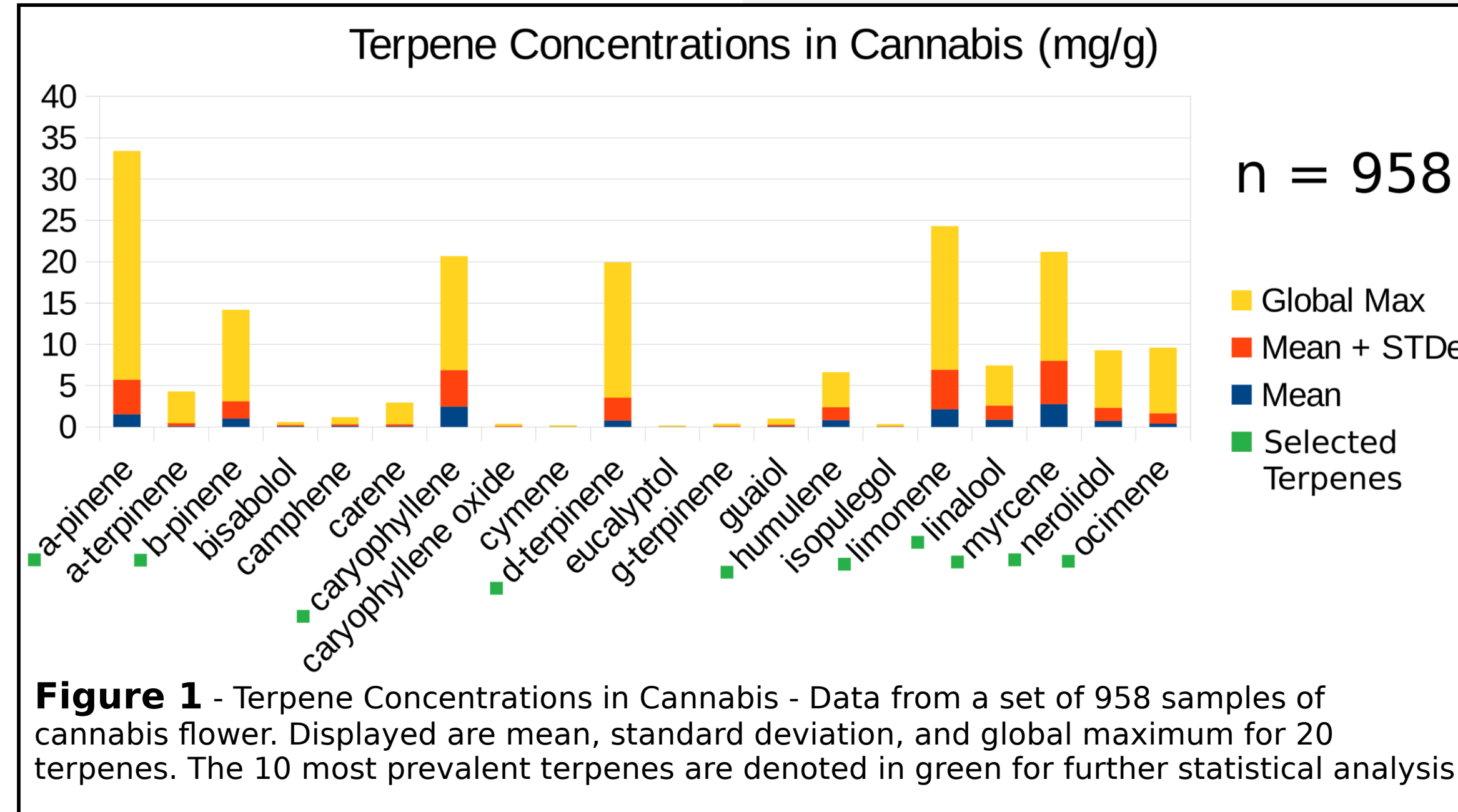


# TERPENES AND TERPENOLS IN CANNABIS

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In Collaboration with Lief Therapeutics



| Table 1 | Terpene   | Total | cancer | anxiety | depression | pain | insomnia | infection |
|---------|-----------|-------|--------|---------|------------|------|----------|-----------|
| Table 1 | Nerolidol | 5     | 3      | 1       | 1          | 1    | 0        | 2         |

