

Teaching botany in times of Covid-19

This file documents online-teaching of botany during the winter term 2020/21 when nearly all classes were online. Teaching three different introductory lectures in botany for five different curricula at BOKU, I tried to include things that would keep students engaged, rise their interest in botany, cover various aspects of the course, and potentially collect interesting data. It also requires some innovative ways to collect data and communicate with students, which may be of interest for other teachers and is described at the end. Because one of the three courses was taught in English and I may want to share some of the information with others, the text is also in English. I start with an analysis of the data we collected and then explain some innovative aspects and organization of the course.

Thanks to Marlene Pogatschnig, my student assistant (tutor) for the courses, and to hundreds of BOKU students who participated, making teaching during this particular semester challenging but also more interesting for me.

Peter Hietz, Jan. 2021

Teaching botany

During the lockdown, all lectures were online. The normal lecture was pre-recorded and students were asked to watch these sequentially during the semester. To encourage their continuous engagement, we had Zoom-meetings every two weeks to answer questions and discuss some aspects in some more depth. There were three online tests, which had to be completed to access the next set of videos and were sample questions (out of a large pool of questions) from part of the final exam, so students knew what to expect in the exam. To a substantial part, however, the online meetings were dedicated to explain the organization and discuss results from the semester project.

A main challenge was the number of students. 750 participated from three different lectures. They contributed >50 000 datasets (information on plant species). Tasks should be of personal interest to each student and thus be individualized, but still required checking and the possibility to provide some feedback and corrections to each. In addition, during the lockdown students could not be sent somewhere to look for plants, so it was to be botany@home.

The first task of the project was for all participants to list the plant species they were consuming during one week with English, German and Latin names. The second task was to list all other plants in their home, again with names and what they are used for. The third was to search for additional data on a selection of 20 different species. These were randomly selected, but each student got at least a few plants used as food (staples, fruit, vegetables, spices) and students from different curricula received somewhat different lists (for instance, forestry students had more trees). For each of these species, students were asked to search for information on the origin of the species, which botanical family they belong to, their life form (tree, herb, climber and so), the organs used, what they are used for, which country is the main producer and how much is produced globally and in Austria.

A very substantial benefit of the specific tasks was that students could relate to the plants because they used them, and the plants and their uses provided a long list of aspects that we discussed during the online meetings. These are examples:

- First, we thought about what plants are. Salt, water, eggs, mushrooms, fish etc. were all listed, as were cyanobacteria, which are photosynthetic but no plants (in the end we accepted them as honorary plants in the list);
- with spices we saw how the search for plants drove seafaring, profits, exploration and wars;
- with Citrus we saw how crossing different species can lead to a variety of fruits;
- with Brassica we saw that breeding can lead to many different vegetables from the same species;

- we found musical instruments made of rare exotic species (rosewood, mahogany) and discussed over-exploitation and regulating the trade of endangered species;
- with sugar (from sugar cane or beet) we learned these can be distinguished by carbon isotopes and about pathways of photosynthesis;
- with coffee and rubber, we discussed major tropical cash-crops from which countries profit where they do not originate from ;
- with fibres we discussed cell walls, natural, semi-natural and synthetic fibres, GMOs (cotton) and forced labour (cotton);
- with cork we saw the value of some traditional systems of cultivation;
- we compared which plant organs we consume in food plants and which substances they store;
- with vanilla we discussed orchid pollination and the challenge of hand-pollination;
- and we saw the diversity of the plants we use, where they come from and could compare our food baskets.

In searching for relevant information, students were also introduced to specialized internet resources such as FAOSTAT (production), GBIF (biodiversity and plant distribution) and globalforestwatch (land use, deforestation) and exposed to geography and production metrics.

Organization of data collection and communication

This part is mainly of interest for teachers and explains various methods and tools used to collect data and communicate with students. A main challenge was the number of students. 750 participated from three different lectures. They contributed >50 000 datasets (information on plant species). Tasks should be of personal interest to each student and thus be individualized, but still required checking and the possibility to provide some feedback and corrections to each. In addition, during the lockdown students could not be sent somewhere to look for plants, so it was to be botany@home.

The first task was for all participants to list the plant species they were consuming during one week with English, German and Latin names. The second task was to list all other plants in their home, again with names and what they are used for. The third was to search for specific additional data on a selection of 20 different species.

Communication and submission of assignments was via boku-learn (running moodle). This permits messages to all or individual students, various forms of tasks and assignments, including the submission of files in different formats. However, dealing with a large number of submissions in an efficient way is very tedious in moodle and combining contributions/data of moderate complexity much more so. Students were therefore asked to submit assignment as Excel files in a strict format. These files can be downloaded in bulk and are saved in the format

<last name> <given name>_<submission number>_assignsubmission_file_<submitted file name>

Note that there is no underscore “_” but a blank “ ” between last name and given name, which is a bit unfortunate.

To be able to deal with a large number of files, each with multiple entries, all data were loaded into R using the following code:

```
file.dir = "your_directory"
# extract student names and submission id from filename
file.names <- list.files(file.dir, full.names=F)
```

```

names = gsub("\\\\$", "", file.names)
names = gsub("~", "", names)
names = stringi::stri_replace_first_regex(names, " ", "_")
names = data.frame(file_name = names)
names$family_name = word(names$file_name, 1, sep = "_")
# problem here if family name is more than one word - needs to be corrected
manually
names$given_name = word(names$file_name, 2, sep = "_")
files = list.files(file.dir, full.names=T)
n = length(files)

# now load each file and combine to one dataframe.
data = c()
for (i in 1:n) {
  j=i+1
  tryCatch({ file = read_excel(files[i], range = cell_cols("B:S"), sheet =
"task1") # set sheet and cells according to your sample file
  file$given_name = names$given_name[i]
  file$family_name = names$family_name[i]
  file$student_number2 = names$student_number[i]
  data = rbind(data, file)
}, error=function(e) {cat(files[i], conditionMessage(e), "\n")})
}
# tryCatch avoids error when files are wrong format and lists these, otherwise,
program would be aborted
write.table(data, "data.csv", sep = ";")

```

Now all submissions are in one file, which can be edited in Excel, sorted by student name, plant name or whatever, corrected and commented. How to refer these corrections back to the students is explained below.

