CLASSIFICATION OF FRUIT AND VEGETABLE CROPS OF PLANT FAMILIES

Bal Krishna Joshi
Nepal Agricultural Research Council, Kathmandu, Nepal

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Summary

Fruits and vegetables are economically very important crop genetic resources. A total of 1097 vegetable species and around 2000 fruit species have been reported in the world. Grouping such a large number of species and huge variation is necessary to help on understanding their nature, biology, response to cultural practices, and environmental factors. Fruit and vegetable crops are generally classified following three systems, namely scientific, economical and operational. Within a scientific system, there are major seven taxa (kingdom, division, class, order, family, genus, and species). Carolus Linnaeus developed the binomial nomenclature in which plants are given two names, genus, and species. Most of the fruits and vegetables are vascular plants, belong to angiosperms and dicotyledons. There are more than 10 bases of classifying fruits and vegetables based on economical values; e.g., food crops, fruit crops, vegetable crops, commercial crops, etc. Under the operational system of classification, more than 15 bases are in practice to classify the fruit and vegetable crops e.g., based on life cycle, genetics and mode of pollination, stem type, sexual expression, habitat, leaf drop, parts used, color, crossability, climate requirement, etc. Some bases of grouping fruits and

vegetables are suitable for species and some bases are for cultivars (variety and landraces). Operational classification is practically very important and helps for doing agronomical research and production for researchers, farmers, and consumers. Species or cultivars may change in both economical and operational classification systems over time and locations. Agro-morphology, floral biology, growth nature, and response to cultural practices are the major factors for classifying fruits and vegetables following an operational system of classification. This chapter describes in detail the classification of fruits and vegetables based on different criteria, use value, traits, etc. Classification of fruit and vegetable crops are explained based on scientific, economical and operational systems.

1. Background

Agricultural biodiversity (in short agrobiodiversity) is the most important subcomponent of biodiversity. More than 28% of total biodiversity is agriculturally important. About 391,000 species of vascular plants are reported in the world and among them, 369,000 species are flowering plants. Agrobiodiversity can be divided into six components namely crop, forage, livestock, insect, microbial and aquatic, and four sub-components namely domesticated, semi-domesticated, wild relative, and wild edible (Figure 1). Since ancient times, different methods have been used to classify and distinguish species and cultivars (varieties and landraces). Horticultural crops are part of the crop biodiversity and are significantly contributing to agricultural business to flourish in the world. Horticultural crops can be viewed from different perspectives and sorted out accordingly; e.g., economically important crops; nutrition-rich crops; aesthetic, therapeutic, and recreational crops; medicinal crops, etc. Fruits and vegetables are major crops within horticulture. Pomology is a science that deals with fruits and olericulture deal with vegetables. Taxonomy is the science of naming and classifying living organisms. It is a common practice of grouping and naming plants since the primitive era based on their different uses in different cultures of the world. The fruits and vegetable plants can be classified into different groups along with scientific classification. Classification helps understand and manage a large number of crop species and cultivars (varieties and landraces). Both consumers and growers have grouped fruits and vegetables, based on their criteria that enable them to easily handle a large number of genetic resources.

Many biologists and taxonomists have developed different classifying systems for living organisms. For example, Carl Woese et al (1990) introduced the three-domain system, and Carolus Linnaeus (a father of taxonomy) introduced a system called the Linnaean system which consists of a hierarchy of taxa, from the kingdom to the species (Figure 2). Each species is given a unique two-word Latin name, a system of naming species which is called binomial nomenclature. Any living individual can be layered in eight different taxa following the botanical system of classification. As an example, potato's taxa are reported in Figure 2. Different systems and bases are in use for classifying fruits and vegetables. This chapter describes different classification systems and bases for fruits and vegetable crops.