| Table 2 | Terpene  | Total | cancer | anxiety | depression | pain | insomnia | infection |
|---------|----------|-------|--------|---------|------------|------|----------|-----------|
| Table 2 | Humulene | 5     | 3      | 1       | 1          | 0    | 0        | 1         |

| Table 3 | Terpene       | Total | cancer | anxiety | depression | pain | insomnia | infection |
|---------|---------------|-------|--------|---------|------------|------|----------|-----------|
| Table 3 | Caryophyllene | 20    | 6      | 10      | 2          | 3    | 1        | 6         |

| Table 4 | Terpene  | Total | cancer | anxiety | depression | pain | insomnia | infection |
|---------|----------|-------|--------|---------|------------|------|----------|-----------|
| Table 4 | Linalool | 18    | 2      | 4       | 4          | 4    | 0        | 5         |

| Table 5 | Terpene     | Total | cancer | anxiety | depression | pain | insomnia | infection |
|---------|-------------|-------|--------|---------|------------|------|----------|-----------|
| Table 5 | d-Terpinene | 6     | 2      | 0       | 0          | 1    | 0        | 2         |

| Table 6 | Terpene  | Total | cancer | anxiety | depression | pain | insomnia | infection |
|---------|----------|-------|--------|---------|------------|------|----------|-----------|
| Table 6 | Limonene | 5     | 3      | 1       | 1          | 0    | 0        | 1         |

| Table 7 | Terpene | Total | cancer | anxiety | depression | pain | insomnia | infection |
|---------|---------|-------|--------|---------|------------|------|----------|-----------|
| Table 7 | Ocimene | 6     | 0      | 1       | 1          | 0    | 2        | 2         |

| Table 8 | Terpene | Total | cancer | anxiety | depression | pain | insomnia | infection |
|---------|---------|-------|--------|---------|------------|------|----------|-----------|
| Table 8 | Mycene  | 8     | 1      | 5       | 3          | 2    | 1        | 4         |

| Table 9 | Terpene | Total | cancer | anxiety | depression | pain | insomnia | infection |
|---------|---------|-------|--------|---------|------------|------|----------|-----------|
| Table 9 | Pinene  | 10    | 1      | 5       | 3          | 2    | 2        | 4         |

| Terpene       | Found In                   | Smell                 |
|---------------|----------------------------|-----------------------|
| Nerolidol     | neroli, ginger, jasmine    | wood, fresh bark      |
| Humulene      | hops                       | hoppy                 |
| Caryophyllene | cloves, hops, black pepper | spicy, sweet          |
| Linalool      | lavender, basil            | lavender, flowery     |
| d-Terpinene   | juniper, myristica         | sweet, diesel         |
| Limonene      | lemon, orange              | citrus, fruity, sharp |
| Ocimene       | basil                      | sweet, herbal         |
| Myrcene       | bay leaf, hops, mango      | sweet, musky          |
| b-Pinene      | pine trees, hops           | pine, green wood      |
| a-Pinene      | pine trees, rosemary       | pine, wood            |

**Figure 2 - Table illustrating the 10 terpenes selected from Figure 1 and their associated plant sources and smell. Listed is also color labels used in Figure 3 and Tables 1-9.**

**THESIS: Data science can allow doctors to prescribe specific strains of cannabis to patients based on their medical condition.**

| Table 5 | Terpene     | Total | cancer | anxiety | depression | pain | insomnia | infection |
|---------|-------------|-------|--------|---------|------------|------|----------|-----------|
| Table 5 | d-Terpinene | 6     | 2      | 0       | 0          | 1    | 0        | 2         |

| Table 6 | Terpene  | Total | cancer | anxiety | depression | pain | insomnia | infection |
|---------|----------|-------|--------|---------|------------|------|----------|-----------|
| Table 6 | Limonene | 5     | 3      | 1       | 1          | 0    | 0        | 1         |

| Table 7 | Terpene | Total | cancer | anxiety | depression | pain | insomnia | infection |
|---------|---------|-------|--------|---------|------------|------|----------|-----------|
| Table 7 | Ocimene | 6     | 0      | 1       | 1          | 0    | 2        | 2         |