There were several challenges here. One is that students need to stick to a uniform data format. For this, a sample file was provided and students were asked to write their data only in clearly marked columns and to not change the filename, sheet names and the first lines. Although this was repeatedly and clearly communicated, perhaps 10% of students did exactly this. This leaves three options: reject these submissions, edit them manually, or ask those students to re-submit a correct format. The tryCatch command will list files that cannot be read, so at least sorting these is quick. You can block excel sheets and cells so that these cannot be changed and students can enter only certain kind of values or select from a dropdown list. As I found out, however, copy-paste overrides this protection. This can be avoided with VBA programming in excel (see <https://www.extendoffice.com/documents/excel/4289-excel-disable-cut-copy-paste.html>), but when this did not work, I left it at this point.

The other issue to grapple with is spelling. To evaluate the data (in our case how many and which plants species were used) spelling needs to be uniform. Below is a list of the variants used for onion/Zwiebel/Allium cepa.

E	G	L
onion	(potato) onion	A. cepa L.
brown onions	braune Zwiebeln	Alium cepa
bulb onion	Gartenzwiebel	Alium oschar
Common onion	Gemeine Zwiebel	Allium cepa
cultivated onion	Gemüsezwiebel	Allium cepa
garden onion	graue Scharlotte	Allium ascalo
green onion	Jungzwiebel	Allium cepa
Jungzwiebel	Küchenzwiebel	Allium cepa L
ognion	Küchenzwiebel	Allium cepa v
onin	Küchen-Zwiebel	Allium cepa v
onioin	Lauchzwiebel	Allium cepa "
Onion	onion	Allium Cepe
Onion/bulb onion	onions	Allium schoe
onions	onoin	Allium ursinu
potato	Reisnudeln	Allium cepa v
potato red	Rote Zwiebel	Alliuma cepa
potato white	roter Zwiebel	Amaryllidace
purple onion	Scallion	Amaryllidace
red onion	Schalloten	balbus
red onions	Schalotte	Bulbus
rice noodles	Scharlotten	Cepa
scallion	Speisezwiebel	cepa feminir
shallot	Weiße Zwiebel	Iris
shallots	Zeibel	Malus dome
shalot	Ziebel	Vere cepa
shalott	Zweibel	
spring onion	Zwibel	
white onion	Zwiebeln	
Zwiebel	Zwiebe	
Zwiebeln	Zwiebel	
	Zwiebel (rot)	
	Zwiebel (weiß)	
	Zwiebel (weiss)	
	Zwiebeln	
	Zwiebeln	
	Zwieben	
	Zwieber	

The 102 ways to say "onion"

Filtering in Excel helps here, also with obvious mismatches between English, German and Latin names (in which cases I trusted the German names more), but is still a time-consuming task. For Latin names, the Global Name Resolver in the R package taxize is very helpful, though not error-proof and does not resolve everything:

```
spec.to.check = levels(as.factor(data$Latin_name))
spec.checked2 = spec.to.check %>% gnr_resolve(data_source_ids = 167,
with_canonical_ranks = T, best_match_only = T, cap_first = T).
```

More interesting than spotting spelling variants and errors is checking which plants were used and what for. Since many students listed the same species, it was relatively easy to add comments and corrections

for many entries in excel. In total, students got 4700 comments on plants consumed and 2479 on other plants at home (not including spelling errors).

Giving feedback

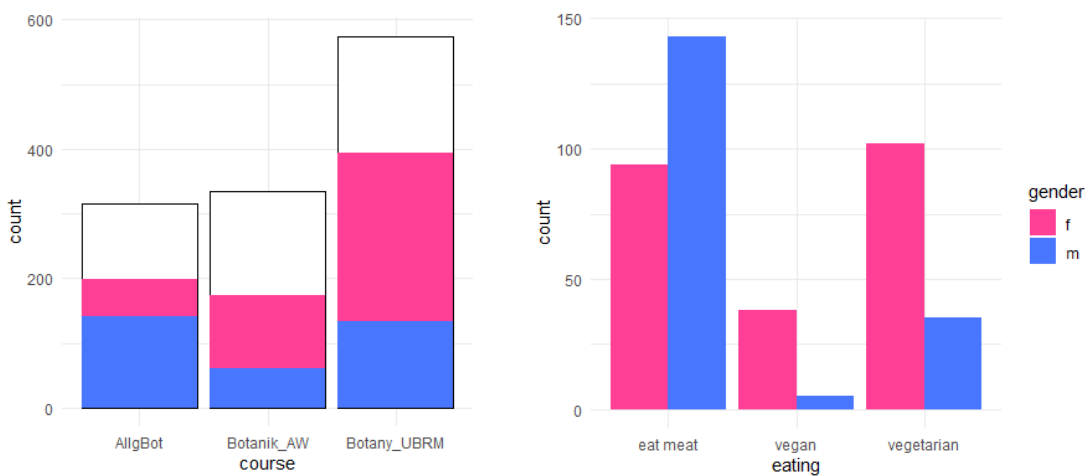
Moodle and boku-learn permit to send bulk emails to many students and personalized emails to individual students, but personalized emails to many students is very tedious and needs to be done one-by-one. I thus use the R library mailR to send mails with personalized attachments to all participating students. Since mailR does not work with groupwise, I set up a gmail account (no.reply.BOKU.hietz@gmail.com), which permits to send 500 mails per day (on some days it still would not send, so be patient and try again if this does not work). Below is a sample code, which involves: selecting one student at a time, creating personal files (for instance extracting their plants from the total dataset with comments, producing graphs with the student's data or a selection of species to work with) and sending this with a short explanation (text1). In the code below, "data1" is their submission of task 1 plus the correct Latin name and comments from me.

```
# personalize output and send email:
for (i in students.to.mail$name) {
  student = students.to.mail[students.to.mail$name == i,]
  cols.to.send =
c("spec", "Latin_name", "English_name", "German_name", "comments", "com_PH")
  task.commented = data1[data1$name == i, cols.to.send] # select this student's
data
  write.xlsx(task.commented, "AllgBot_Aufgabel_com_PH.xlsx", sheetName =
"task1", col.names = TRUE, row.names = TRUE, append = FALSE, showNA = FALSE)
  fam.name = student$family_name
  # create personalized graph
  your_plot = plot1 + geom_vline(xintercept =
length(na.omit(task1.commented$spec)), colour = "red") +
  geom_text(aes(label = paste(student$given_name, student$family_name), x =
50, y = 60 ), size = 4, hjust = 0)
  ggsave("plants_consumed.jpg", plot = your_plot)
  salut = "Dear Ms."
  if (student$sex == "m")
  { salut = "Dear Mr."}
  recipients = student$email
  mail.text = paste(salut, fam.name, text1 )
  email <- send.mail(from = sender, to = recipients,
                    subject="Botanik VO, Aufgabe 1 - do not reply",
                    body = mail.text,
                    attach.files = c("AllgBot_Aufgabel_com_PH.xlsx",
                                     "plants_consumed.jpg " ),
                    smtp = list(host.name = "aspmx.l.google.com", port = 25), #
ports 465 and 587 do not work for me
                    authenticate = FALSE,
                    send = FALSE)
  email$send() # execute to send email
}
```

