UNIVERSITY OF COPENHAGEN
FACULTY OF SCIENCE

Fruit and Berry Crop Physiology and Quality
NPLK14014U

Notes taken during the course, including lectures, exercises, curriculum, and practicals

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Link to GitHub reporsitory

Preface

These course notes have been prepared as part of the NPLK14014U course Fruit and Berry Crop Physiology and Quality at the University of Copenhagen, covering the period from September to November 2025.

The notes compile material and reflections relevant to the course and are intended as a resource to enhance the learning experience for students. The content is shared freely and may be used as study material or as a template for structuring individual notes.

All information is provided without responsibility for its correctness, and users are encouraged to verify data, formulas, and interpretations with the original sources and course materials.

Please enjoy reading these notes, and feel free to reach out if you have any questions.

Course Description

Education

MSc Programme in Agriculture

Content

The focus is on fruit growth and fruit quality in relation to the use as fresh fruits or for processing. How is fruit growth and quality affected by the plants' physiological and genetic basis and how can it be influenced by different growing techniques and environmental factors? Similarities and differences among the fruit crop types (pit fruits, stone fruits, berries and nuts), with regard to demands in growing conditions are discussed. Furthermore, we analyze which physiological parameters are important in the different fruit species for determining yield and important quality components. Emphasis is on temperate fruits, nuts, berries and fruit vegetables, grown mainly in open field or in tunnel systems. The reference growing systems are the common commercial systems, including organic growing. The course also addresses examples of the genetic and quality variation among cultivars and the importance of different quality attributes in relation to postharvest use (fresh consumption, cooking, juice processing or fruit wine making). In general the crop specific aspects of the following main topics will be covered:

- Yield and quality components (organ development and interactions) and determinant factors
- Allocation of dry matter and nutrient among sources and sinks in fruiting plants
- Control of vigour and plant structure by pruning and management of nutrients and irrigation
- Effects of preharvest factors (climate, a-biotic or biotic stresses) on internal and external quality of fruits
- Content and development of secondary and bioactive compounds in fruits.
- Maturation, ripening and assessment of optimal harvest and quality aspects of fruits and berries.
- Post harvest usability and sensory aspects of different cultivars and fruit types.

In addition to fresh use, special attention is given to production and quality of fruit juices. Biotechnological aspects are addressed at a limited level.

Learning Outcome

The course is targeted to students interested in plant science (Horticulture and Agriculture) and food science students who are particularly interested in fruit and berry crops and the quality and use of the raw materials/food products these crops provide.

Knowledge

- The physiological basis for production of fruiting crops (including fruit vegetables such as tomato and cucumber).
- Overview of development of the major plant organs with focus on the fruit and its quality and understand how and why it varies with genotype and preharvest growing conditions
- Describe the variation among the major cultivars used of fruits and berries in terms of development and quality parameters.
- Reflect on the importance of fruit and berries for human health

Skills

- Apply basic knowledge of physiology and biochemistry from plant and food science at the whole plant and organ level.
- Analyse a fruiting crop based on the crop specific yield and quality components.
- Explain how and why different techniques are used in the fruit industry and how it affects plant growth and product/fruit quality.

Competences

- Analyse the methods used to obtain optimal productivity and product quality.
- Discuss trade offs in management, such as between optimal sensory quality and storability, between yield and quality or pesticide use vs organic growing

Litterature

Literature lists will be available from the course responsible.

Recommended Academic Qualifications

Academic qualifications equivalent to a BSc degree is recommended.

Teaching and Learning Methods

Besides lectures the course will include practicals, where the students are working with cultivar evaluation, quality analysis or aspects of fruit growing physiology (plant and organ development etc). Part of the hands on teaching will be field based in the experimental fruit collections at the Pometum.

The practicals will be made in groups, while the individual student is given the opportunity, in a major report written throughout the course, to focus on an area of special interests. Thus individual competences with emphasis on either fruit growing physiology or fruit quality aspects of fruits as raw materials for industry processing or fresh consumption can be developed. The topic of the major report are to be presented to the class in a short lecture based on a selected journal paper.

2 or 3 excursions will be arranged in connection with the different course subjects.

