongued bee and thus can only feed on open faced flowers (Mader 2011). One specific halictid, the alkali bee (*Nomia melanderi)* is a particularly efficient pollinator of alfalfa and it nests in alkaline, undisturbed soils (Moisset 2011). Yellow-faced bees (*Hylaeus* spp) resemble wasps. They preferentially nest in pithy hollow stems such as rosebushes (Buchmann 2011). Digger bees (*Anthophora* spp) are large, solitary bees that feed from long, tubular flowers like beardtongues, the genus *Penstemon* (Buchmann 2011). Long horned bees (*Melissodes* spp) also nest in the ground and are generalist pollinators as well, although they feed heavily on sunflowers (*Helianthus* spp) which double as a commercial agricultural crop (Mader 2011).

Site History & Matrix

The Union Bay Natural Area (UBNA) is located in Seattle just north of Lake Washington over what used to be the Montlake Fill, which was closed in the 1960s and functions as a teaching and experimental natural area. It was to act as a model for natural area restoration and is the location for numerous University of Washington student projects and fieldwork experiments. It was seeded with non-native grasses, and many other exotic and invasive species such as Himalayan blackberry (*Rubus armeniacus*), Scotch broom (*Cytisus scoparius*), and purple loosestrife (*Lythrum salicaria*) have colonized the area. One goal for UBNA at its inception was "to increase wildlife habitat" (Ewing 2010).

UBNA is already a unique natural habitat located in the middle of an increasingly urbanized area. It is therefore an ideal location for experimentally planting an agricultural hedgerow to attract native pollinators. Graves and Shapiro (2003) investigated the impact of exotic plants on butterfly populations and found that the invasive Himalayan blackberry actually acted as a "magnet species" of plant that could initially draw populations to the area. Looking at UBNA through a similar lens, it follows that the existing natural area, filled with both native and exotic plants, has likely already drawn a number of pollinators to the general area. It is somewhere between a "remnant habitat" and a "managed park" — categories in Hernandez et al's classification of urban green spaces (2009) — and because of this is likely to provide both forage and nesting requirements for pollinators; a feat usually difficult to achieve in urban areas. Bee species richness is positively correlated with the percent of arable land in an area, and negatively correlated with the percent of impervious surfaces (Dauber 2003). Simply due to UBNA's size, the hedgerow at the CUH farm will be surrounded by land that is adequate, if not ideal, for pollinators to thrive and survive. A study of genetic variability between bumble bee populations determined that the majority of gene-flow limitation is due to land-use patterns (e.g., urbanization) and that extent of queen bee migration is limited to sites less than 9 kilometers away; so, conservation areas such as hedgerows or habitat patches should be placed within 9 kilometers of an agricultural area (Jha 2013). Planting a hedgerow directly adjacent to the farm area should encourage bumble bee colonization and residence, solely based on proximity.

The UW Farm is an approximately 0.8 acre area within UBNA, farmed since 2011. The base layer of soil is glacial till and some fill from various construction projects around the University of Washington campus. This is supplemented every year with organic material and soil before planting. Cover crop is grown over the crop rows during the winter (Geurkink, personal communication). The hedgerow was ultimately planted just south of the farm area, and was not supplemented with the same organic material as the crop area.

Why Agricultural Hedgerows?

Hedgerows are historically part of the fabric of agriculture and land-use, especially in Europe. As early as 57 BC, the Nervii tribe in the region of modern-day France and Belgium used to cut and lay down small trees woven with brambles as a barrier to keep cattle safe (Maclean 2006).

Historians believe that living hedgerows were already well established by the year 1000 (Streeter 1982). Their two main purposes are delineation of boundaries and establishing barriers, but they also have the benefits of blocking unpleasant views, muffling sound, and growing aesthetically pleasing flowers (Whitehead 1991). Although specific implementations vary by region, a hedgerow is usually defined as an approximately 2 meter wide, 1.2-1.8 meter tall, thick wall of vegetation that forms a boundary around a garden or field or along a roadside (Streeter 1982). In addition to designating property lines and boundaries, hedgerows also provide extensive habitat for wildlife including birds, small mammals, and pollinating insects. In Europe, hedgerows tend to be remnants of the original forested area; hedgerow trees can be considered a keystone structure with a larger effect on the ecosystem than just the space occupied by the original tree (Merckx 2012).

If the services of native pollinators are to be harnessed to improve crop yields, there must be sufficient alternate forage and habitat for them to utilize in addition to just agricultural plants. Pollinators require resources outside of the window of time when crops are flowering (Mandelik 2012). Gardens located in close proximity to small farms have a positive effect on pollination, shown by increased seed set of *Campanula persicifolia*, a phytometer (indicator plant species) at test farms close to residential flowering gardens. Adding a flowering hedgerow close to a farm would yield similar results (Samnegärd 2011). Pollinators themselves benefit as well: buff-tailed bumble bee (*Bombus terrestris*) nest sizes at season’s end showed an increase with close proximity to showy suburban gardens (Goulson 2002). These gardens generally do have a higher floral abundance and diversity than traditional hedges but utilizing native flowering shrubs would be a closer simulation of a garden landscape than simply evergreen hedges.

Hedgerows, if planted with all the proper considerations in mind, can significantly increase wildlife diversity and abundance, including that of native pollinators. Compared to unrestored, weedy sites, floral hedgerows show increased persistence and colonization — especially of specialist pollinators — as well as species richness of bees (M'Gonigal 2015). Hedgerows harbor greater abundances of uncommon bee species and an overall greater diversity of bees and syrphid flies. In fact, 40% of species collected at restored sites were unique to hedgerows and not found at any control strips (Morandin 2013b). In the United Kingdom, diversity of macro-moths, an indicator species for ecological health, was found to increase with the addition of agricultural hedgerows. High-feeding species (the majority of moth species) benefitted more than low-feeders (Merckx 2012). Hedgerows are more valuable than simple wildflower strips: they are larger, and thus contain more potential habitat which ultimately enhances pollinator diversity and abundance in adjacent fields and results in higher crop yield (Garibaldi 2014). Hedgerow restoration is most beneficial to species that are at a higher risk for habitat degradation, and an eight-year continuous study comparing hedgerows to weedy controls saw a continual increase in species richness over the full study period (M'Gonigal 2015). Because of the short flight distance of many small and medium sized native bees, hedgerows have the greatest relative impact on small, nearby farms, and each farm should take responsibility for its own individual hedgerow management (Garibaldi 2014).

Worries about economic losses and hedgerows poaching pollinators from foraging in agricultural crop areas are unfounded. There has been no observed reduction in honey bee numbers in fields adjacent to hedgerows indicating no economic cost of lost pollination (Morandin 2013b). A basic cost/benefit analysis of planting hedgerows demonstrates that even with a slight negative profit the first year, by the fourth year after installation economic gain from enhanced crop yield made up for any initial planting and continuing maintenance costs (Garibaldi 2014). With hedgerows present a larger number of native bees was observed at distances of up to 100m into agricultural fields compared to control sites. This demonstrates that hedgerows are not just concentrating pollinators on their own shrubs and forbs but actually exporting them into the nearby farm area (Morandin 2013b).

Hedgerow Composition: Native or Exotic Plants?

Current and future climate change is an important consideration when selecting the plants for any restoration project, including pollinator hedgerows. Climate change will have effects on both plant phenology and insect emergence, posing a large threat to existing plant-pollinator mutualisms. Exotic species could be used to more closely match altered insect phenology but planting non-natives creates a dangerous potential for invasivity (Dixon 2009). Instead, it is more prudent to plant a large number and diversity of native flowering plants to increase time during the year where blooms are present and can provide a continuous nectar resource for bees throughout the changing seasons (Menz 2011). Temporal variability in emergence and foraging habits has been observed in Pacific Northwest grasslands among several genera of bees: *Bombus* were observed early- to mid-season in the spring, *Lasioglossum* were seen mid-summer, and *Melissodes* were observed late summer to fall, demonstrating the importance of ensuring blooms through a long time period (Kimoto 2012). Resource stability is required not only to support one season of pollinators, but to maintain successive populations in future years (Hernandez 2009).

In both new and mature hedgerows overall bee abundance is greater on native plants than on exotic plants. Native bees prefer to feed on native plants even on newly planted sites where the relative ratio of native to exotic plants is low (Morandin 2013a). There are, of course, “super generalist” exotic plants that can provide habitat and forage to a number of native bees, but many wild bees are specialized pollinators: squash, cactus, blueberry, and globe mallow pollinators all co-evolved with their host resource plant (Moisset 2011, Zuefle 2008). “Plant mixes”, or compositions of a variety of pollinator-friendly plants, are the most effective at encouraging colonization and persistence of native bee populations (Dixon 2009). Floral density is the primary factor that initially draws bees to an area. In urban areas of San Francisco, wild bumble bees effectively buzz-pollinated garden-grown tomatoes and the indicators of yield (fruit set, mass, seed set) were highest in tomato plants close to urban gardens. Even a small garden footprint was sufficient to encourage pollination services, provided that floral density was high (Potter 2015). High floral richness communities attract more generalist pollinators which then travel and strengthen connections between habitat plots (Cusser 2013). Local-scale variables, such as total bloom area, are more important than larger, landscape-scale variables for bee abundance (Burgess 2013).

Although honey bees are more generalist than solitary native bees, they also preferentially visited native plants in established hedgerows (Morandin 2013a). Not only do native plant hedgerows play host to a number of wild bees, they are also useful for promoting honey bee colony health.

Methods

Existing Bees in Union Bay Natural Area

The plant list for the hedgerow was designed in part based on recommendations from Cameron Newell's research (2015) on pollinator sampling at various Puget Sound farms. After several sampling sessions over one summer at the UW Farm, he found that although there were native bees already present near the farm there was a notable absence of several larger groups of bees: long-horned bees (*Melissodes*), green metallic bees (Halictidae family, specifically the sweat bees *Lasioglossum* and *Agapostemon*), and Megachile bees, particularly mason and leafcutter bees (*Osmia* and *Megachile*). Other suggestions for habitat restoration with the purpose of attracting native pollinators include dense planting (which creates habitat, and in the future has the benefit of suppressing weed growth), and placing the hedgerow in close proximity to the farm.

Appendix 4. List of pollinator friendly plants to use in hedgerows around the Pacific Northwest.

Spring blooming
Bald hip rose (*Rosa gymnocarpa*) Choke cherry (*Prunus virginiana*) Evergreen huckleberry (*Vaccinium ovatum*) Indian plum (*Oemleria cerasiformis*) (early) Mock orange (*Philadelphus lewisii*) Nootka rose (*Rosa nutkana*) Red-flowering currant (*Ribes sanguineum*) Salal (*Gualtheria shallon*) Salmonberry (*Rubus spectabilis*) Snowbrush (*Ceanothus velutinus*) Thimbleberry (*Rubus parviflorus*) Willow (*Salix spp*) (early)
Summer blooming
Ocean spray (*Holodiscus discolor*) Pacific ninebark (*Physocarpus capitatus*) Redstem ceanothus (*Ceanothus sanguineus*) Snowbrush (*Ceanothus velutinus*)
Fall blooming
Coyotebrush (*Baccharis pilularis*) Ocean spray (*Holodiscus discolor*)

Figure 1. List of Pollinator Friendly Plants to use in Hedgerows around the Pacific Northwest (Newell 2015)

Hedgerow Details

The hedgerow was originally designed to be a 300 foot long by 8 foot wide strip, stretching along the southern boundary of the UW Farm. The western end is adjacent to an existing apple tree (*Malus* spp*)*, and the eastern end is approximately 100 feet away from Wakhiakum Trail, and is most visible to passersby walking through UBNA.

Figure 2. Google Earth satellite map of proposed hedgerow location (yellow), with endpoint Malus fusca (red circle) and Wakhiakum trail marked

In addition to plant selection, described below, several other characteristics of adequate pollinator habitat were considered. Leaving mud or bare ground for bee nesting sites is a crucial component of proper habitat, whether inside the hedgerow area itself or at alternate sites within or around the farm (Garibaldi 2014). As well, mason bees (*Osmia*) lay their eggs in beetle holes, but an equally effective alternative is to drill 7-8 mm wide holes about 12-13 cm deep into a block of wood (Buchmann 2011). Other popular nesting sites are in pithy and hollow stems. Roses (*Rosa* species) specifically are great potential homes for a variety of bees (Moisset 2011).