| Table 8 | Terpene | Total | cancer | anxiety | depression | pain | insomnia | infection |
|---------|---------|-------|--------|---------|------------|------|----------|-----------|
| Table 8 | Mycene  | 8     | 1      | 5       | 3          | 2    | 1        | 4         |

| Table 9 | Terpene | Total | cancer | anxiety | depression | pain | insomnia | infection |
|---------|---------|-------|--------|---------|------------|------|----------|-----------|
| Table 9 | Pinene  | 10    | 1      | 5       | 3          | 2    | 2        | 4         |

| Table 10 | Terpene | Total | cancer | anxiety | depression | pain | insomnia | infection |
|----------|---------|-------|--------|---------|------------|------|----------|-----------|
| Table 10 | Terpene | 10    | 1      | 5       | 3          | 2    | 2        | 4         |

| Table 11 | Terpene | Total | cancer | anxiety | depression | pain | insomnia | infection |
|----------|---------|-------|--------|---------|------------|------|----------|-----------|
| Table 11 | Terpene | 10    | 1      | 5       | 3          | 2    | 2        | 4         |

| Table 12 | Terpene | Total | cancer | anxiety | depression | pain | insomnia | infection |
|----------|---------|-------|--------|---------|------------|------|----------|-----------|
| Table 12 | Terpene | 10    | 1      | 5       | 3          | 2    | 2        | 4         |

| Table 13 | Terpene | Total | cancer | anxiety | depression | pain | insomnia | infection |
|----------|---------|-------|--------|---------|------------|------|----------|-----------|
| Table 13 | Terpene | 10    | 1      | 5       | 3          | 2    | 2        | 4         |

The medical benefits of cannabis are becoming more evident in the medical research community. Many of the studies that study cannabis focus on cannabinoids, such as tetrahydrocannabinol (THC) and cannabidiol (CBD). Many studies have found that cannabinoids can help treat inflammation, cancer, chronic pain, neurological dysfunction and many mental health issues.

Although cannabinoids are most likely the major component of the medical efficacy of cannabis, anecdotal evidence from medical patients in the United States indicate that some strains of cannabis are beneficial for certain ailments, conditions, or particular patients, while others are not. This strain variation cannot be accounted for by cannabinoid composition because the large majority of United States medical cannabis is 90% or greater THC by cannabinoid composition. What does vary greatly from strain to strain of cannabis is the chemical profile of terpenes and terpenoids found on the plant.

Terpenes and terpenoids are a class of volatile hydrocarbon compounds produced by many species of plants. Terpenes often responsible for the unique smell of each strain of cannabis. Terpenes are present in the trichomes of the plant and are chemically bound to cannabinoids forming crystalline structures.