Some results of the semester project

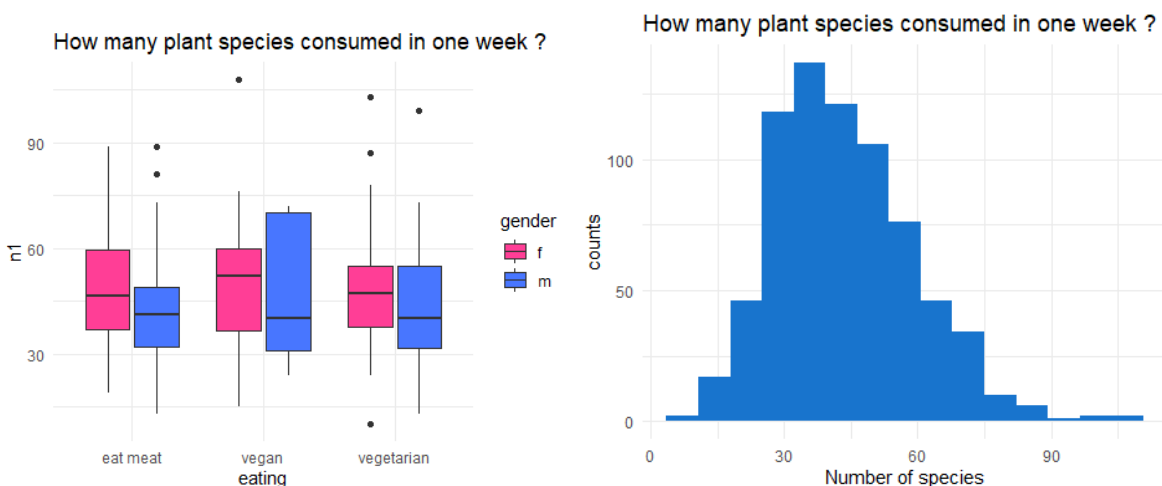
Participation

About 2/3 of students who inscribed to the courses participated in the semester project. Participation was voluntary, but students could collect points for the final exam or skip one of the questions in the final exam. At one point students were asked to indicate whether they eat meat, vegetarian or vegan as this might be related to the plants they eat. Their gender is known, but we did not attempt to collect additional information about the students, in part for privacy considerations (though some additional information might have been of interest for the evaluation of data). Out of those who indicated their eating habit, 56% said they eat meat (at least once every two weeks), 33% eat vegetarian and 10% vegan. Vegetarian/vegan students were predominately women. Austria-wide, c. 8% reported to eat vegetarian or vegan in 2019 (<https://de.statista.com/themen/3804/vegetarismus-und-veganismus-in-oesterreich/>) and these are often female, young and well educated, so BOKU's students are in line with this.

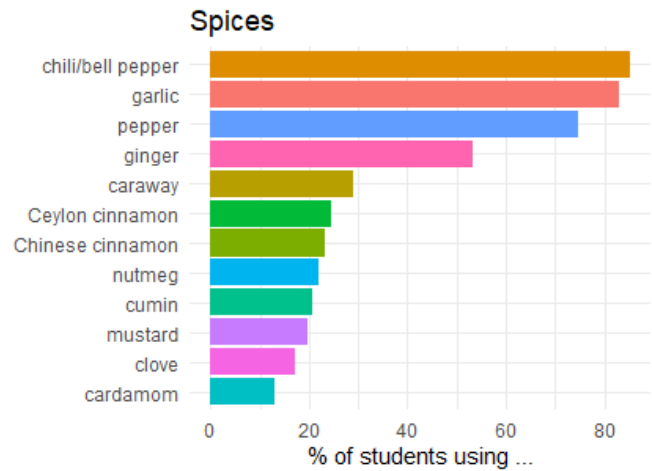
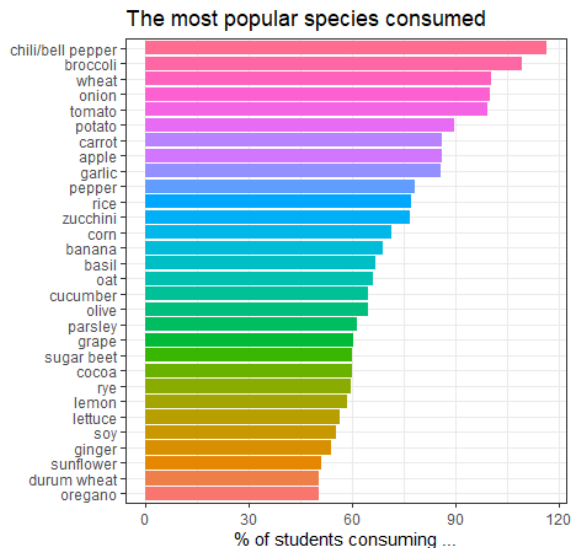


Students participating per course (white: inscribed for the lecture, but never submitted anything) and their eating habit.