Plant Selection

The Center for Urban Horticulture (CUH) is located in Plant Hardiness Zone 8b, with annual minimum temperatures ranging from -9.4 to -6.7°C (15 to 20°F). This hedgerow can therefore serve as a model for any Pacific Northwest region in the same zone (USDA 2012). Generally, any hedgerow in the Puget Sound region (Bellingham to Olympia), along the Olympic Peninsula coasts, and western Oregon along the I-5 corridor, could utilize a similar plant association since the plants selected are all native to the Pacific Northwest.

Figure 3. Plant Hardiness Zone Map of Washington State (USDA 2012)

UBNA's environment set the most notable constraints on plant selection. During the summer, Seattle receives little to no rainfall and dries out substantially. Additionally, due to the open grassland-like nature of the area, all the plants in the hedgerow will be exposed to full sunlight with no shade (Ewing, personal communication). The soil in the area is primarily clay; no supplementation was added and any root media was removed to prevent inhibition of root development outside of the planting hole (Chalker-Scott 2009). An added difficulty of the site is that in the winter, particularly with heavy rainfall, the hedgerow area receives the bulk of runoff or drainage water from the farm, since it is oriented slightly downslope from the planted area.

Figure 4. Flooding in proposed hedgerow location

This flooding precluded planting in some areas that were originally included in the design, however future work parties are encouraged to fill in the gaps in the case that proper drainage is installed to prevent standing water and ponding.

There was some discussion over whether to plant a wildflower strip that could then be mowed, tilled, and re-seeded in subsequent fall seasons versus a perennial shrubby hedgerow. Ultimately, the consensus was that a hedgerow with permanent plantings would be less expensive in the long run; any maintenance and necessary pruning would be minimal enough for UW Farm interns and volunteers to complete the effort quickly each year (Geurkink, personal communication). Herbaceous groundcover can be added in the future, however they were not selected for the initial planting because of the high risk of encroachment from the surrounding area of UBNA.

In addition to the aforementioned recommendations from Newell (2015), the Xerces Society's guide to planting for pollinators helped narrow down a final list. Shrubs that provide excellent habitat and nectar for pollinators include evergreen huckleberry (*Vaccinium ovatum*), red-flowering and golden currant (*Ribes sanguineum* and *R. aureum*), oceanspray (*Holodiscus discolor*), a particular favorite of syrphid flies and wasps, and Nootka rose (*Rosa nutkana*) for pollen-collecting bee species (Mader 2011). A number of plants selected are also host plants for butterflies. Roses, hawthorn (*Crataegus douglasii*), oceanspray, and serviceberry (*Amelanchier alnifolia*) are suitable hosts for several species of swallowtails (*Papilio rutulus, P. eurymedon,* and *P. multicaudata*), admirals (*Limenitis arthemis, L. lorquini*), and Viceroys (*Limenitis archippus*) (Mader 2011). Pojar and MacKinnon (1994) was an excellent resource for selecting native flowering shrubs that can tolerate full sunlight, and both xeric and mesic conditions, depending on the time of year.

Name	Common Name	Quantity
Cornus sericea	Red-twig dogwood	20
Gaultheria shallon	Salal	15
Solidago canadensis	Canada goldenrod	10
Amelanchier alnifolia	Serviceberry	20
Physocarpus capitatus	Pacific ninebark	20
Ribes sanguineum	Red flowering currant	20
Rosa nutkana	Nootka rose	20
Crataegus douglasii	Douglas hawthorn	30
Holodiscus discolor	Oceanspray	15
Berberis aquifolium	Tall Oregon grape	15
Malus fusca	Pacific crabapple	15
Oemleria cerasiformis	Indian plum	15
Philadelphus lewisii	Mock orange	15
Rosa pisocarpa	Peafruit rose	15
Vaccinium ovatum	Evergreen huckleberry	15

Figure 5. Final plant list for pollinator hedgerow

Installation

Site preparation

To prepare the site for planting, the 300 foot long stretch was first mowed and tilled in July 2015, to cut down tall grasses and dig up roots. Then, solarizing plastic was applied in a single tent layer. Clear plastic was selected, as it raises soil temperature more than black plastic (Fraser 2013), and ideally solarization would have continued for six full weeks in July and August. However, a severe windstorm in mid-August tore up and destroyed the majority of the plastic in place, so solarization only ultimately lasted for three weeks. It is likely that the disruption reduced the effectiveness of the technique, as weedy grasses were able to recolonize the area by planting time.

Plants were purchased from two vendors: the Society for Ecological Restoration (SER) UW Chapter's Native Plant Nursery, and Fourth Corner Nursery in Bellingham, WA. Plants from SER-UW were potted, most in 1 gallon containers, with several small serviceberry (*Amelanchier alnifolia)* in 4" pots. Plants from Fourth Corner Nursery were mostly bare-root, ranging in size from 6" to 18", and evergreen huckleberry (*Vaccinium ovatum)* and Indian plum (*Oemleria cerasiformis)* were plug size. On February 12, 2016, the day before planting, containers and labeled pin flags were staged at the site to expedite volunteer planting efforts. Douglas hawthorn (*Crataegus douglasii)* was used as a spine along the center of the hedgerow, spaced at six feet, and the remaining trees and shrubs were spaced out about two to three feet in a staggered pattern (Appendices 2 & 3). The area in the center of the originally demarcated plot was left unplanted, because of a large amount of standing water on the site from heavy rains and inadequate drainage.


Figure 6. Flooding in proposed hedgerow area

Ultimately, two 140 foot long strips (extending from the easternmost and westernmost ends) were the two areas planted, with the center 20 feet left open.

Planting

On February 13, 2016, volunteers from UW's ESRM 100: Introduction to Environmental Science course, the UW Farm, and SER-UW planted the hedgerow. Recruiting volunteers, particularly those who will have continued involvement in farm activities, was important in regards to future management; active participation and community involvement can lead to bee-friendly development because of the experience and time volunteers invest while working on the site (Hernandez 2009).

Figure 7. Volunteers on hedgerow planting day

After planting, mulch was placed over any non-planted area on the original plot, leaving a 6-8" diameter area bare around the base of each plant. At planting time, larger weeds and plants were removed by hand, and areas around the base of the new plants will be maintained and kept clear through the spring. Although leaving bare ground or mud is recommended for pollinator nesting (Garibaldi 2014), many of the plants were small and difficult to see, and mulch, along with leaving pin flags in place, helped designate their locations. Additionally, visitors to UBNA and students in the area are less likely to walk through and trample an area that has been visibly marked. The layer of mulch is relatively thin (1-2" at most), and is not intended to be replenished in the long-term; once existing woodchips have decayed, the ground will once again be exposed and suitable for nesting.

Figure 8. Planted and mulched hedgerow segment

Management Plan

Plant Maintenance

For the first few years, a part of future maintenance work will involve continued weeding around the base of the plants. Based on the dense planting design of the hedgerow, and to ensure that there are no gaps between plants, dead vegetation should be replaced if survival drops below 85%. This can be accomplished with a yearly walkthrough in late summer or early fall to compare planted vegetation to the designed planting map (Appendices 2 & 3). In addition, appropriate vegetation selected from the included plant list (Figure 5) can be supplementally added to any areas in the hedgerow displaying large gaps. Species that had difficulty with transplanting were serviceberry (*Amelanchier alnifolia)*, tall Oregon-grape (*Berberis aquifolium)*, and salal (*Gaultheria shallon)*. Personal observations are that tall Oregon-grape often takes a year or more to recover after transplanting; although leaves may drop, the plant may still be alive. Watering is recommended for the first three to five growing seasons: once every two weeks in standard summer conditions (Tanner 1995). To address this need, an irrigation system will be extended from the farm area south to the hedgerow and the adjacent site which will become the future Children's Garden. This work will be accomplished in collaboration with Amy Hughes and James Boeckstiegel, who works on irrigation maintenance for the UW Farm.

Intensive pruning should not be necessary, especially because the hedgerow is designed to be dense and full to provide ample habitat and blooms, and to act as a barrier for the farm. Limited hedgerow pruning (approximately once every three years) results in twice as many flowers, and 3.4 times the fresh mass of berries, as annually cut English hawthorn (*Crataegus monogyna*) trees and completely uncut trees yield 75% more flowers and 83% more berry mass than pruned trees (Staley 2012). Pruning should only be carried out as necessary, to trim back overhanging branches and keep the hedgerow from spreading into any other UBNA experimental plots. This hedgerow should retain an informal shape, as opposed to a well-manicured garden hedge (Figure 9). To keep bases of shrubs full and bushy, tops can be lopped off to send out adventitious buds (Whitehead 1991), and the width of the top can be maintained at an equal or smaller circumference as the bottom, to ensure the base limbs receive adequate sunlight (Tanner 1995). Maintenance and trampling should be avoided in the winter, to keep from disturbing pupae or insects in diapause in underground nests (Mader 2011).

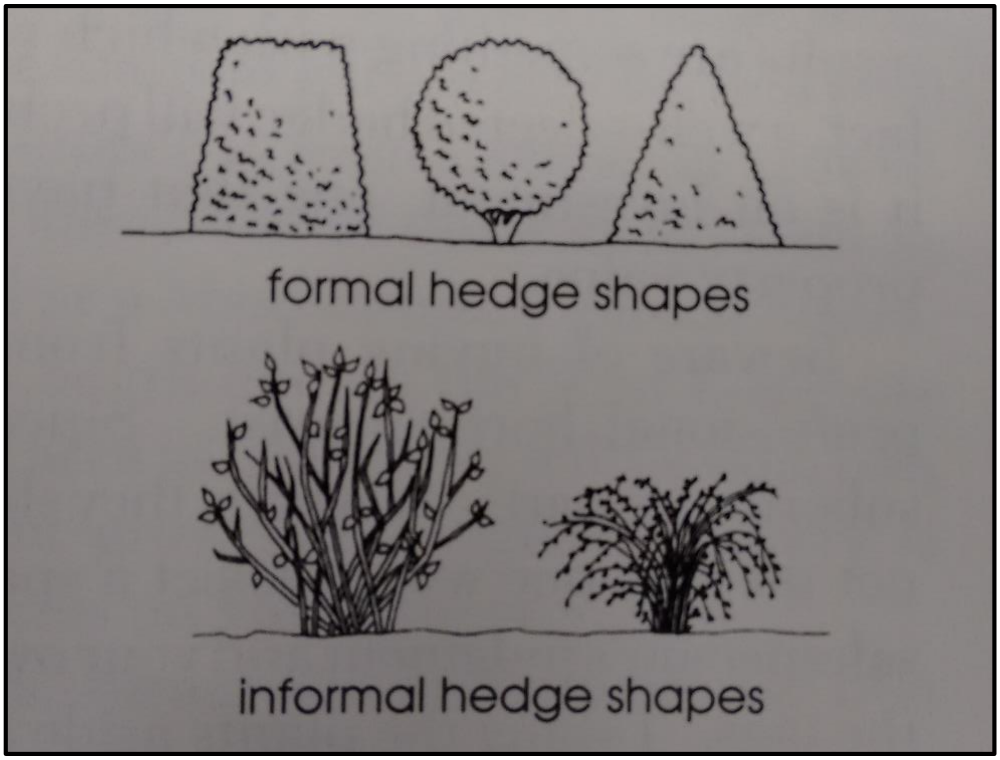

Figure 9. Informal hedge shape vs. formal hedge (Whitehead 1991)