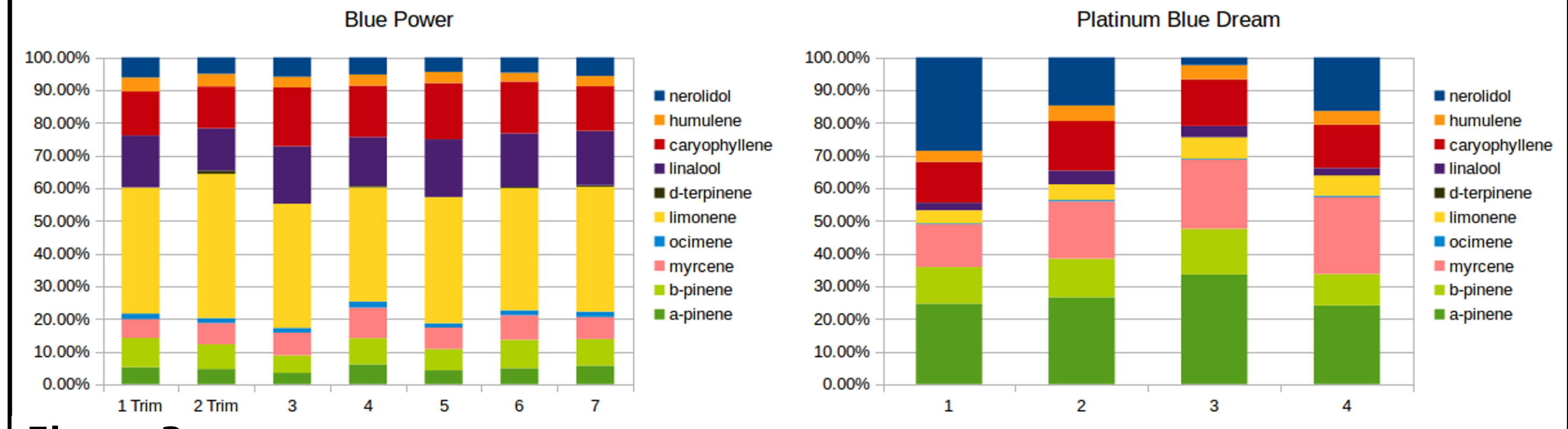
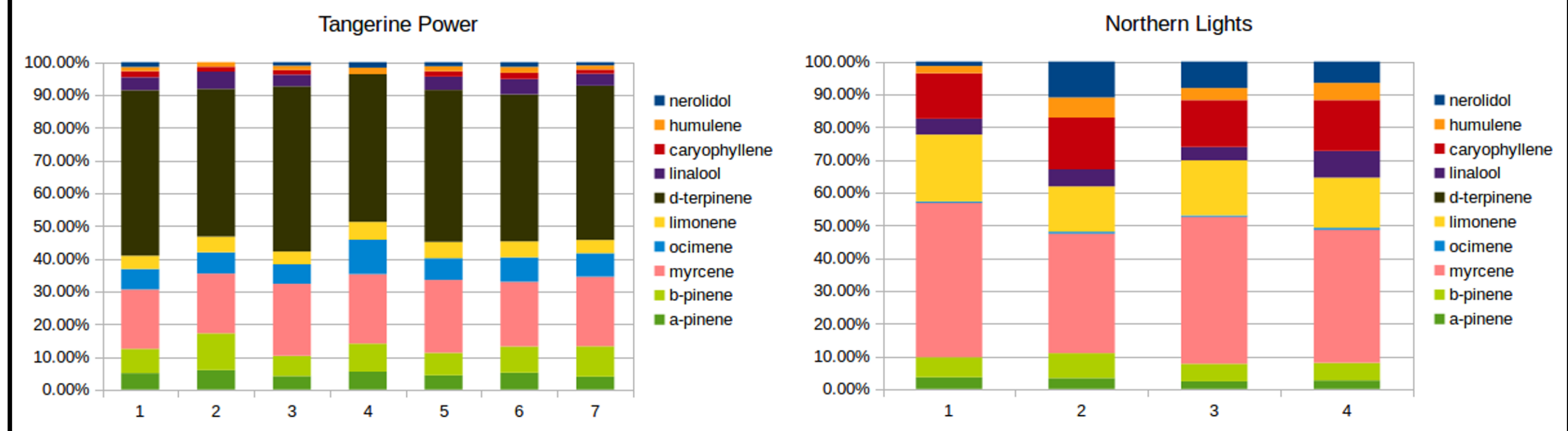
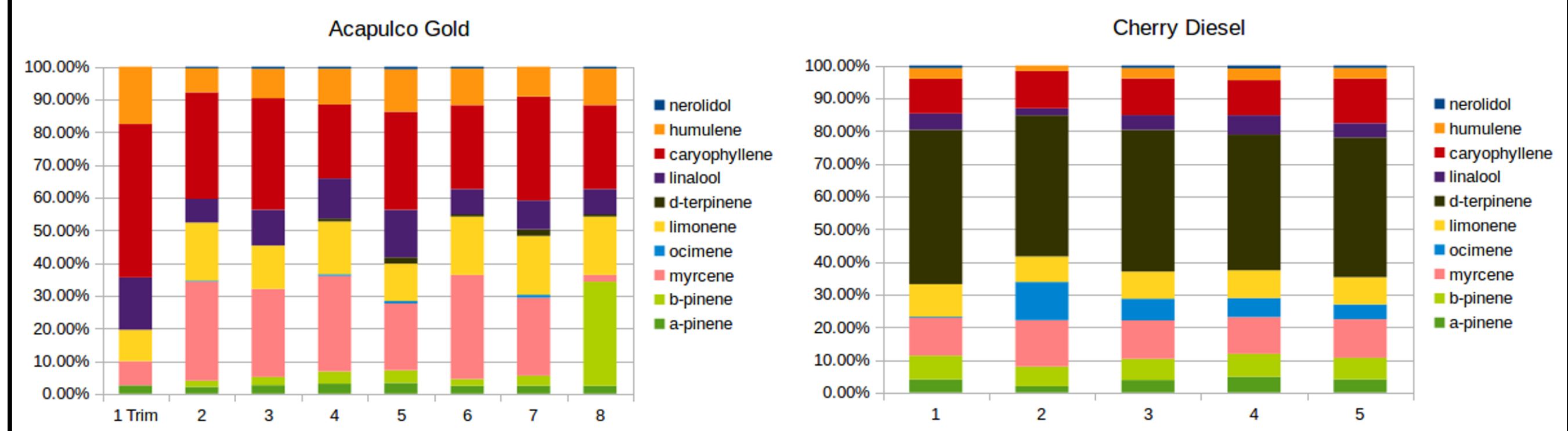
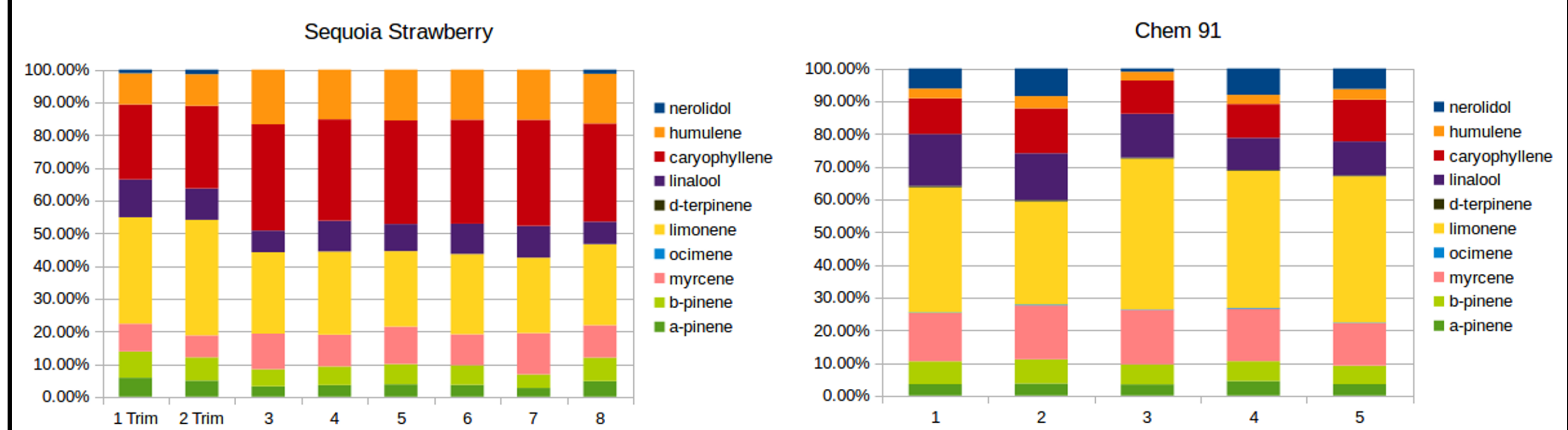
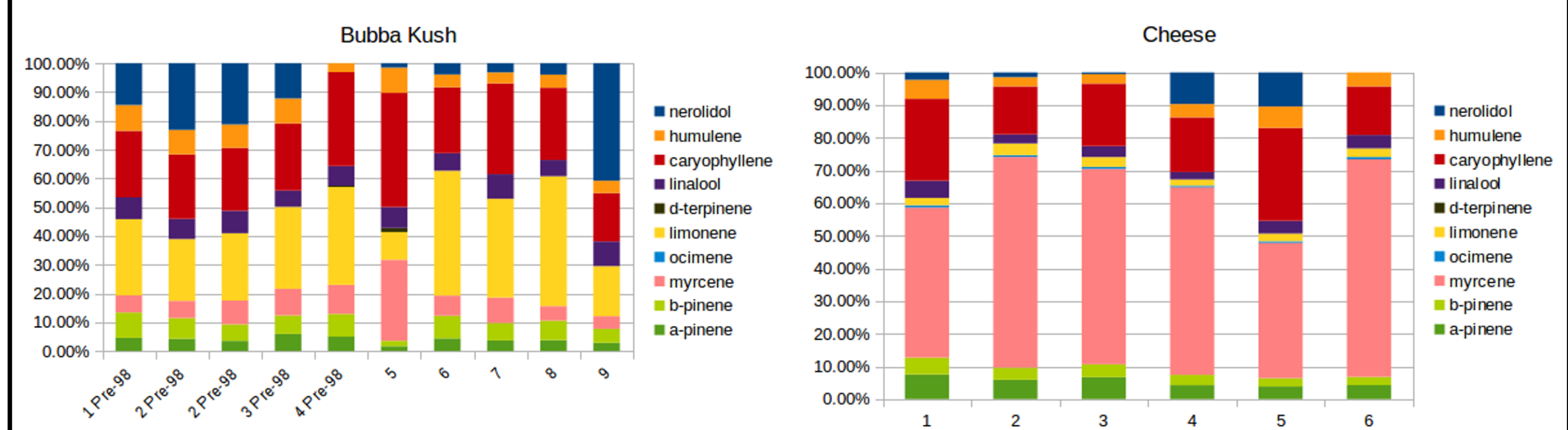
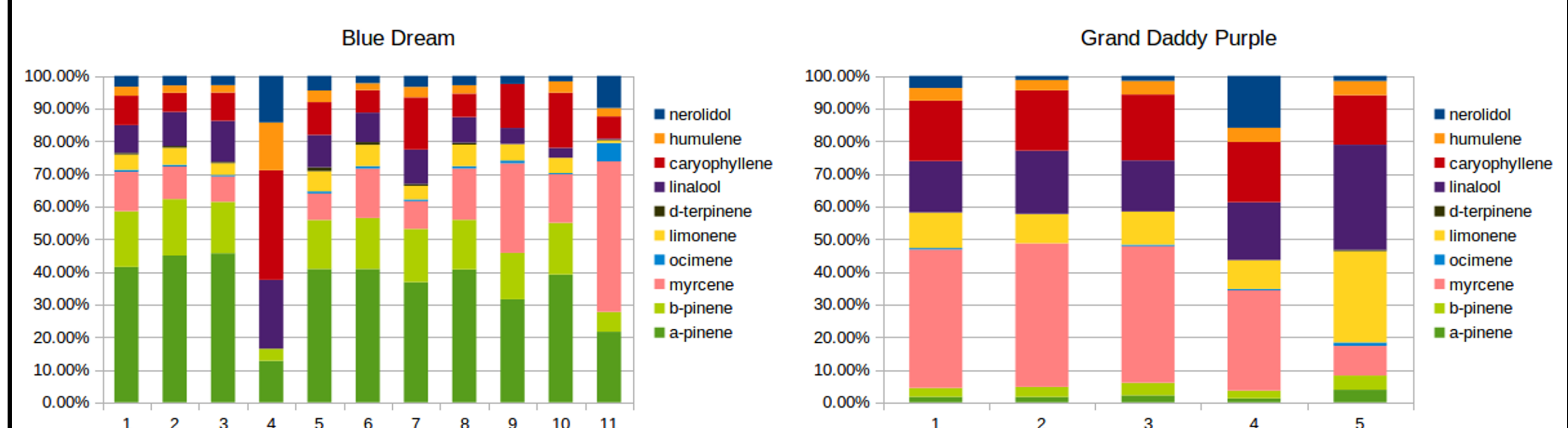
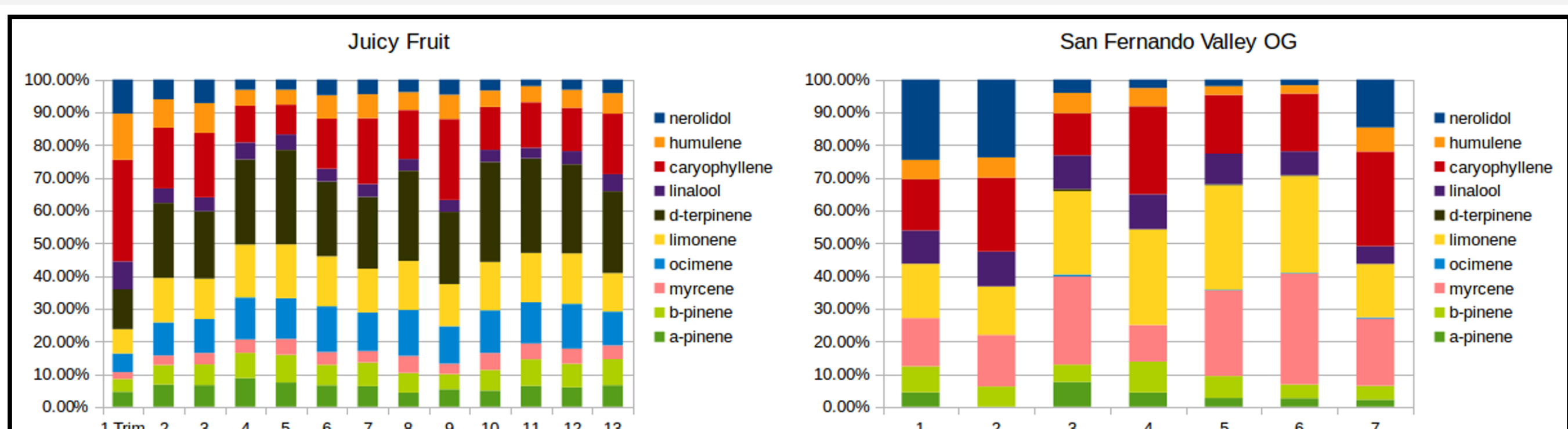
Terpenes also have many medical benefits, even when not associated with cannabinoids. Using databasing technology, it is possible to bridge the gap of knowledge between the medical benefits of terpenes found in cannabis and the chemical knowledge of each cannabis strain's terpene profile. To accomplish this, we built two custom databases: one to organize medical research papers on cannabis, and one to organize chemical data on cannabis samples. Using both of these data sets, it is possible to give doctors and patients the tools to understand the relationship between their cannabis' terpene profile and its medical benefits.