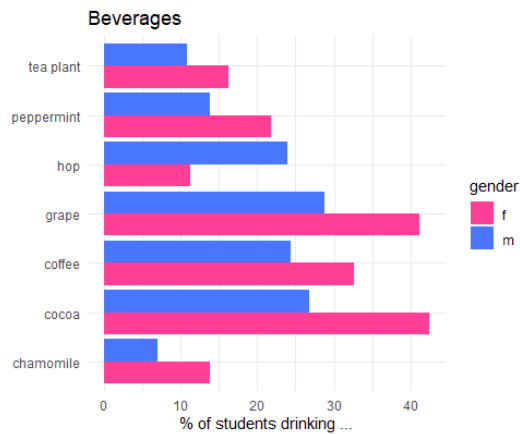
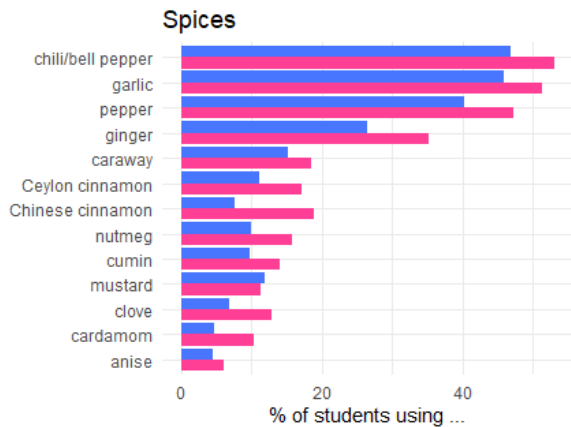
The 724 students who participated in task 1 reported a total of 395 plant species consumed (the majority was used for food and drink, seven were smoked). Women listed more species on average (46.6) than men (40.4), the maximum was 108 different plant species consumed during seven days. Students eating vegan and vegetarian listed more than meat eaters, and this appears to be due to more women in these groups (men consumed about the same number, whether eating meat or not).



There are numerous ways to look at these data. I first look at the most popular plants overall and in some food groups. We discussed these results with students in the Zoom-meetings and they suggested additional ways and asked questions, some of which can be answered with our data, others not. For those (students and others) interested, all (corrected) raw data are made available as an Excel file (students anonymized), so everyone can search for specific details. If you come across additional interesting aspects or need other information, please contact me.

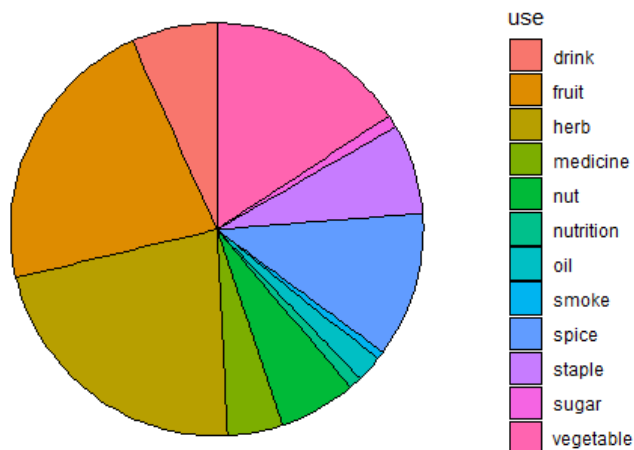


Most spices were more popular with women, as were most plants used for drinks, except for hop. Since students were only asked which plant species they consumed but not in which way, the list does not inform if grapes were consumed as fruit or wine and cocoa as drink or chocolate. Also, *Capsicum annuum* is bell pepper as well as chili (those very interested in this will find some more details in the raw data).

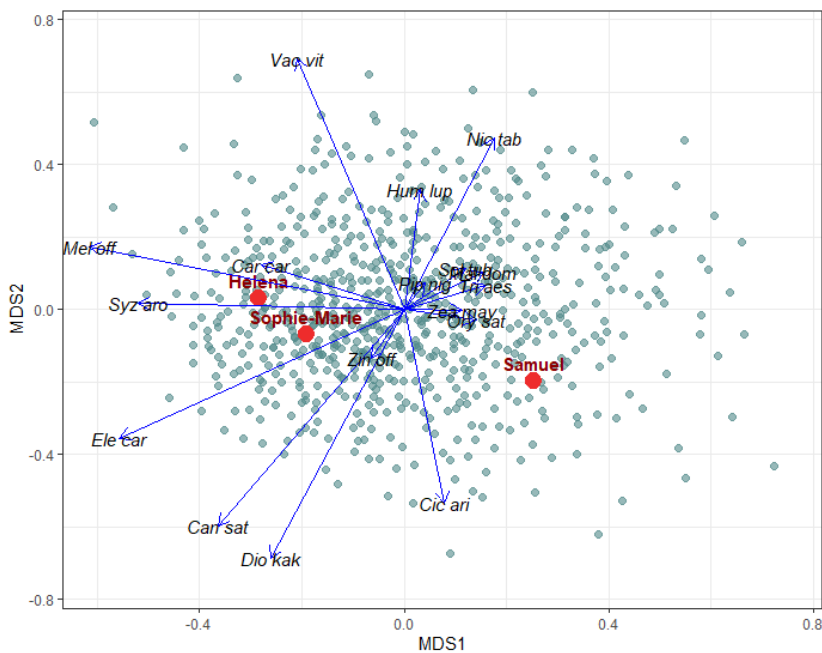


While the distinction between different uses are not clear cut, most species were consumed as fruit, herbs, vegetables and spices.