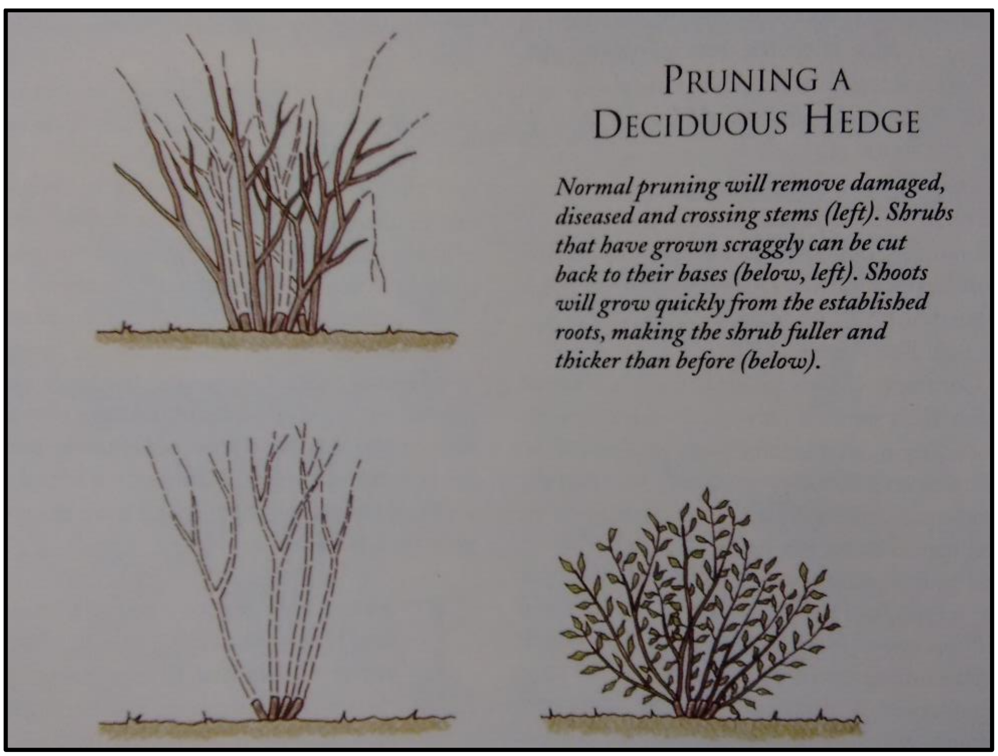

Figure 10. Cutting off damaged limbs at the base can stimulate new, full growth (Tanner 1995)

After one year (in Spring 2017), more herbaceous perennials and annuals can be added either to the hedgerow area or elsewhere on the farm. Sunflowers (*Helianthus annus*) are recommended both for commercial seed harvest and to attract a specialized pollinator: the sunflower chimney bee, *Diadasia enavata* (Hernandez 2009). Sunflowers can also help attract long-horned bees: *Melissodes*, a species not currently found in UBNA (Mader 2011, Newell 2015). Wildflowers in the Asteraceae family are also known to specifically attract long-horned bees (Kimoto 2012). Fescue (*Festuca rubra*) and lupines (*Lupinus*) are excellent host plants for duskywing and skipper butterflies (Mader 2011). Herbaceous perennials should be planted in clumps rather than individually, since they are much smaller than shrubs and trees and must be aggregated to visually attract wild bees.

Future considerations

Bee monitoring can be carried out during the summer months following the timing and schedule of Newell (2015) to ensure continuity and ability to accurately compare data to previous years. Detailed and accurate recording, trapping, and monitoring protocol — including timing — is crucial to data continuity since bees have different phenology and activity throughout the day (Kimoto 2012). Reporting species compositions is equally as important as simply abundance and species richness. Another factor to consider during future pollinator monitoring is collection method. In a study that used several strategies, pan traps yielded no difference in bee numbers and diversity between control plots and hedgerow. However, flower-netted results showed higher abundance at hedgerows, perhaps due to the fact that pan traps attract insects that have nowhere else to feed, whereas flower netting captures those species that preferentially land on flowers. (Morandin 2013b).

As well as supplementing the immediate hedgerow site, habitat restoration projects should be encouraged elsewhere in UBNA's surrounding matrix. Combinations of different local and small scale practices such as hedgerows, flower strips, organic farming techniques, and maintaining nearby natural areas, are all context-dependent, effective ways to enhance nearby farming practice and improve connectivity for wildlife (Garibaldi 2014). Ecologically minded urbanization, containing less than 50% non-impermeable surfaces, significantly enhances bumble bee gene flow and dispersal, strengthening the population (Jha 2013). Pollinator diversity, as well as species composition, is negatively correlated with distance from remaining habitat. Connectivity is crucial to maintaining populations of native bees, specifically rare or unique species that are more vulnerable to land-use change (Cusser 2013, Ghazoul 2006, Carvalheiro 2010). Strengthening the surrounding matrix is sure to benefit the pollinator populations of the area.

Conclusions

In summary, the installation of this hedgerow will benefit the University of Washington Farm at the Center for Urban Horticulture in several ways: the plants selected are known to provide food and habitat for a variety of native pollinators including wild bees and butterflies; it will act as a barrier (visual, auditory, and windbreak) between the farm and the rest of the Union Bay Natural Area to the south; and it can be used as an educational component for the farm, Seattle Youth Garden Works, and the future Children's Garden on site about the importance of pollinators.

Future maintenance will be simple, especially after irrigation is installed, with plant replacement responsibilities the first few seasons tapering off after approximately three years to just occasional trimming or pruning to remove overhanging branches. Maintenance protocol will be given to both the UW Farm Manager and the Society for Ecological Restoration – UW Chapter.

In addition to cited literature, invaluable resources for information about native pollinators and initiatives both in the Pacific Northwest and nationwide are:

- NW Pollinator Initiative (http://nwpollinators.org/) – work closely with The Common Acre (http://commonacre.org/)
- Pollinator Partnership (http://pollinator.org/)
- Xerces Society (http://www.xerces.org/pollinator-conservation/)
- Pollinator Pathway: a Seattle-area project (http://www.pollinatorpathway.com/)
- Ladybird Johnson Wildflower Center (http://www.wildflower.org/)
- BugGuide.com (http://bugguide.net/node/view/15740)
    - Native Bees of North America (http://bugguide.net/node/view/475348)

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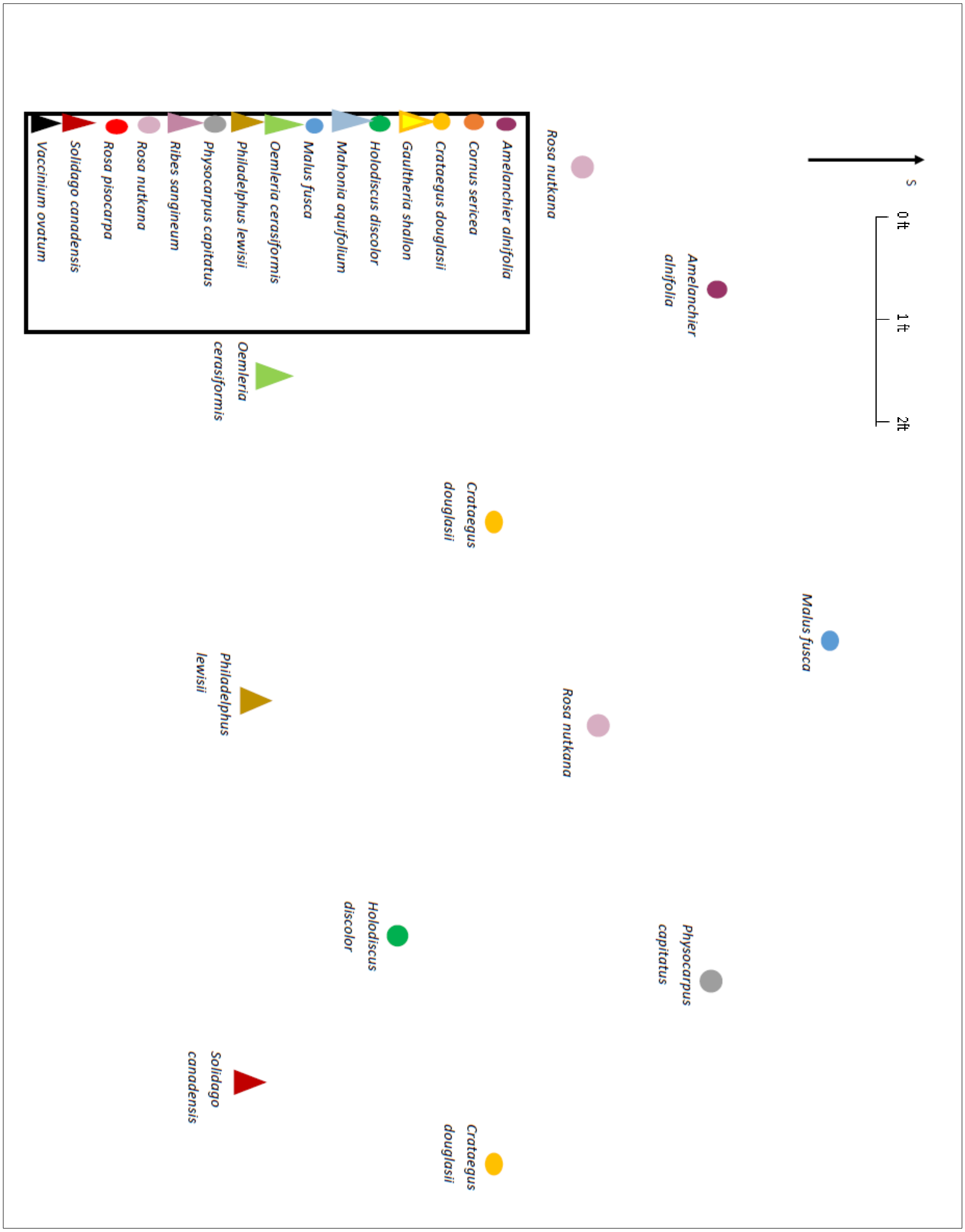
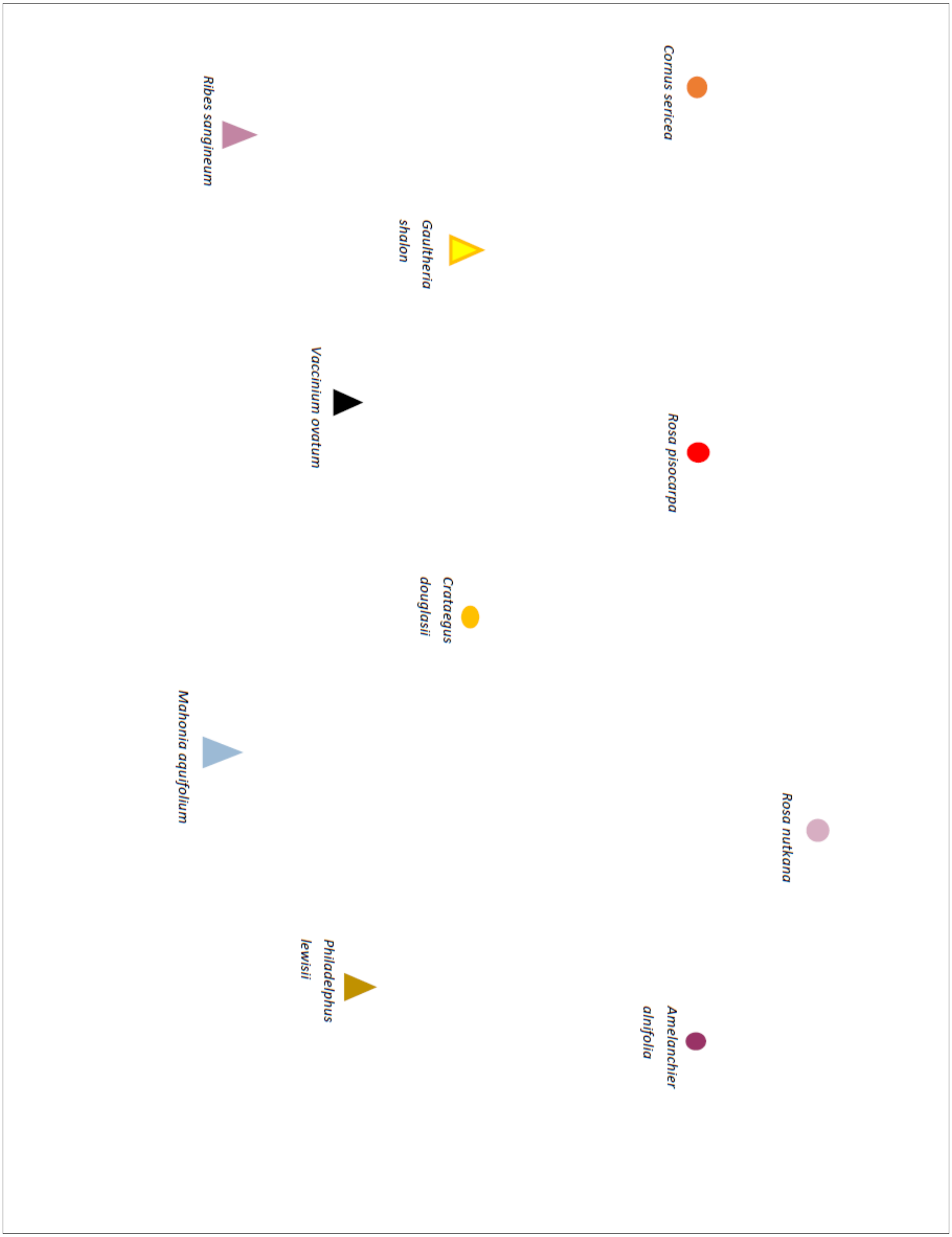
Appendices