Workload

Table 1: *A table with an overview over the workload for the course.*

Category	Hours
Lectures	35
Class Instruction	5
Preparation	40
Practical exercises	30
Excursions	21
Project work	75
Total	206

Exam

Table 2: *A table with an overview over the elaborated description of the course*

Credit	7.5 ECTS
Type of assessment	• Oral examination, 20 minutter • Written assignment, ca. 3 uger
Type of assessment details	The portfolio includes a major report and 2 out of 4 additional products (e.g. exercise reports or presentation) Weight of exam components: Evaluation of major report 50 %, oral examination in portfolio contents and curriculum 50%.
Examination prerequisites	Submitted and approval of the reports for theoretical and practical exercises
Aid	All aids allowed Read about how to use Generative AI on KuNet
Marking scale	7-point grading scale
Censorship form	• No external censorship • One internal examiner
Re-exam	The exam is an oral exam, as for the ordinary exam. Submission of an individual major report 1 week before the oral re-exam is required. The topic may be as for the ordinary exam but in a revised version.

Contents

Chapter 1
Lecture Notes

1 Lecture 01 - 02/09-2025

Fruit and Berry Crop Physiology and Quality or Fruit and Berry Crop Physiology, Quality and Use
Torben T-A, KU-PLEN

The course aims to provide broad knowledge on the physiology and growing of fruit and berry crops (including pit-, stone-, cane-, and bush fruits, other berries, nuts, and fruit vegetables), focusing at the whole plant and organ level. Key objectives are the development of specialized knowledge on a course topic, the ability to analyze a crop to identify important aspects in growing and quality, and understanding how fruit quality is influenced, specifically balancing productivity vs. quality. The curriculum seeks to build links between the production and quality of raw materials and the food science aspects of their use, including sensory aspects. The underlying idea is to address both the Plant science and the Food Science aspects of fruits and berries, emphasizing the importance of these crops for human health and addressing lacking knowledge regarding the potentials in different genotypes (raw materials). The course focuses primarily on temperate fruits, nuts, and berries grown mainly in open field or tunnel systems. While fruit vegetables such as tomato may be included in the individual report, the emphasis includes common commercial systems, organic growing, and relevance for small-scale/home gardening. These crops are characterized as Diverse (many species and cultivars), high value crops, demanding intensive hand labor and resources, and often requiring manipulation at the single plant level. Although often fresh consumed/used, there is a large diversity in processed uses, such as juice, jam, fruit wine, vinegar, cakes, desserts, and ice cream. They are important to human health and provide pleasure through nice aroma and taste. The course content is structured around eight main topic areas:

1. Genetic basis and Cultivar variation
2. Yield and quality components and determinants, including Organ development and interactions
3. Allocation of dry matter and nutrients, focusing on 'Sources' and 'sinks' in fruiting plants
4. Effects of pre-harvest factors on fruit quality, such as the importance of control of plant vigour and shape
5. Content and development of secondary compounds in fruits
6. Maturation, ripening, and assessment of optimal harvest time and quality aspects
7. Post-harvest usability (fresh consumption, cooking, industry processing, especially juice)
8. Sensory aspects of quality evaluation

Pedagogic methods utilize a mix of Lectures, Exercises ('Hands on'), Written assignments, Student lectures, and Excursions. Specialization is achieved through the individual report and the student lecture, which provide case specific supplements to the general lectures. The individual report is an opportunity to develop specific competence

on a free topic relevant to the course (e.g., Bud dormancy, Aroma development, Canopy management). The report structure mandates an Intro (1-2 pages), Detailed presentation and discussion based on international literature (4-6 pages), and Summary/conclusion (½ - 1 page), not exceeding 8-9 pages in total (max 10 pages including figures). Students must use their own writing and avoid 'copy-paste' and plagiarism. The assessment is an Oral exam lasting 25 minutes in total. The exam includes a short talk about the individual report, followed by two curriculum questions: one focusing on crop physiology and one on quality aspects. The final grade is based on 50% the individual report and 50% the curriculum questions.