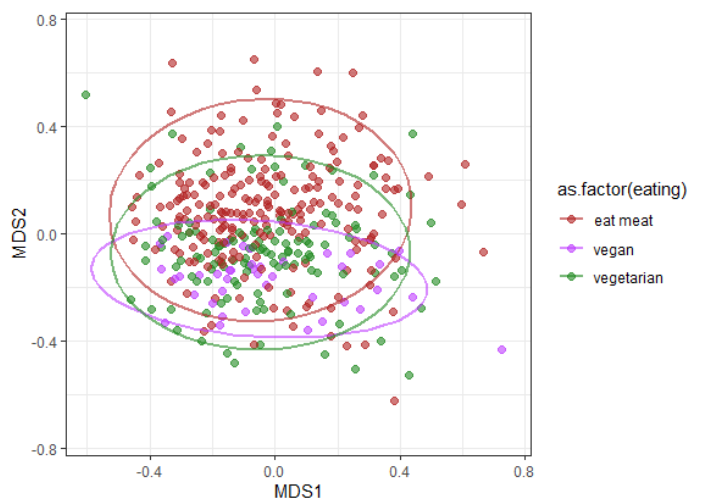
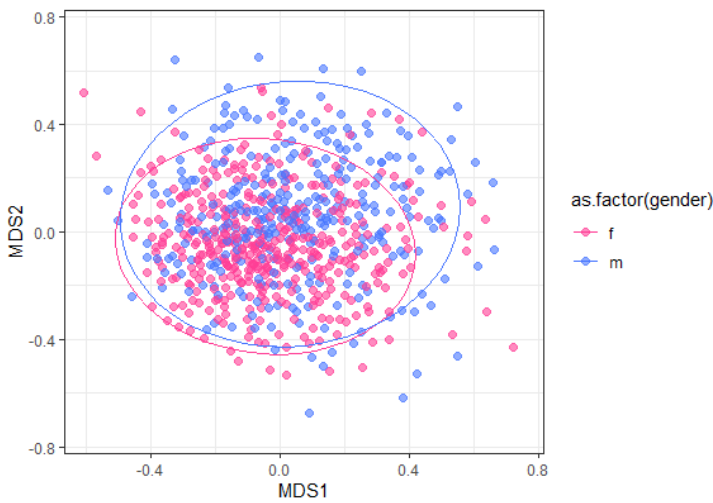
How many species are consumed as ...



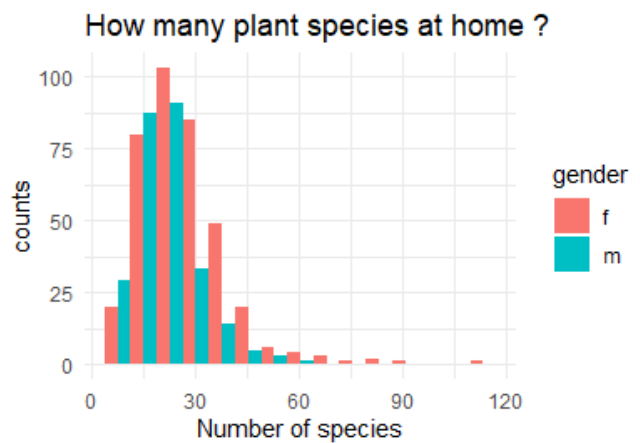
Somewhat more sophisticated, we can also look at how similar or dissimilar our eating habits are. For this, I am using a statistical method called non-metric multi-dimensional scaling (or NMDS). As you guessed, this is a non-metric version of the normal multi-dimensional scaling. This method is much used in a scientific field known as plant sociology (yes, plants also socialize!) to compare plant communities. The details are not needed here, suffice to say here: two points (representing students in our case) that show up close together in the graph reflect similar eating habits (based on their plant list) and those at greater distance rather different food plants. I added a few of the plant species with arrows, which indicate how likely it is that a student in that corner recorded them. For instance, those in the upper right are more likely to smoke (Nic tab for *Nicotiana tabacum*) and somewhat more likely to drink beer (*Humulus lupulus* for hop), in the upper left to eat blueberry, towards the bottom chickpea (fittingly, students eating vegan tend to sort at the bottom) and towards the left eat more exotic spices.



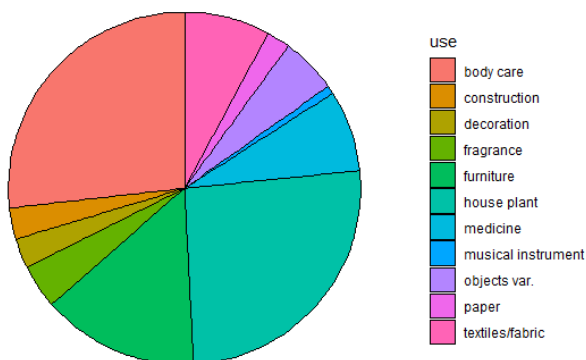
Overall, there was little difference in the plants eaten by men and women, but plants in a vegan diet did differ from plants consumed by meat-eaters, with vegetarians in between.



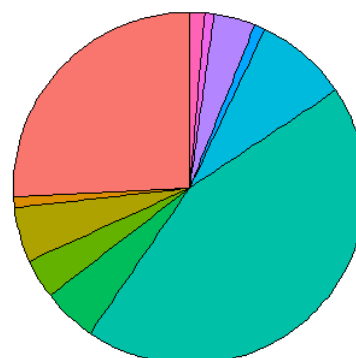
For the second task, students were asked to list all other plants used in their home. This was more challenging as in some cannot be identified (paper) or are difficult (wood products). To some extent these were therefore guesses based on likely plant sources. I tried to filter implausible species. 1156 species of plants that are not for consumption were listed from students' homes. On average, students listed 25 non-food plants at home, women again listed substantially more than men, but there was no difference between vegetarian and other eaters.