Appendix 1: Planting Schematic (East Half)

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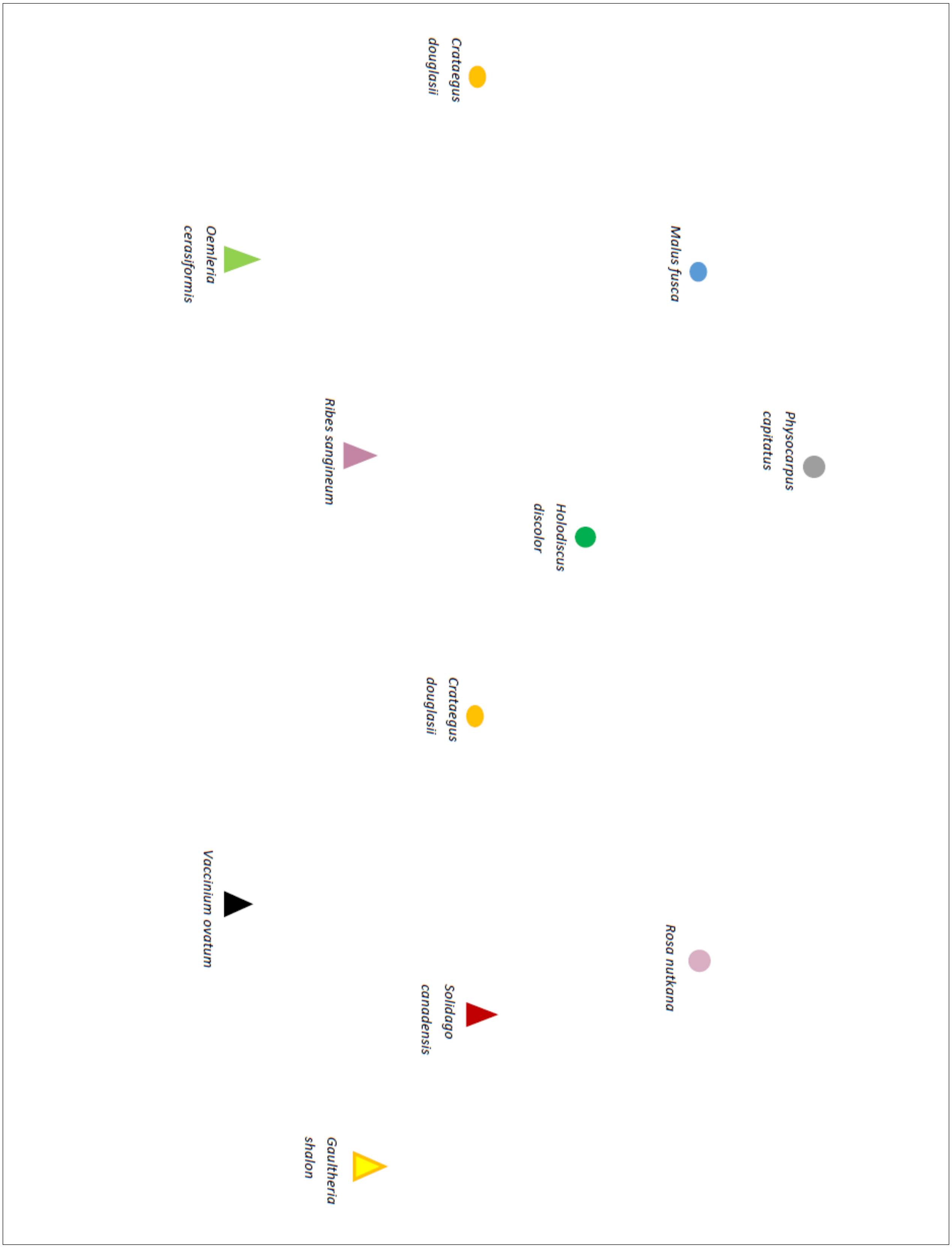

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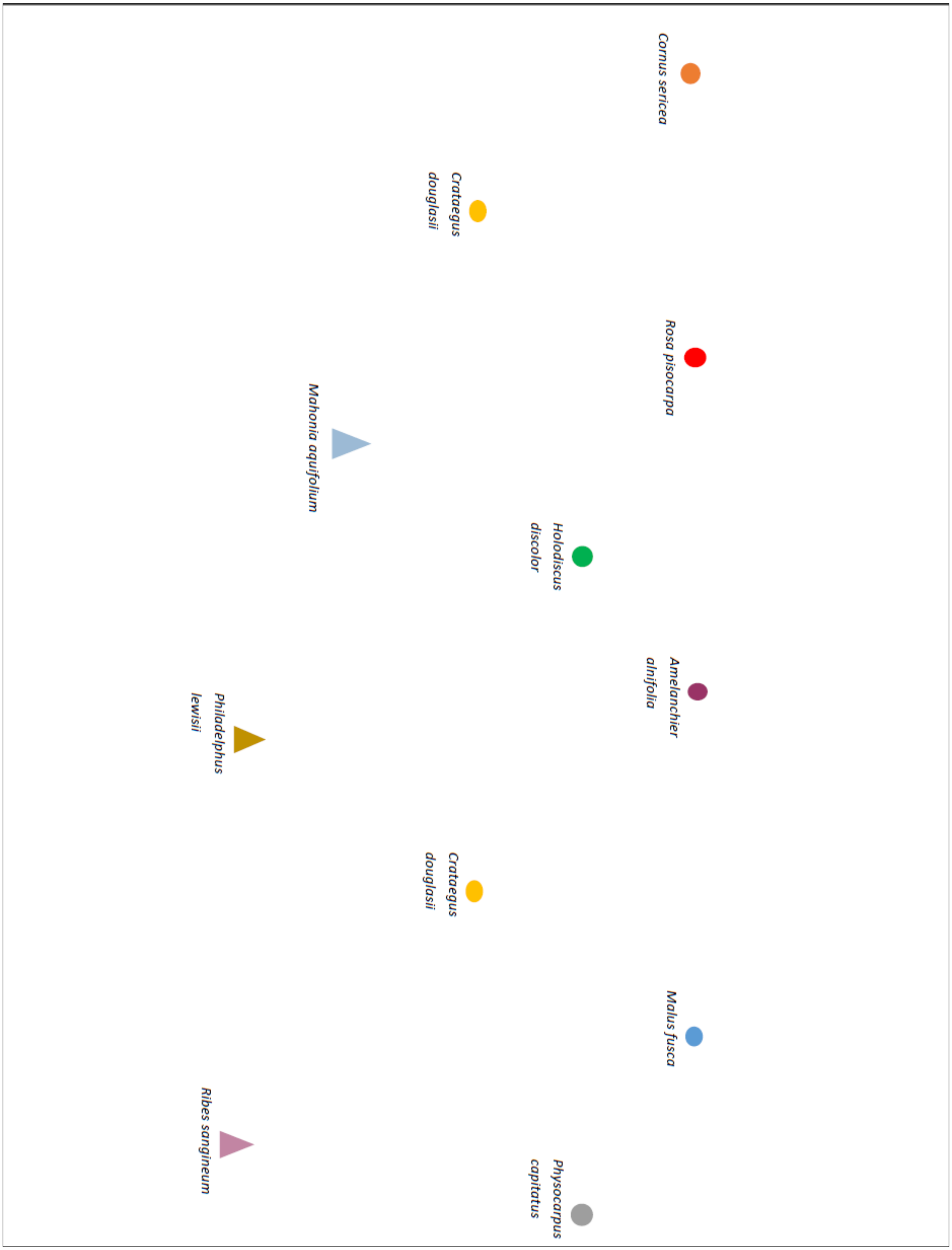
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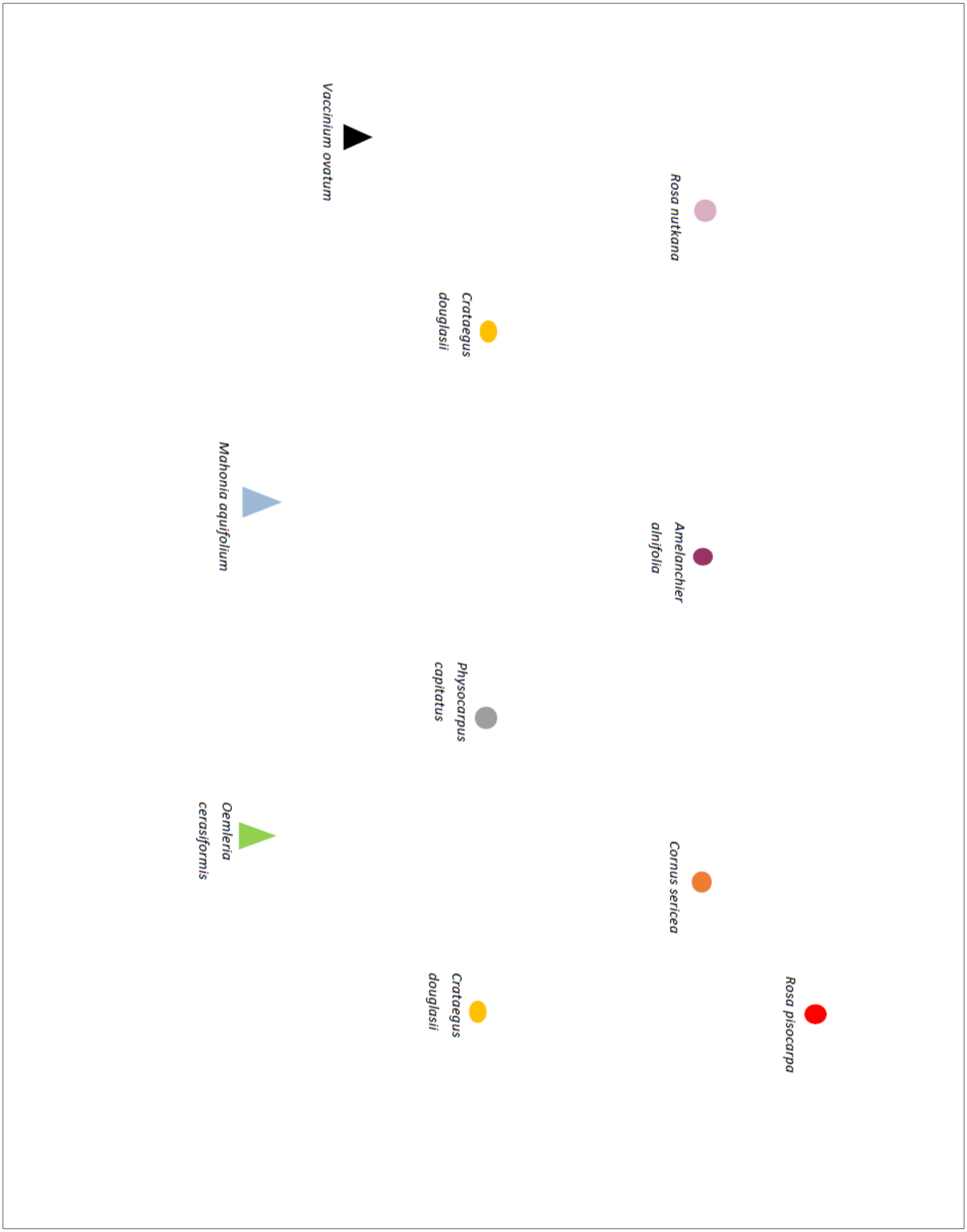