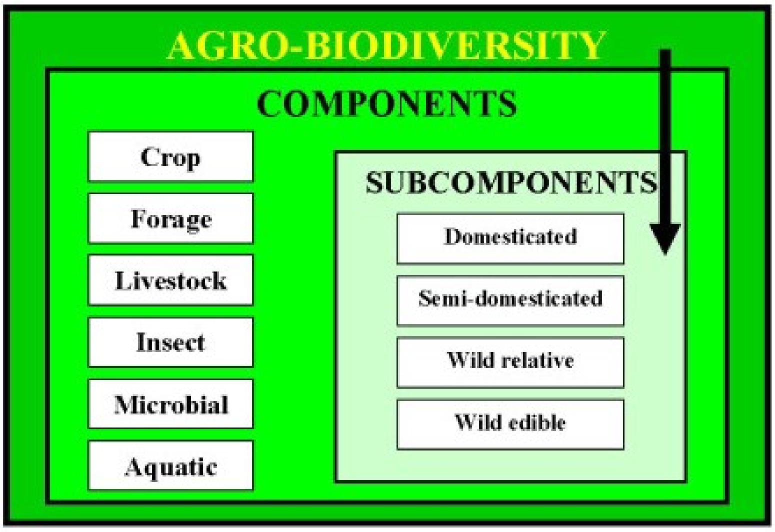

Figure 1. Components and sub-components of agrobiodiversity

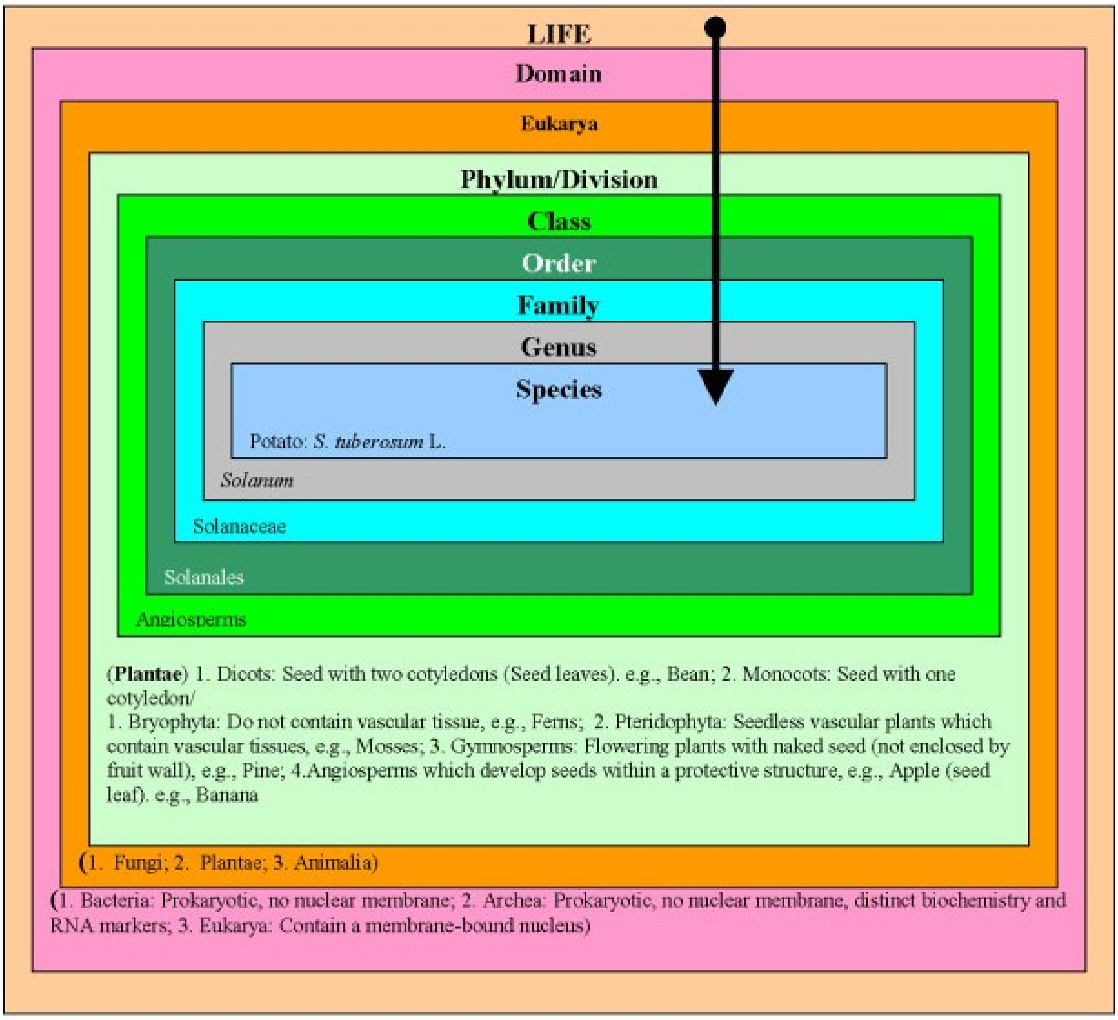

Figure 2. A hierarchical classification of living things (taxonomic levels) with a typical example of Taxonomy of potato. (Source: Woese et al 1990, http://www.gbif.org/)