Terpene data was taken from two analytical laboratories in distant parts of the United States: Massachusetts and Nevada. These labs were participating in their state's medical marijuana program and generated data over a span of over 12 months. The cannabis samples were analyzed by headspace-gas chromatography-mass spectrometry (HS-GC-MS). Laboratories were screened based on proper quality control, certifications, and GLP and ISO standards. All data is reported in mg/g, which is equivalent to per mille (‰) or part per thousand.

Chemical data entries were collected as samples and organized by strain and terpene values. These values were analyzed for statistical mean, standard deviation, and global maximum and this data was used to find 10 prevalent terpenes in cannabis samples for further statistical analysis (Figure 1). The data set was analyzed for the 14 most common strain names, and the 10 selected terpenes were graphed as normalized values (Figure 3). Values were normalized to the total mass of the 10 selected terpenes.

Medical data entries were collected as medical research publications and organized by publication data (author, date, etc), cannabinoids studied, terpenes studied, and associated medical disorders. This data set was restricted to papers focusing specifically on terpenes with an associated medical disorder, and organized by terpene (Tables 1-9). Totals of the numbers of paper referencing each terpene, and the subtotals for the following medical disorders were generated: cancer, anxiety, depression, pain, insomnia, and infection.

The chemical database contained 958 cannabis flower samples with data for 20 terpenes. Of these, ten were identified to be more prevalent in cannabis: nerolidol, humulene, caryophyllene, linalool, d-terpinene, limonene, ocimene, myrcene, and alpha and beta pinene. These terpenes were selected from the set of 20 based on global maximum, standard deviation and mean, which have been illustrated in Figure 1. The remaining 10 terpenes can be said to consistently be present in trace quantities in cannabis over the data set examined.



**Figure 3 - Terpene data taken from the 14 most common strain names in the data set.**