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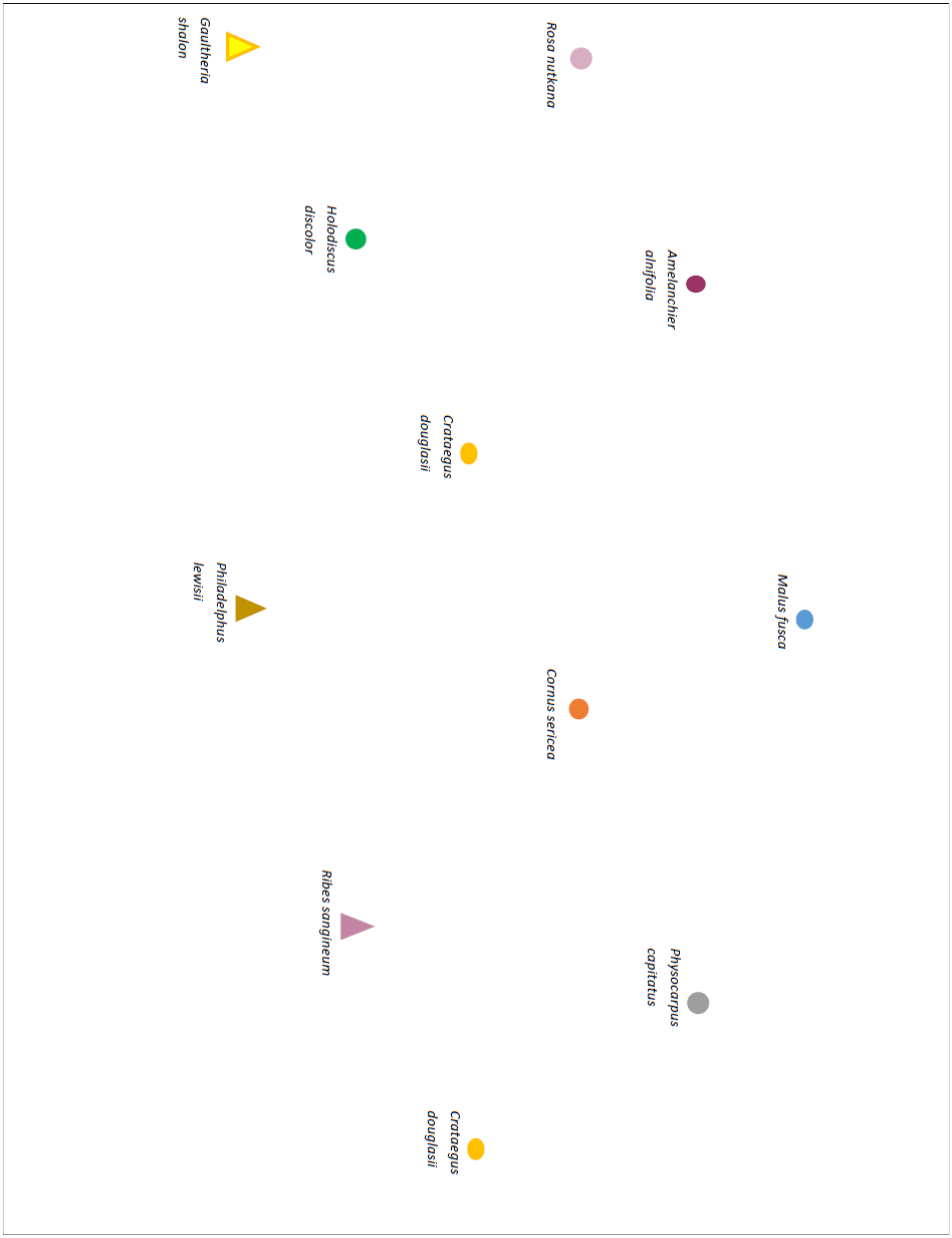
Rosa pisocarpa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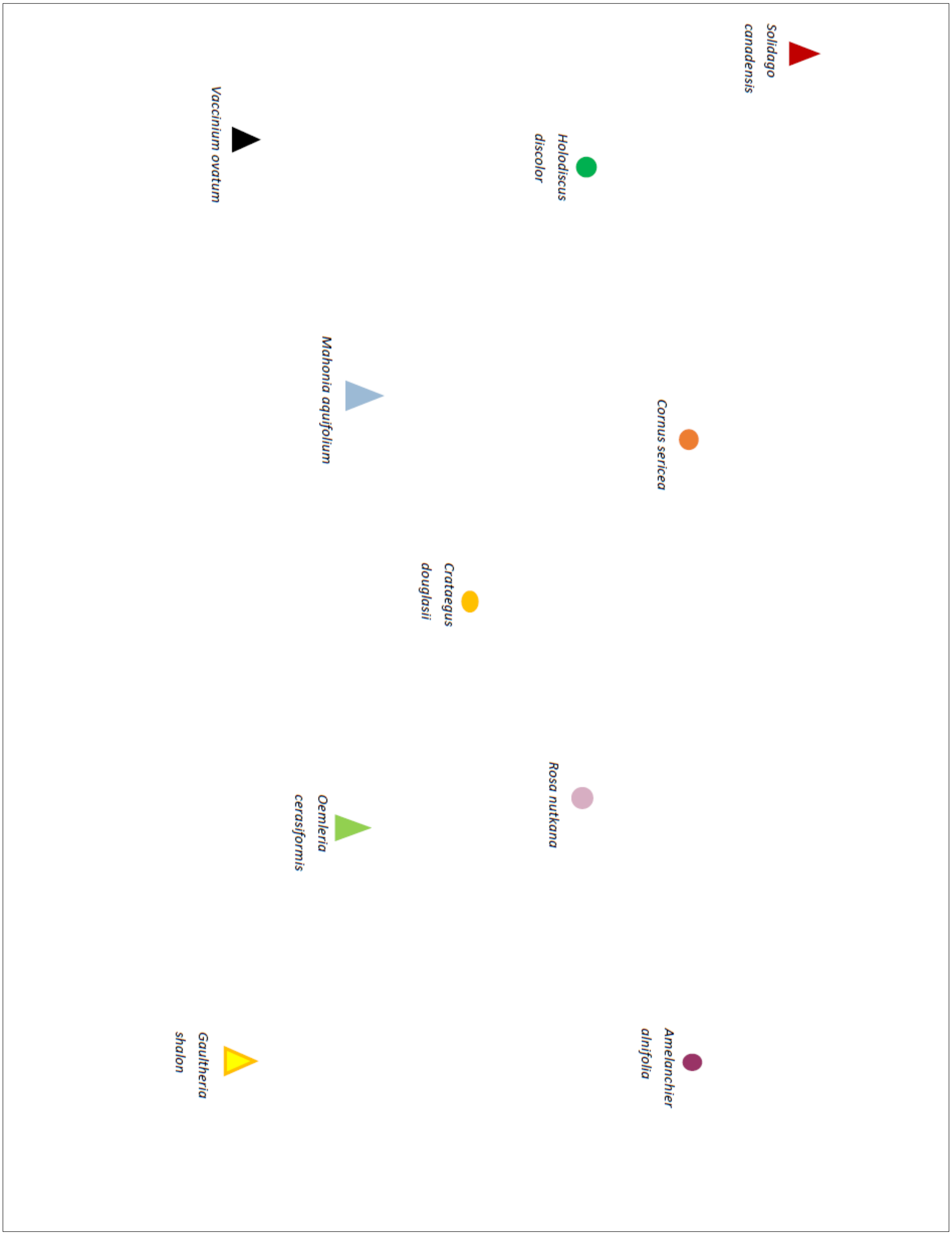
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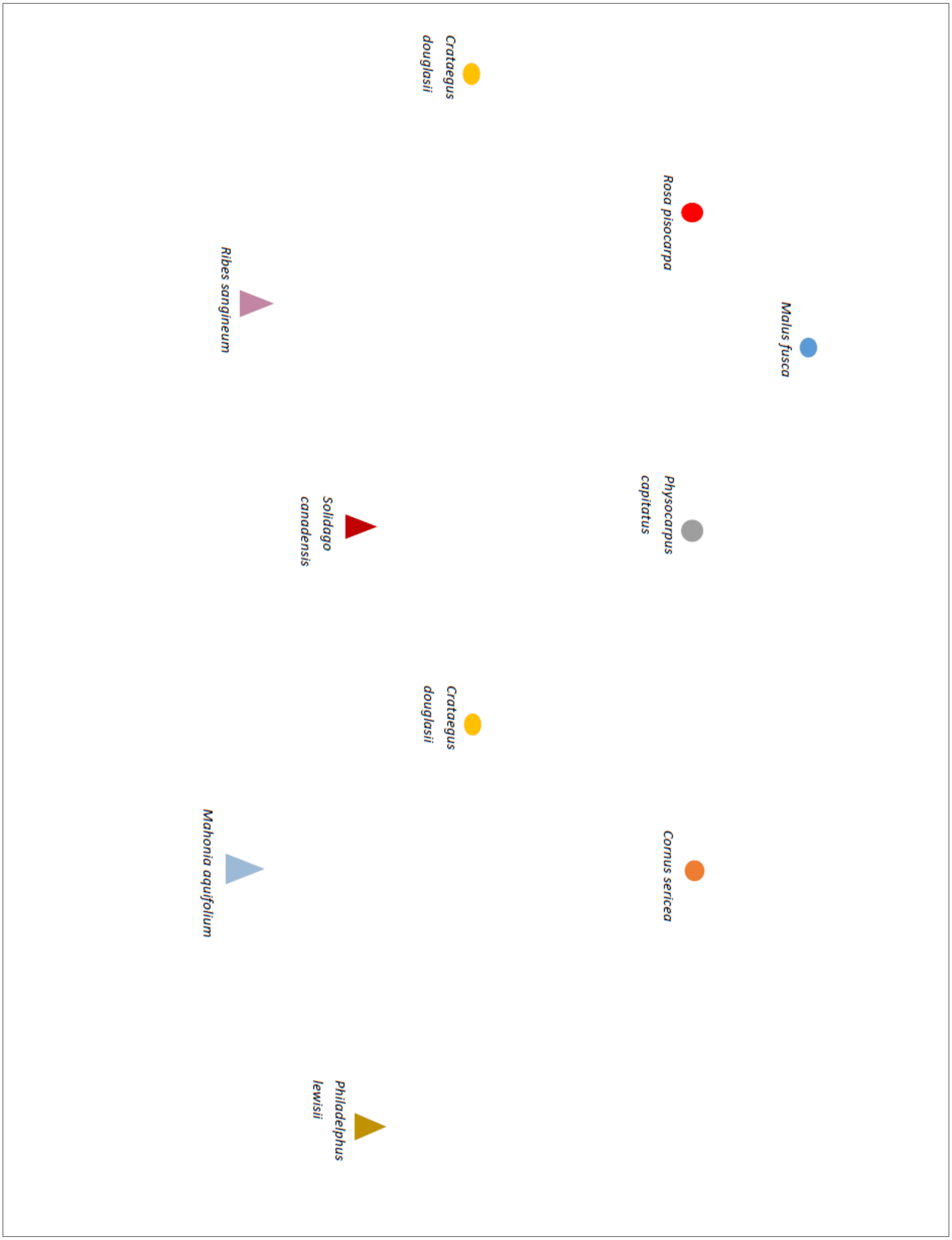