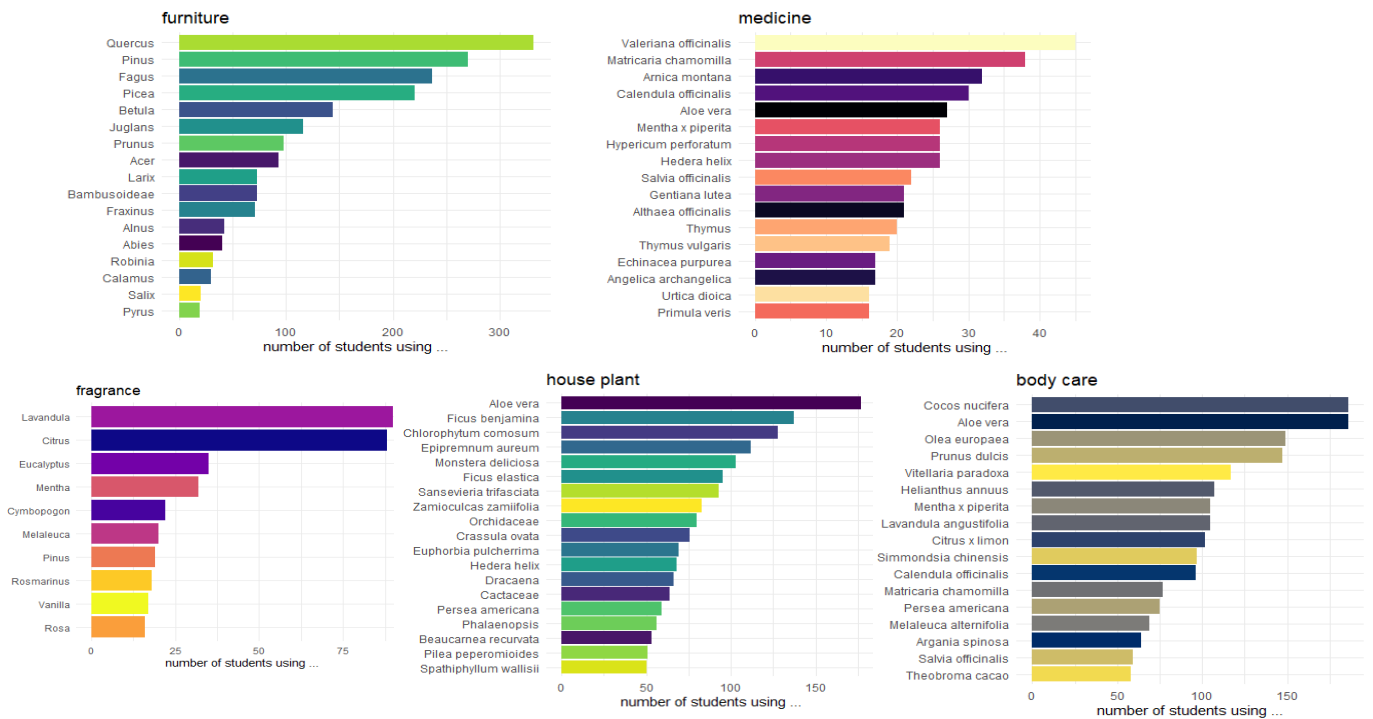
How often are plants used as ...



How many species are used as ...

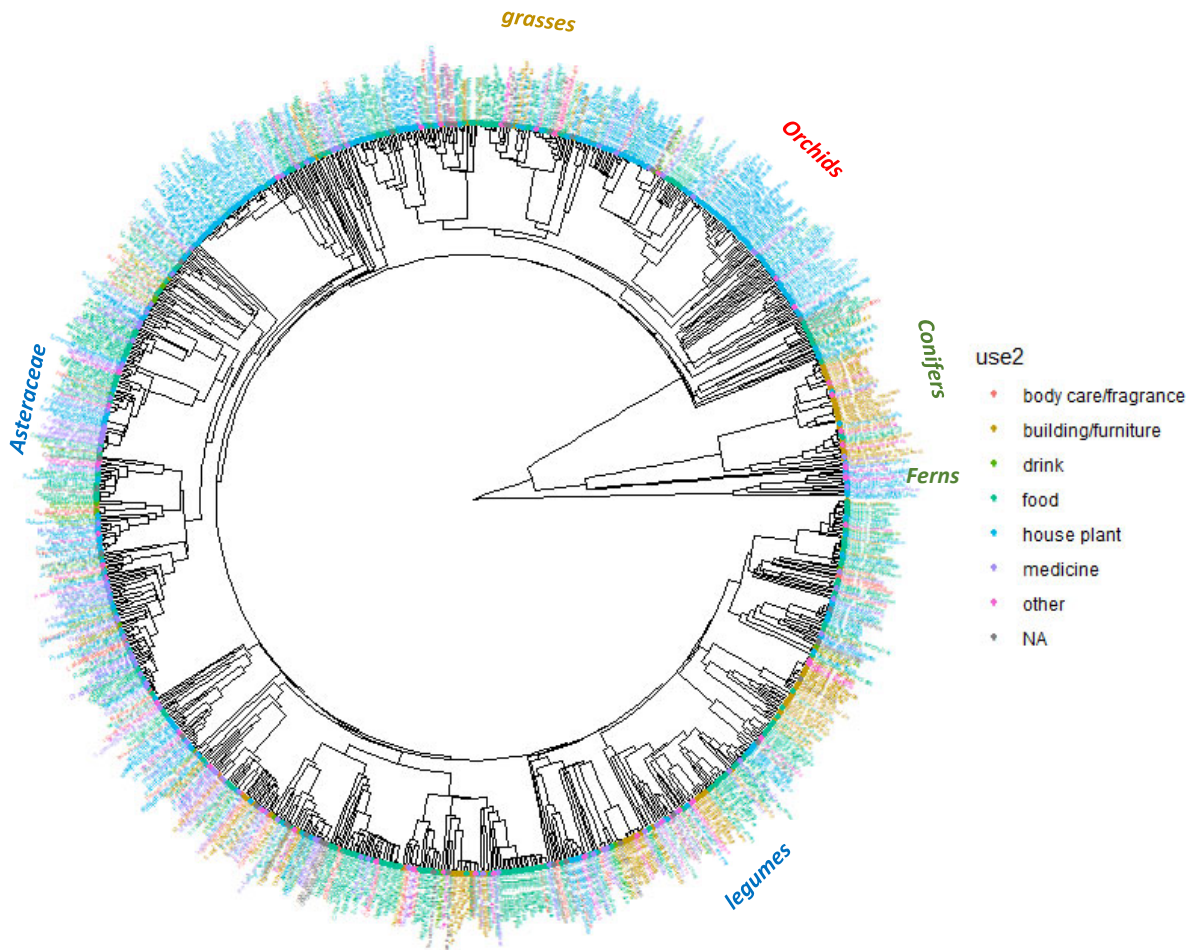


Nearly half of these species were house-plants, followed by plants used for body care, medicine and fragrances. By individual plant listed, about a quarter were house plants and as many used for body-care, followed by furniture and medicine. These are the most popular plants for various uses at home. One that show up most is Aloe vera, the most popular house plant but also frequently used for body care and medicine.