2 Lecture 02 - 05/09-2025

Yield and quality components Torben T-A, KU-PLEN

The overarching aims in fruit growing are to maximise fruit yield and maximise fruit quality. The tools utilized to achieve these aims include Genetic choice (cultivars) and Growing technique. Fruit science focuses heavily on the physiological background informing the growing technique. Maximized Yield is typically expressed as tons/Ha (or hekto L/ha of juice or wine) and is fundamentally a product of the components Fruit number X Fruit size. Determinants influence the size or the level of development of single components within the genetic potential. These physiological elements are connected to growth and development and can be influenced by growing techniques, climate, and growing conditions. Maximized fruit quality is less clearly defined than yield and may vary with fruit species and final use. Important quality parameters include Colour and other aspects of appearance (especially for Fresh consumption), Taste components (sugar, acid, aroma), and 'Health components' (vitamins, phenols .....) which are a focus of research. Fruit size serves as both a yield and a quality component. The presence of unwanted substances such as pesticides is also an important aspect of fruit quality. The optimal compromise is crucial because physiological and technical factors may have opposite effects on yield and quality components. The environmental impact of the growing technique used, such as carbon footprint and pollution, also requires knowledge. The physiological elements that serve as yield and quality components and determinants include:

1. Planting system and Growing system (fx Rubus, strawberry), determining Number of plants/ha.
2. Plant size and structure, including Elongation growth, shoot type development, Bud development, and Flower bud initiation.
3. Bud number/plant, bud type, and the ratio of leaf bud/flower bud.
4. Flower development, specifically Number of flowers/cluster and Flower quality (e.g., Number of seed primordia, Position in cluster).
5. Pollination, fertilization, and initial set, defining Initial fruit number/flower.
6. Fruit drop (June drop), which determines the Final fruit number/initial number of fruits.
7. Fruit growth and fruit development, the Leaf/fruit ratio, and specific factors like Number of seeds/fruit (Pollination) and Amount of flesh/seed (in Strawberries), leading to Fruit size and quality.
8. Yield/ha (Fruit number x fruit size) and Fruit quality (content).

Specific crop examples illustrate the variability: Sour cherry yields may vary drastically, from 3 to 18 tons/ha, due to factors like Bud death (sometimes reaching 90%) and Fruit set percentage. Unstable yields in sour cherry 'Stevnsbær' pose a significant problem for the Market (Industry). In strawberries, vegetative growth (runner production) is influenced by long days and high temperature, while flower cluster formation is promoted by short day and low temperature. Pollination is very important in strawberries as the final fruit size depends on the Achenes/berry. For grapes, yield components include Number berries/cluster x weight/berry and Number of clusters x weight/cluster, influenced by factors like pruning, thinning, and the growing system. Analysis of 51

grape cultivars harvested in 2018 showed a high correlation ($R^2 = 0.9516$) between Yield kg/plant and total sugar (Fruktose + Glukose g/plante).

3 Lecture 03 - 08/09-2025

Bud and shoot development Torben T-A, KU-PLEN

This lecture explores Bud and shoot development, covering Meristems, Bud types and shoots, and seasonal Growth patterns. Embryogenesis initiates plant development by establishing the primary meristems and determines the Apical ↔ basal axial development, including the Shoot apex, Hypocotyl (The stem), Root, Root apical meristem, and Root cap. It also establishes Radial patterning, such as Epidermal cells, Cortical tissue, and the Vascular cylinder. The initial stages of development include Cotyledons (The first leaves). Development transitions from meristem to shoot, detailing the structure of the shoot apex in 3D and the Transition from vegetative to floral meristem. Variation exists among species in how strong the xylem or wood develop, with Trees having strong development and Bushes and canes exhibiting weak development. The purposes of leaves include Production of assimilates (the source of carbon), Water transpiration resulting in uptake and transport of water and nutrients, Production of hormones, and Control of water status/cooling. Buds are defined as locations of growth with a potential for development. The Types (fates) of buds include Vegetative, Generative, Sleeping (not dead), and Dead. Buds determine the plant's dimensions by forming shoots of different lengths, such as Short shoots (spurs), emphasizing the Importance of the shoot's position. In strawberries, the vegetative bud results in a side crown or a 'runner'. Pome fruits, exemplified by apple and pear, possess mixed buds, while Stonefruits utilize 'naked' buds. The topography of flowerbuds differs between pome- and stonefruit, which raises questions about which structure bears flowers in the terminal position on short shoots and the Importance of this difference. Seasonal growth patterns involve a Flush of growth in spring and early summer, followed by Growth termination or indefinite growth, depending on the species. Terminal bud formation also occurs, alongside Adventive buds formed along with shoot development. The timing of terminal bud formation depends on Shoot type (short spur is early, long terminal shoot is late) and Vigour level (strong is late, weak is early). These factors interact: low vigour results in fewer and more short shoots, whereas high vigour leads to more and longer shoots. Factors influencing seasonal growth include:

1. Shoot type and vigour.
2. Correlative inhibition within the plant, defined as 'communication among buds'.
3. Apical dominance, which influences adventive buds and inhibition. This involves Polar gravitropic transport and the activation of adventive buds upon Removal of the terminal bud. The underlying Auxin - Cytokinin balance varies among species (peach < apple < sweet cherry) and strongly influences the Branching pattern.
4. Competition for assimilates, specifically the relationship between fruits ↔ vegetative growth.
5. Number of growing meristems in top/root ratio.
6. Tree age, where Older trees produce many shoots but exhibit weak growth, and Young trees produce few and strong shoots.
7. Management and climate factors, such as Pruning, water and nutrient availability.

Development after terminal bud formation Happens suddenly, and differentiation continues inside the bud(s). A compact shoot is formed, and development continues until bud break next spring, though the intensity of this differentiation varies (dormancy).

4 Lecture 04 - 09/09-2025

Chapter 2
Lecture Exercises

1 Lecture 02 - TE_02

How to increase soil fertility of degraded soils?

- In this exercise we will discuss possible ways to improve the fertility of degraded soils. We discuss different options in groups. After the group discussions we will discuss in plenum.
- Your inputs for the discussion counts as the deliverable of the exercise.
- Potential Management Options to increase Soil Organic Matter (SOM):
    1. Integration of legumes as intercrops or in rotation
    2. Inorganic fertilizer
    3. Manure (livestock)
    4. Green manure, mulching, residue retention
    5. Agroforestry techniques (including fallowing)
    6. No tillage

Questions:

1. What are the benefits of the option?
2. Which problems could (potentially) limit the adoption?
3. What are possible solutions to the problems/limitations?

Question 01

1.

Question 02

Question 03

Question 04

Question 05

Question 06

Chapter 3
Exam Questions and Answers

This chapter of the course notes compiles the exam questions for the course held in November 2025, along with their respective answers prepared by me. The purpose of this section is twofold: firstly, to provide a reflective exercise that consolidates understanding of the course material; and secondly, to document my comprehension of the course topics as assessed through the exam questions.

To ensure citation accuracy and academic transparency, NotebookLM has been employed as the primary generative AI platform. Its use has focused on verifying that all citations accurately reference the uploaded course materials and lecture slides provided by the professors. Beyond citation control, this section also represents an ongoing exploration of prompt engineering — refining interaction design to optimise AI output quality, precision, and academic reliability. Through this approach, the work aims to maintain a high academic standard while enhancing clarity, structure, and depth in written responses.

There are a total of 17 questions in the exam, each comprising between three and five sub-questions. The numbering of the sections in this chapter corresponds directly to the numbering of the exam questions, ensuring a clear and consistent structure throughout. Questions 1-9 address aspects related to crop physiology, while questions 10-17 focus on fruit quality, maturity, and usability. Each question is presented below, followed by its respective sub-questions and answers.

Questions within: Crop Physiology aspects

1 Yield and quality determinants and components

Shoot and bud development, growth and flower bud development

1.1 Characterise the development and importance of spurs and extension (long) shoots

1.2 Describe differences in bud development and structure between stone and pome fruits

1.3 Describe some important yield components in strawberry and in sour cherry

1.4 Describe some conditions which may affect the development of flower buds negatively

2 Yield and quality determinants and components

Flowers, pollination and fruit set (sterility and fertility)

2.1 Describe important factors determining fruit set?

2.2 What is the importance of EPP?

2.3 What are important quality parameters for pollen and flowers?

2.4 Why and how do we use pollinators?

2.5 Are insects (fx bees) needed in pollination of self-pollinating crops?

3 Fruit development

Fruit development of small and large fruited species

3.1 Describe the general developmental phases in fruit development

3.2 Which sugars and acids are important in fruit development and how do they develop during fruit development? Example of species differences.