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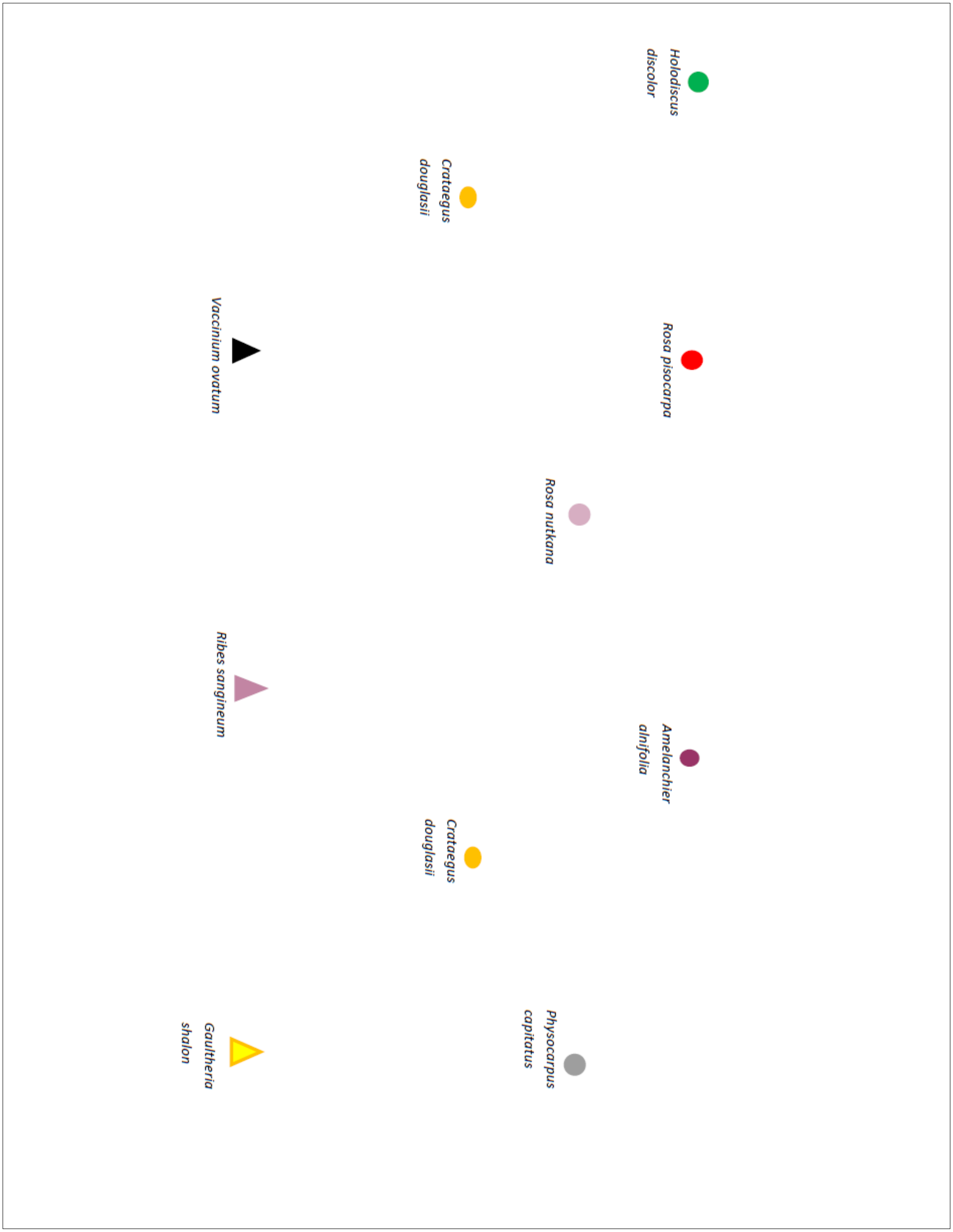
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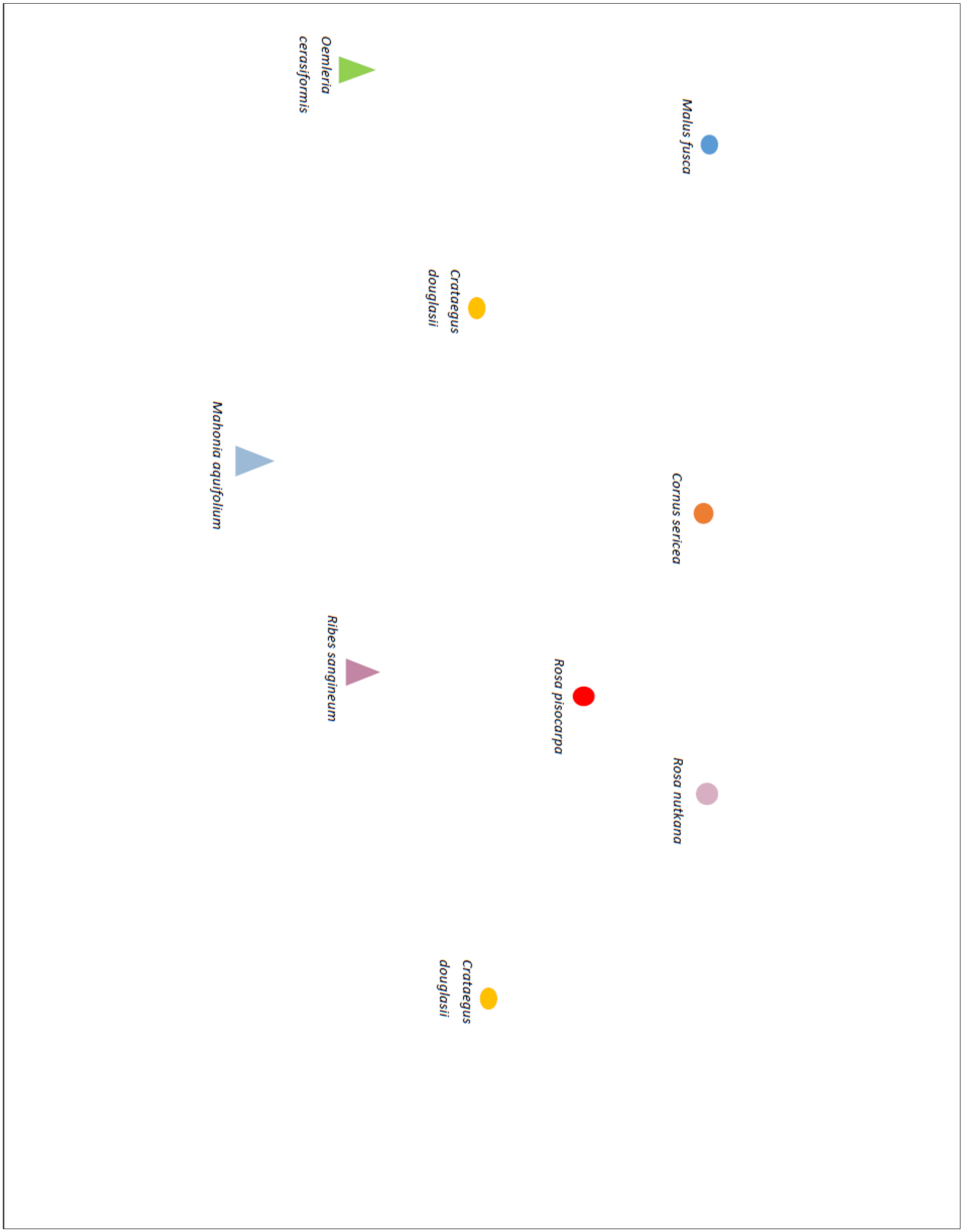
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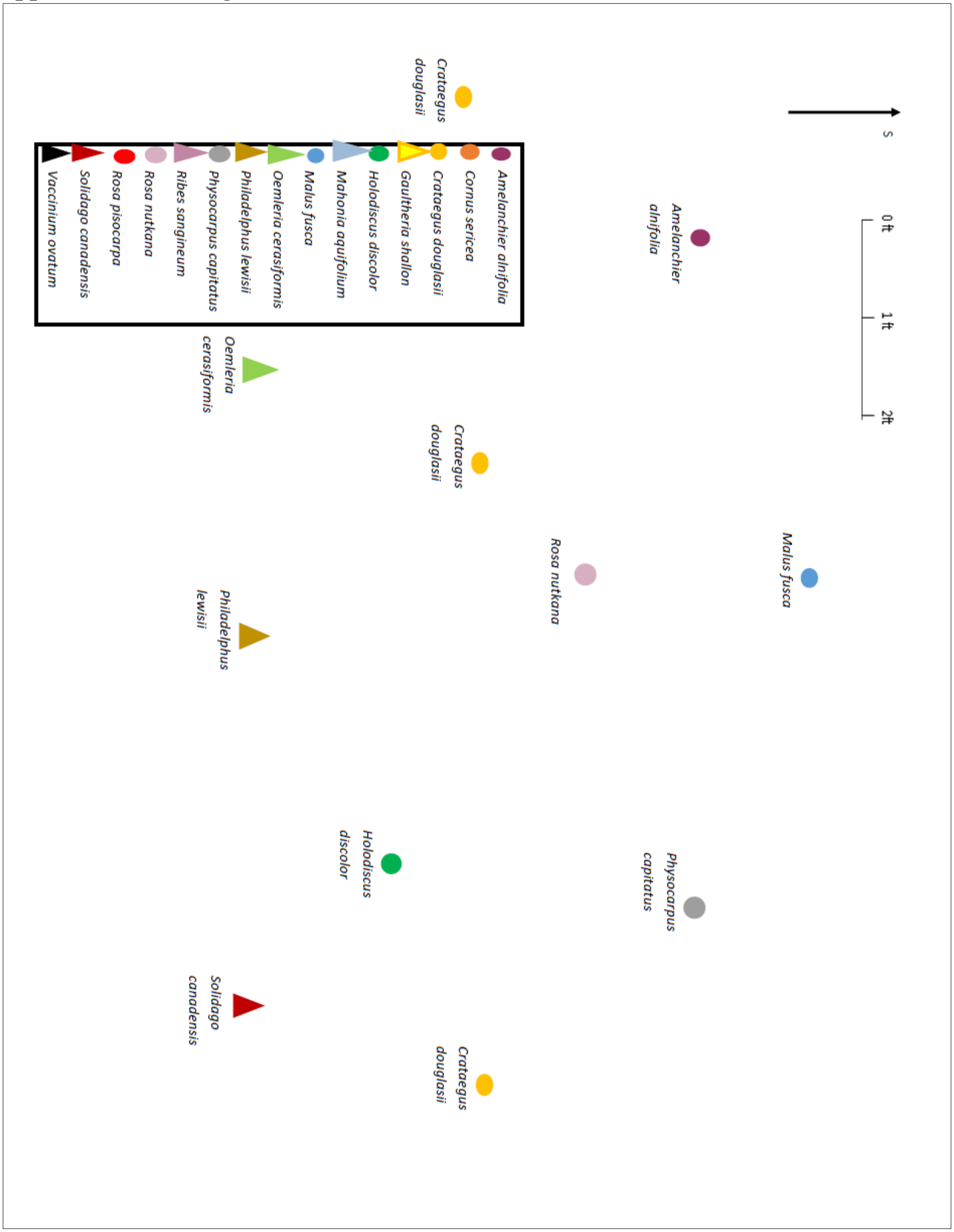
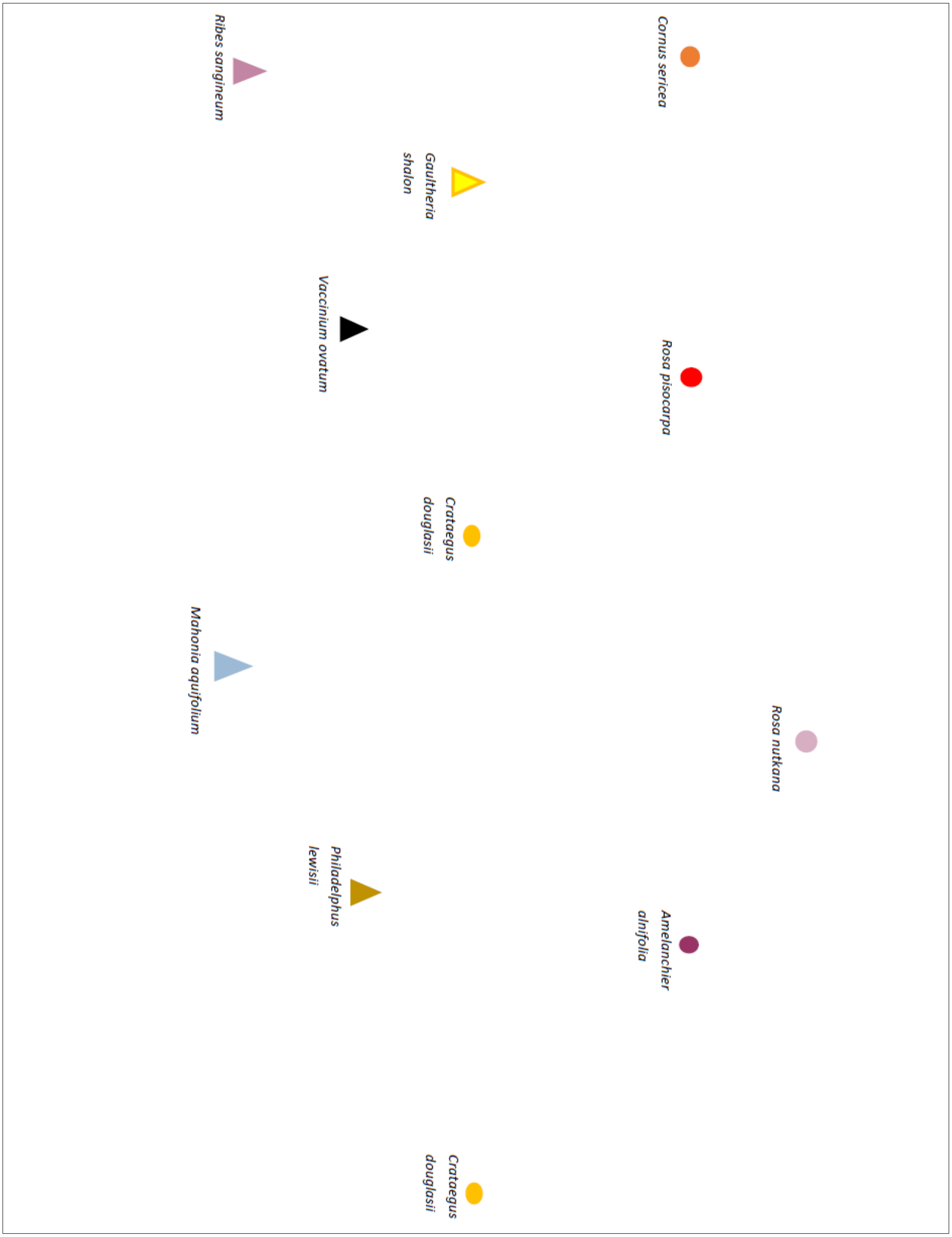
Appendix 2: Planting Schematic (West Half)