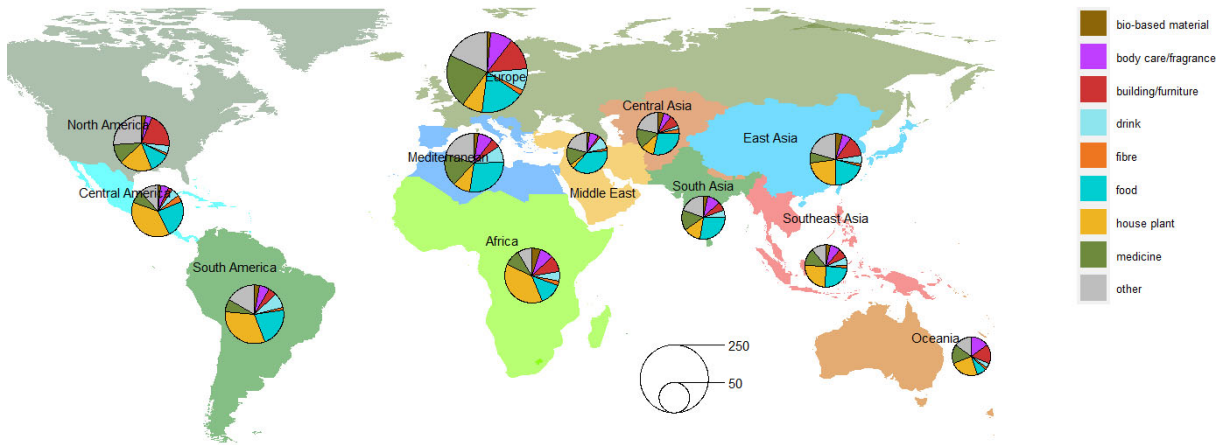
Different plant families have different uses. For furniture and construction, mostly trees are used, so the most important families we found are Pinaceae (pine, spruce, fir) and Fagaceae (oaks, beech). For food, it is legumes, Rosaceae, grasses and Brassicaceae; for house plants it is cacti, orchids and aroids.

A fancy way is looking at the phylogenetic distribution. I here plotted the tree of life (for vascular plants in our case) that shows the relationship between species listed, with their use indicated by colour. Those who are interested can look up the family and use for each species in the dataset. The point to show here is that use is not randomly distributed. Some groups are used mainly for one thing (such as conifers for wood or orchids for decoration), others have diverse uses (such as grasses or legumes).

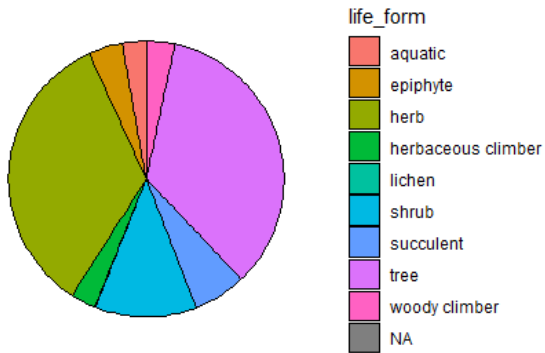


For the final task, each student was sent a list of 20 species. These were randomly selected, but all got at least a few plants used as food (staples, fruit, vegetables, spices) and students from different curricula received somewhat different lists (for instance, forestry students had more trees). For each species, students were asked to search for information on where the species originates from, which botanical family they belong to, their life form (tree, herb, climber and so), the organs used, what they are used for, which country is the main producer and how much is produced globally and in Austria.

The first map shows from which regions plants used in different ways come. House plants are predominately from the tropics, plants for building/furniture (generally trees) from North-temperate forests, food plants from Europe, the Mediterranean, Middle East and Central Asia.



Plant life form ...

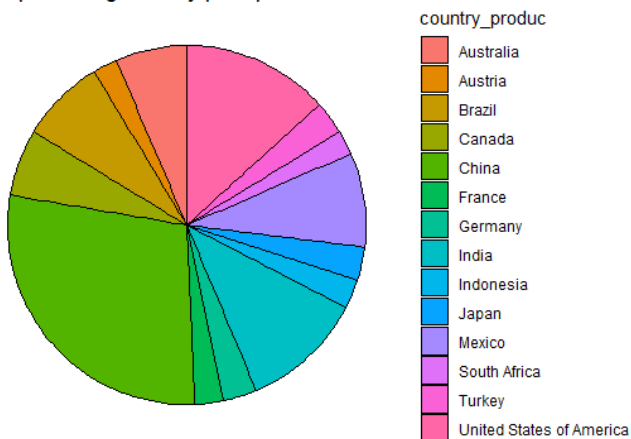


How often are plants used as ...

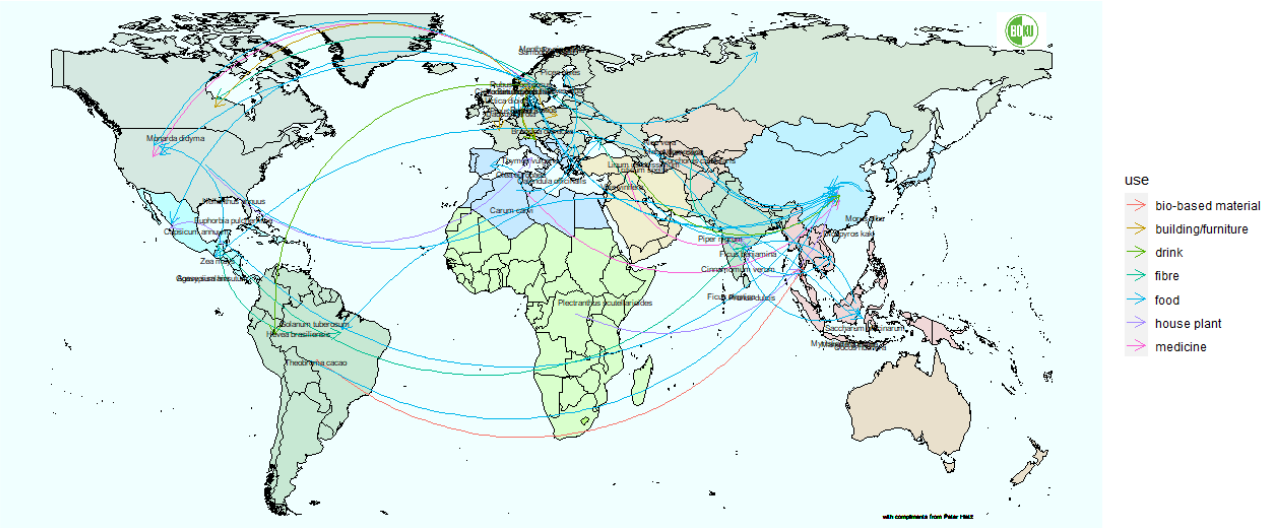


Which country is the main producer is often difficult to say. From what students found and some guesses, China appears to be the main producer for most of the species listed, followed by the United States, India and Mexico. If we connect the region of origin with the main producing countries in the map below, we obtain a global plant travel map (each student obtained a personal plant travel map for the plants in their lists). Of course, plants are not produced only in one country, but the map nicely illustrates the connectedness of the globe also for plant matters and how we all make use of and profit from this exchange and diversity. In the end, all species listed found their way to Vienna, Austria.