2. Agricultural Crop Genetic Resource

Crop genetic resource is the main component of agrobiodiversity. All cultivated plant species and cultivars (variety and landrace) are called crops e.g., apple, radish, potato, etc. Plants include both cultivated and non-cultivated species. The natural system classified plants into vascular and non-vascular plants (Figure 3). Vascular plants have lignified (vascular) tissues (conducting tissues) for conducting water and minerals throughout the body of the plant, whereas non-vascular plants lack such specialized vascular tissues. Non-vascular plants do not flower and bear spores for example mosses.

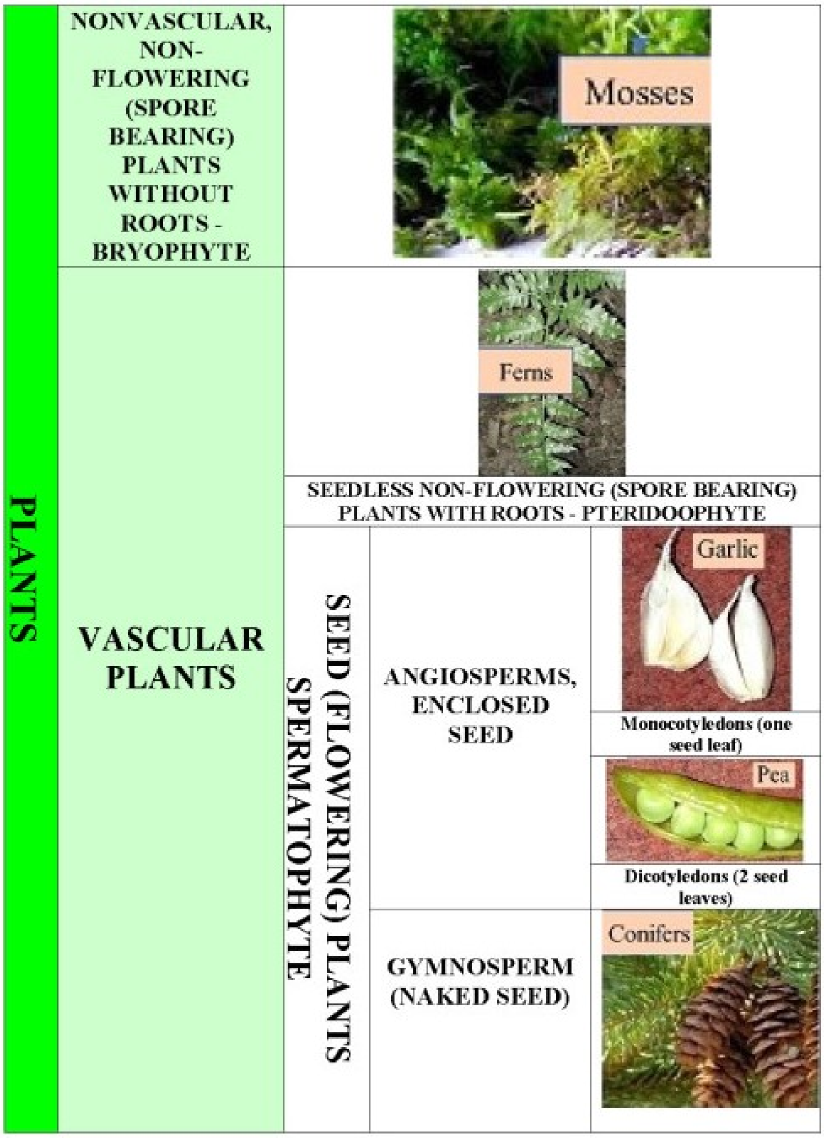

Figure 3. A natural system of classification of plants, based on characters of the reproductive organs, structural relationships as well as all other important characters

Vascular plants are of two types, seed plants, and seedless seed plants. Seedless plants, also called pteridophyte, do not flower but produce spores for example ferns. Different fern species are used as vegetables. Seed plants are flowering plants and are also called spermatophytes. Spermatophyte is further grouped into angiosperms and gymnosperms. Gymnosperms are flowering plants that produce cones and opened seeds. An example of a gymnosperm is the conifer plant. Angiosperms produce seeds in fruits and they are divided further into monocot and dicot based on the number of seed leaf (cotyledon). Monocot contains one embryonic leaf e.g., garlic where as dicot contains two seed leaves; e.g., pea. The majority of fruit and vegetable crop species are included in angiosperms and dicots.