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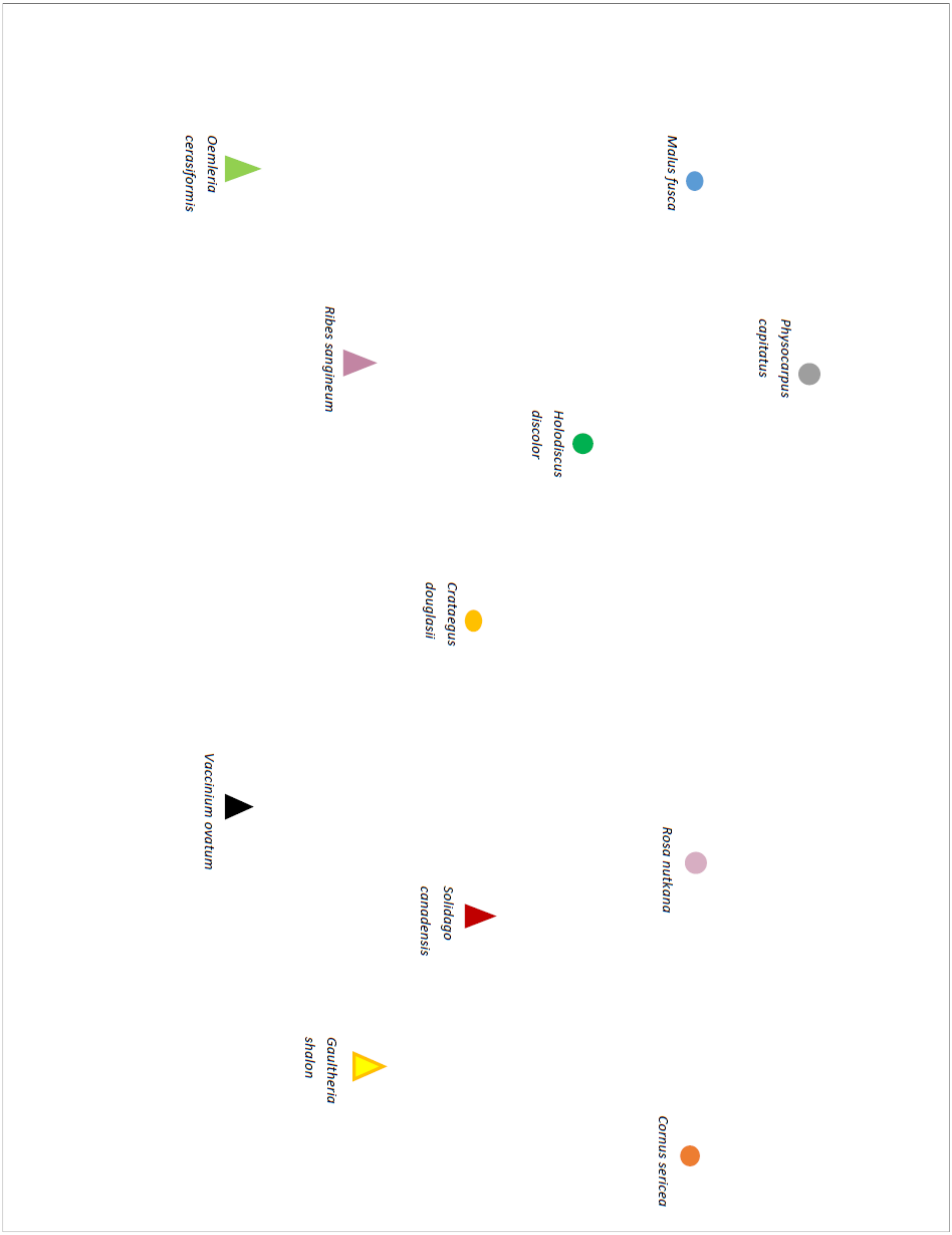
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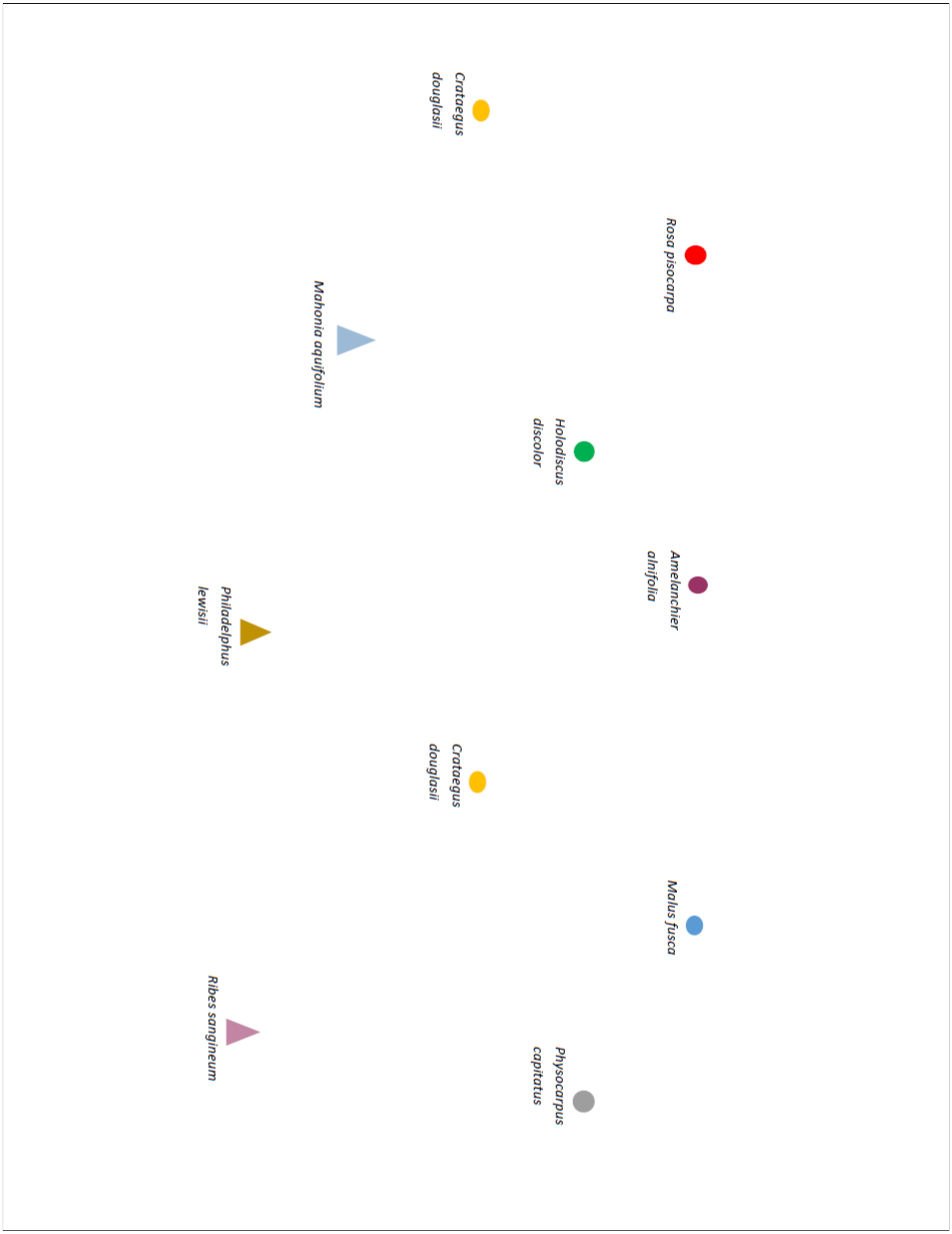
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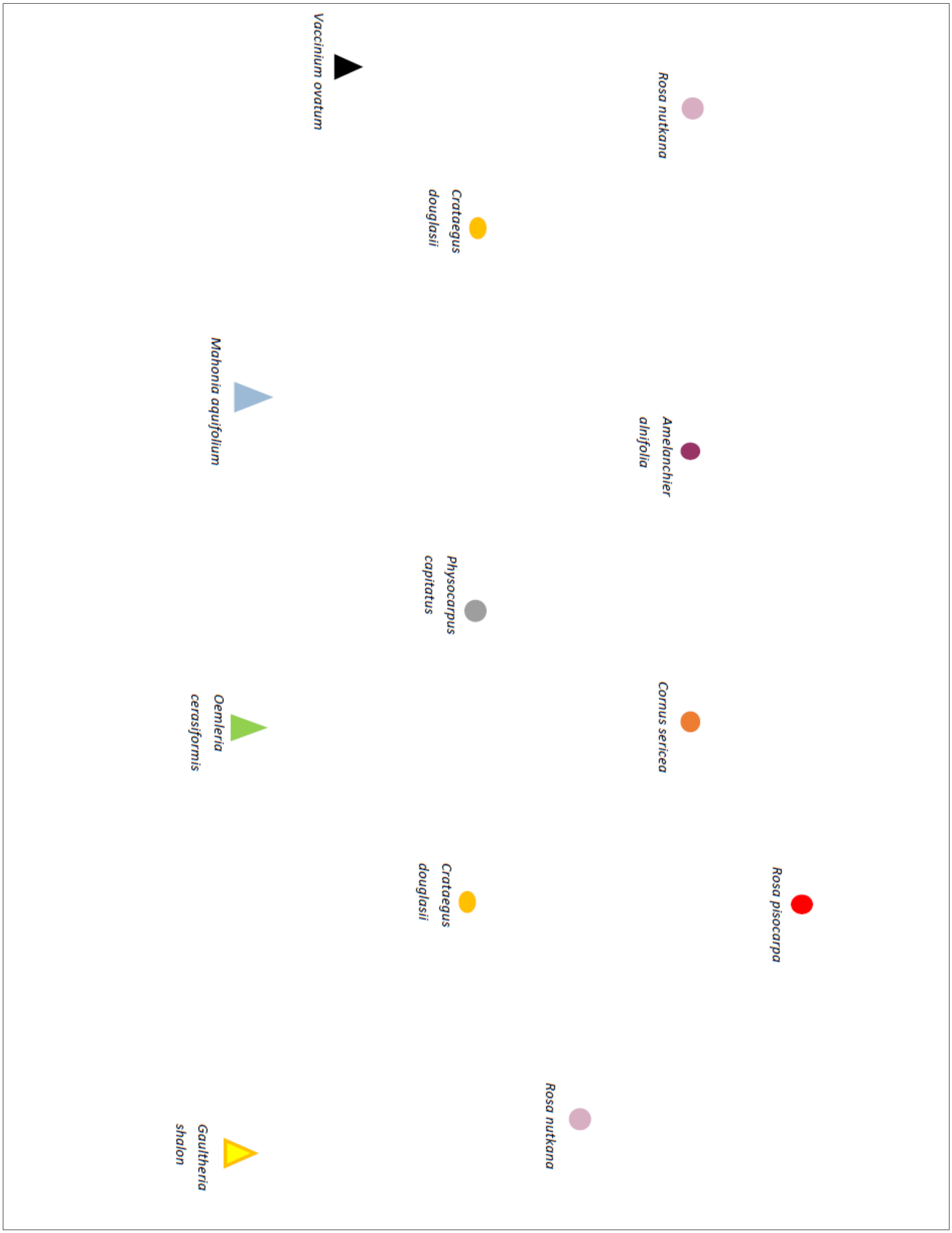
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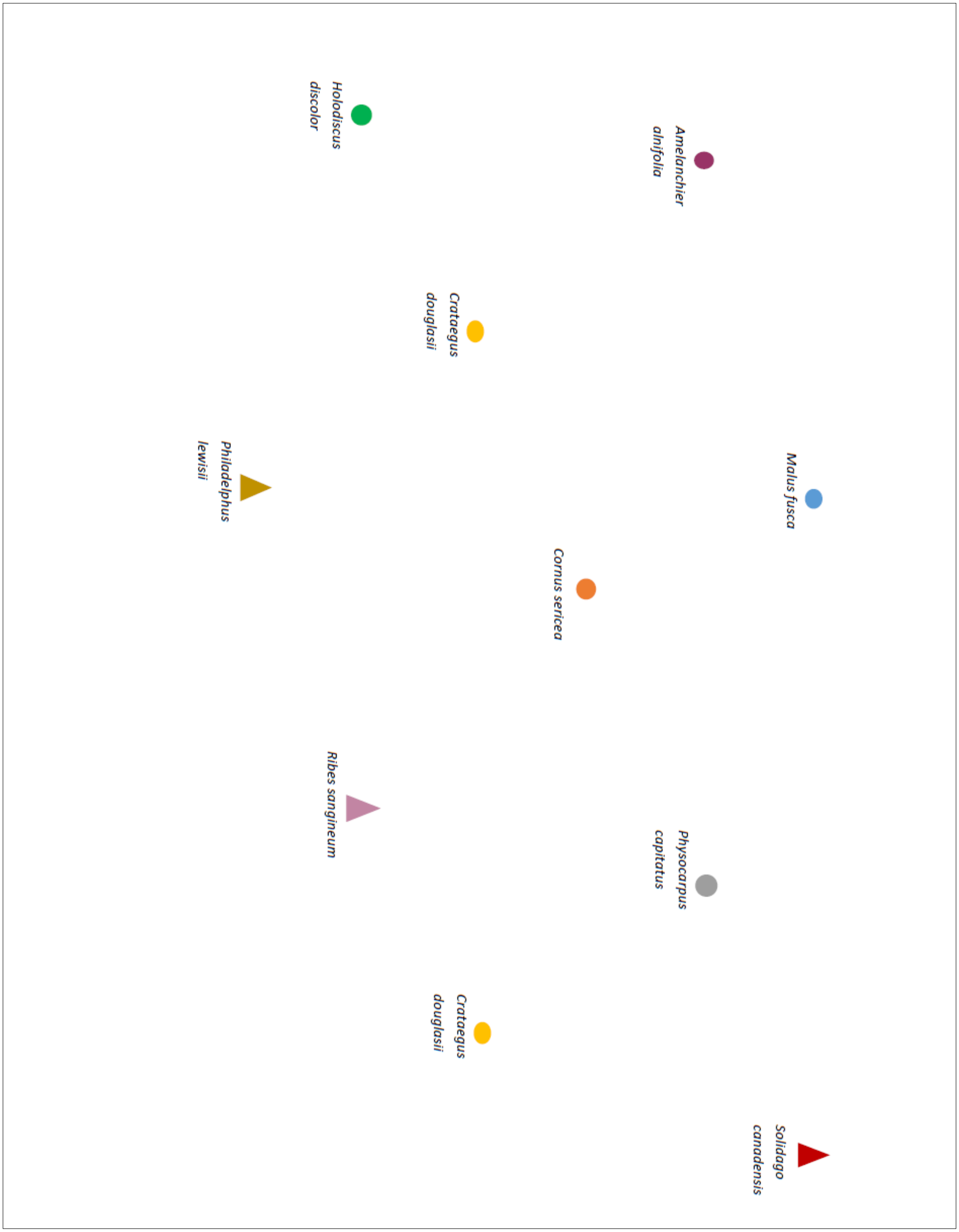
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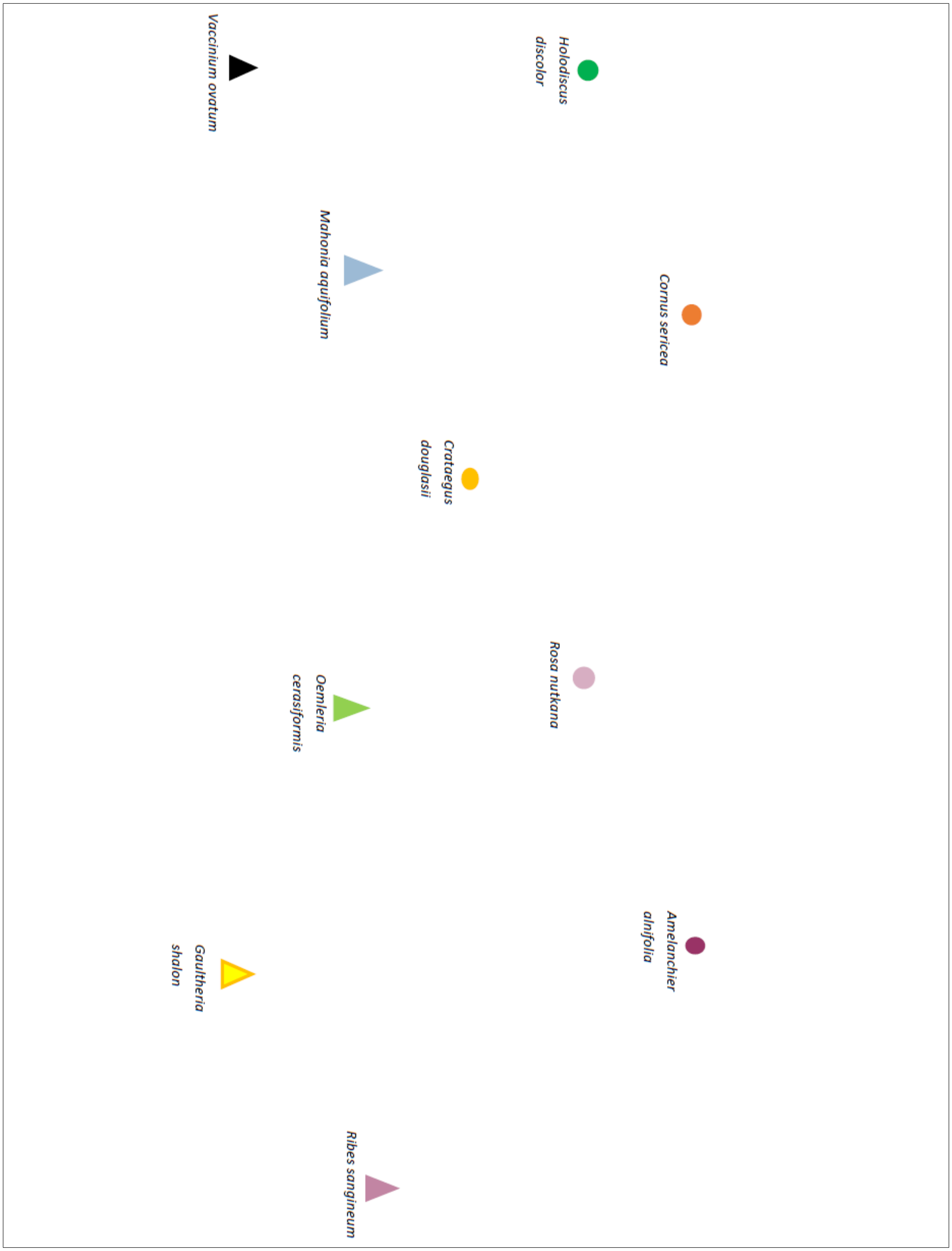