3.3 Which sugars are transported in the plant?

3.4 What is the role of starch in the carbon balance of an apple tree and an apple fruit?

4 Light use, vigor control and canopy management

Canopy management (pruning, growing systems, light use)

4.1 Why do we manipulate the canopy structure in most fruit crops?

4.2 Describe the pruning response during the year. Why do we get differences in the growth response to pruning?

4.3 How does pruning affect fruit development and quality? (direct and indirect)

4.4 Characterise important factors (except from time in the year), which may influence the growth response to pruning?

5 Crop load and canopy management

Carbon allocation (source-sink, fruit/leaf)

5.1 How does a high fruit load influence photosynthesis and transpiration?

5.2 Explain the concept of source strength and sink strength

5.3 How do source-sink relationships develop during the season in an apple tree?

5.4 Why may some leaves be more important than others for fruit development?

5.5 Why do premature fruit drop occur?

6 Crop load management, fruit quality and vigor control

Thinning of fruits, how, why, when and effects

6.1 Give an example of a crop in which crop load has a strong impact on fruit development - and one where it does not.

6.2 Characterize the effects of fruit thinning on growth and development

6.3 When is it most optimal to perform fruit thinning? Why?

6.4 Explain why the optimal thinning strategy may dependent on the end use of the fruits.

6.5 Why do we not want fruits on a young tree the first year(s) after planting?

7 Preharvest factor management and quality

Use and management of nutrients

7.1 Characterise the differences in nutrient requirements of a vegetative growing and a fruiting plant?

7.2 Calcium is important for fruit quality. Why? - And why is the level of calcium low in many fruits, especially big fruits?

7.3 When and why are fertilizers often sprayed on the leaves and fruits in the production of apples?

7.4 Characterize the importance of potassium for fruit development

8 Preharvest factor management and quality

Effects of nutrients on yield and quality

8.1 Describe the effects of nitrogen status on plant development

8.2 In which ways do nitrogen levels influence the yield components?

8.3 Impacts of nitrogen levels on fruit quality?

9 Preharvest factor management and quality

Effects of stresses on yield and quality

9.1 Describe the effects of stresses of nutrients and water on fruit development and quality.

9.2 Why are deficiency symptoms by some nutrients seen in the young leaves and by others in the old?

9.3 Describe how water stress can be used as a tool for growth control.

Questions within: Fruit quality, maturity and usability aspects

10 Fruit development

Influencing factors

10.1 Describe some important factors for optimal fruit development in small and large fruited species. Are there differences?

10.2 What would you do to optimize fruit development and fruit quality in an apple crop?

10.3 What is important for fruit development and quality in raspberry and strawberry?

11 Fruit maturity, harvest and quality assessment

Maturity measures, Harvest time and methods

11.1 How would you determine the optimal harvest time in apple?

11.2 Describe the problems and quality effects you might get, if you harvest either too early or too late.

11.3 Hand picking vs mechanical harvest - problems and benefits?

11.4 What are the main reasons for post harvest losses and what may be done to minimize it?

12 Fruit maturity, cultivar variations and important quality parameters

Aromas in fruits and effects on aroma development

12.1 When do aromas develop in fruits?

12.2 Characterise some important aroma substances and changes in aroma with maturity

12.3 Characterize the importance of harvest time on aroma development

12.4 What might affect aroma development pre and post harvest?

13 Fruit maturity, cultivar variations and important quality parameters

Colors in fruit and berries and effects on colour development

13.1 Characterise some important colour substances in fruits and berries

13.2 How does colour change with maturity?

13.3 What might affect colour development pre and post harvest?

13.4 What is the mechanism behind the occurrence of red clones in fruit cultivars (fx apples, pears and grapes)?

14 Cultivar variations and important quality parameters (fresh use and juice)

Cultivar characterization and uses. Fruit composition and human health

14.1 Characterise some of the most important (internal and external) quality characters, which may vary among cultivars in a fruit crop. (Fx strawberries or apple)

14.2 Which compounds are considered especially important in fruit and berries for human health and where are they located?