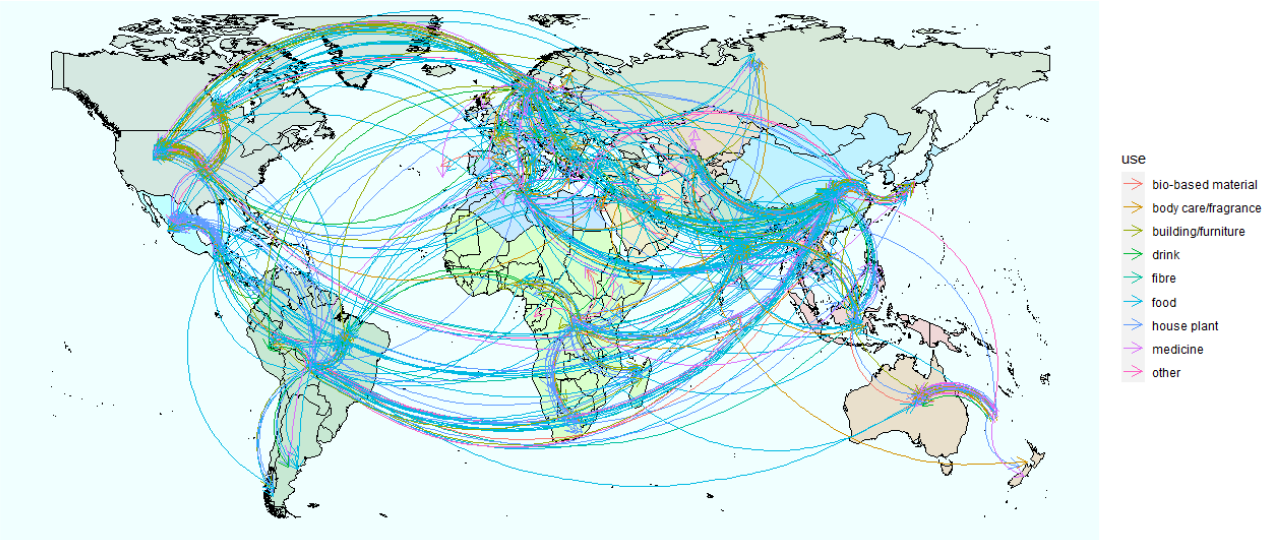
Main producing country per species



Personalized plant map for Ada



Where all our plants come from...



Example of email sent. The attachment would contain information on their personal food basket

Dear *,

I have had a closer look at your plant list and did some additional analysis. We are still checking the data from the third task and more details plus all raw data will be put online towards the end of the semester.

For now, I am sending two graphs. The first shows arrows from where (which region or continent) the plants you listed originally come from, to, when known, the main producing country. There are likely additional plants without a known "main producing country" that also ended up on your plate or in your house. I like this presentation as it shows us how connected the earth is and how we profit from these connections. You may not be able to read all scientific names and there may still be some erroneous or missing information. Many species can come from more than one region and some information you provided will still be checked. The names are only approximately placed where the plant comes from as the information is not very detailed and I tried to avoid printing names on top of others. Please don't ask for details for the time being, towards the end of the semester we'll provide a list of all plants, and you can of course search the internet for any information you are interested in.

*We can also look at how similar or dissimilar our eating habits are. For this, I am using a statistical method called non-metric multi-dimensional scaling (or NMDS). As you guessed, this is a non-metric version of the normal multi-dimensional scaling. The details are not needed here (if you really want to know, you can attend our course on Multivariate Methods in Ecology in a later semester), but NMDS is much used in a scientific field known as plant sociology (yes, plants also socialize!) to compare plant communities. Suffice to say here: two points (representing students in our case) that show up close together in the graph have similar eating habits (based on your plant list) and those at greater distance eat rather different plants. Your point is marked in red. I also added a few of the plants with arrows indicating how likely it is that a student in that corner recorded them. For instance, those in the upper right are more likely to smoke (Nic tab for *Nicotiana tabacum*) and somewhat more likely to drink beer (*Humulus lupulus* for hop), in the upper left to eat blueberry, towards the bottom chickpea (fittingly, students eating vegan tend to sort at the bottom) and towards the left eat more exotic spices. (If this figure is missing, your food list was probably < 14 species, which was excluded from the NMDS).*

If this appears somewhat abstract, you still might make use of this knowledge. A major problem with online-teaching is that students don't get to know each other. This is particularly a problem during the first semester, part of which is normally spent getting to know your colleagues and socializing. There is not much we teachers can do about this. However, for the time when you can return, I suggest you show your food-sociology plot to your colleagues. If you meet a group of students with similar scores in the NMDS, you might find it easy to agree on a menu and cook together. Alternatively, if you are a bit adventurous and find someone from the other end of the NMDS-plot, perhaps ask him or her to cook for you once. Getting to know and tasting different plants can make an interesting experience.

With this I would end the interpretation of our semester project and you should not make important decisions such as with whom you team up with based solely on a list of plants eaten during one week in the lockdown of 2020. That said, food and plants can be a good starting point for a conversation and are enriching our dinner and lives.

I wish you Merry Christmas, relaxing holidays and a Happy New Year with healthy plants, be it on the table, in pots or as a Xmas tree. And above all: stay healthy yourself.

Peter Hietz