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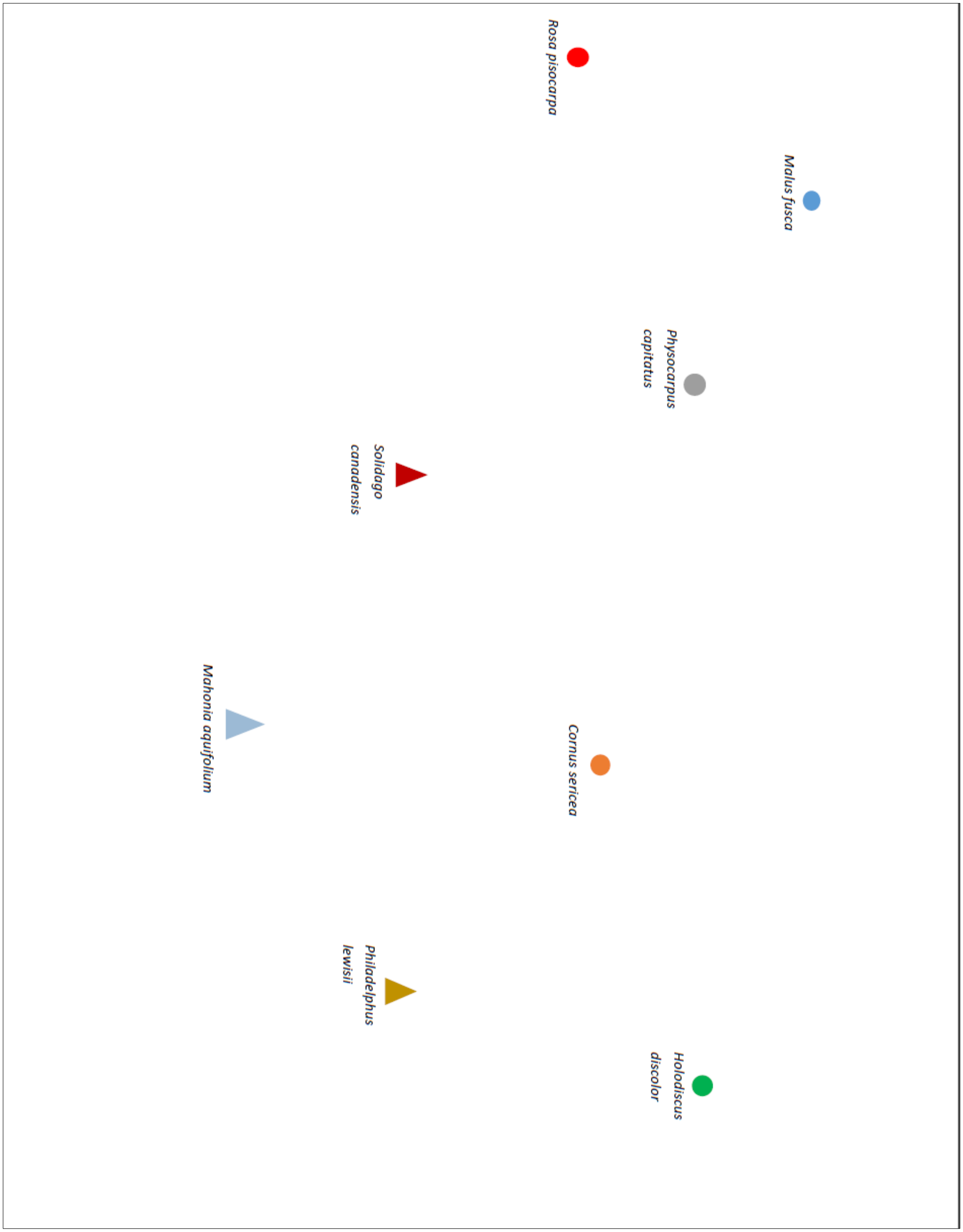
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Physocarpus capitatus
Solidago canadensis
Mahonia aquifolium
Cornus sericea
Philadelphus lewisii
Holodiscus discolor

Appendix 3: Bees of the Pacific Northwest

Bombus vosnesenskii (photo credit Kevin Cole)

Bombus morrisoni (photo credit Lauren Sobkoviak)

Osmia lignaria (photo credit Robert Engelhardt)

Megachile (photo credit Bob Peterson)

Hylaeus (photo credit James K. Lindsey)

Anthophora (photo credit Aiwok)

Melissodes (photo credit John Baker)

Agapostemon (photo credit Bob Peterson)

Lasioglossum (photo credit James K. Lindsey)

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