14.3 Which species are believed to be especially healthy to eat? Comment on the consumption of raw or processed fruits and berries.

15 Cultivar variations and important quality parameters (fresh use and juice)

Juice processing and juice quality

15.1 How does the level of fruit ripening impact on juice processing and juice quality?

15.2 Which enzymes may be used in juice processing and why?

15.3 Comment on the effects of different juice processing steps on juice quality.

15.4 Why are juices pasteurised, and what are important factors for a successful pasteurisation?

16 Potentials for producing fruit and berry wines

Challenges and opportunities

16.1 Comment on the challenges and potentials in making fruit wine from different fruit and berries

16.2 High levels of acidity may be a problem. How may it be handled?

16.3 Characteristics of so called 'cider apple cultivars'

16.4 Comment on the importance of ripening levels of fruit and berries for wine making

16.5 Characterize the process of cryo-concentration and the impacts on the juice quality and the potential for wine style development

17 Domestication of wild berries

Challenges and opportunities

17.1 Why may wild berries be attractive to domesticate?

17.2 Comment on some major challenges/barriers.

17.3 Describe important yield and quality components in wild/European blueberries.

17.4 Blueberries are one of few fruiting plants adapted to low pH soils. Comment on the challenges it causes in growing the plants.

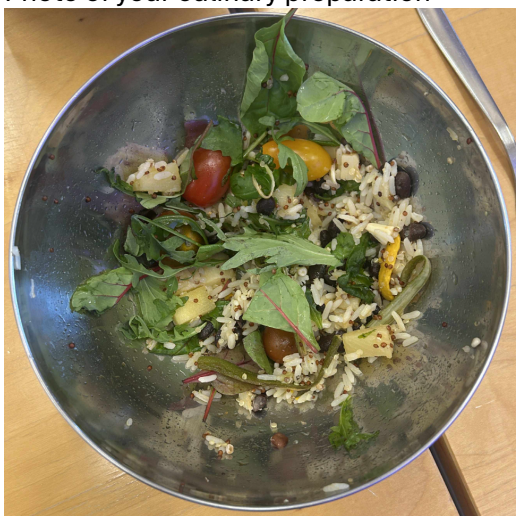
17.5 Comment on the importance/impacts of propagation method in European blueberries. European blueberries.

Chapter 4
Abbreviations and Explanations

Topic	Abb.	Description
Leaching	**n.a.**	*leaching refers to the process by which substances, such as ions, minerals, or nutrients, are removed or lost from the soil. This often occurs due to water penetrating the soil and displacing these substances*

Appendices

1 Appendix 1 - Practical Exercise 01

PE1: Tropical Crop products
Group n. 01 Group members: - Lucas Daniel Paz Zuleta, TZS159
Photo of your culinary preparation 
List the tropical products used: White rice, Pequi, Okra, Black beans, lentils, Cassava, salad (mix; rocula, spinach), Assorted Cherry tomatoes, Pineapple, Lentils, Olive oil, Palm hearts, and Jílo.

Discuss the potential macro nutrients composition of your dish (Use chatgpt):

Potential Macronutrient Composition of the Dish

- **Carbohydrates:**
  White rice, cassava, lentils, and black beans are major carbohydrate sources, providing both starch and dietary fibre. Pequi and pineapple add natural sugars. Okra, cherry tomatoes, salad greens, palm hearts, and jiló contribute smaller amounts of carbohydrates, mainly fibre.
- **Proteins:**
  Black beans and lentils are the primary plant-based protein sources. Spinach, arugula, and other salad vegetables contribute minor amounts of protein.
- **Fats:**
  Olive oil and pequi are the main fat sources. Pequi contains monounsaturated fats, while olive oil contributes healthy unsaturated fats. Small contributions may also come from palm hearts.
- **Fibre:**
  High levels of dietary fibre come from legumes (black beans, lentils), okra, cassava, salad greens, cherry tomatoes, jiló, and pineapple. Okra in particular also adds soluble fibre (mucilage).

This dish is **balanced**:

- **Carbohydrates** from rice, cassava, and legumes.
- **Proteins** mainly from legumes.
- **Fats** from olive oil and pequi.
- **Fibre and micronutrients** from vegetables, fruits, and jiló

[H]