Plants species with food values and economic importance are agricultural pant genetic resources (APGRs). Based on habitats, APGRs can be divided into cultivated, semi-domesticated, and wild species (Figure 4). Horticultural species include cultivated species, semi-domesticated species, wild relatives, and wild edible species. Horticultural species are grouped under different categories based on economic importance and use values (Figure 4). Fruits and vegetables are the major and most significantly important groups of horticultural crops. Agronomic or field crops are generally extensively grown and less intensively managed compared to horticultural crops. Some crops can be either agronomic or horticultural crops depending on the growing purpose, their stage of maturity at harvest, and their end-use.

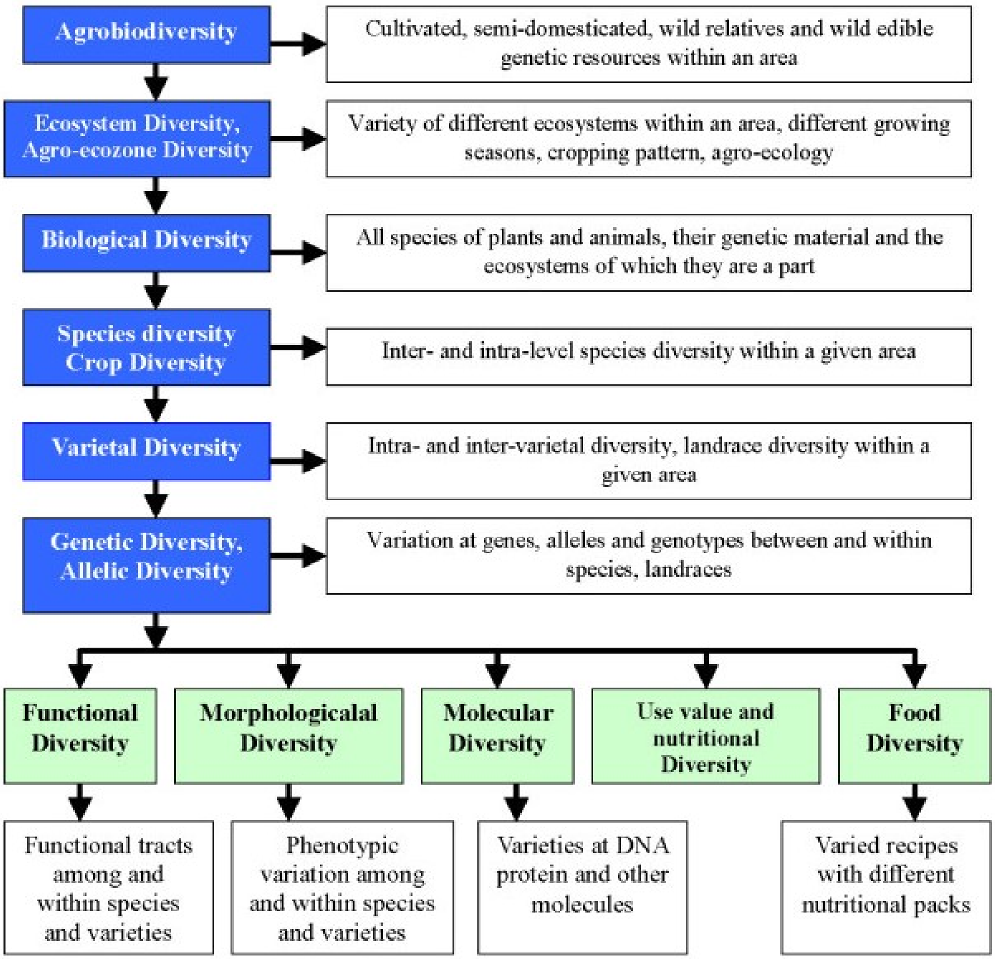

Figure 4. Classification of agricultural plant and crop genetic resources based on economic importance and use values

3. Agrobiodiversity Measurement

Agrobiodiversity can be classified using different systems and bases as well as measured diversity using different indexes and criteria. Both classification and measurement are important for better understanding, managing, and utilizing them. Diversity can be measured at five levels as given in Figure 5. The main objects for agrobiodiversity measurements are species and cultivars (variety and landraces). These can be assessed both at spatial and temporal status.

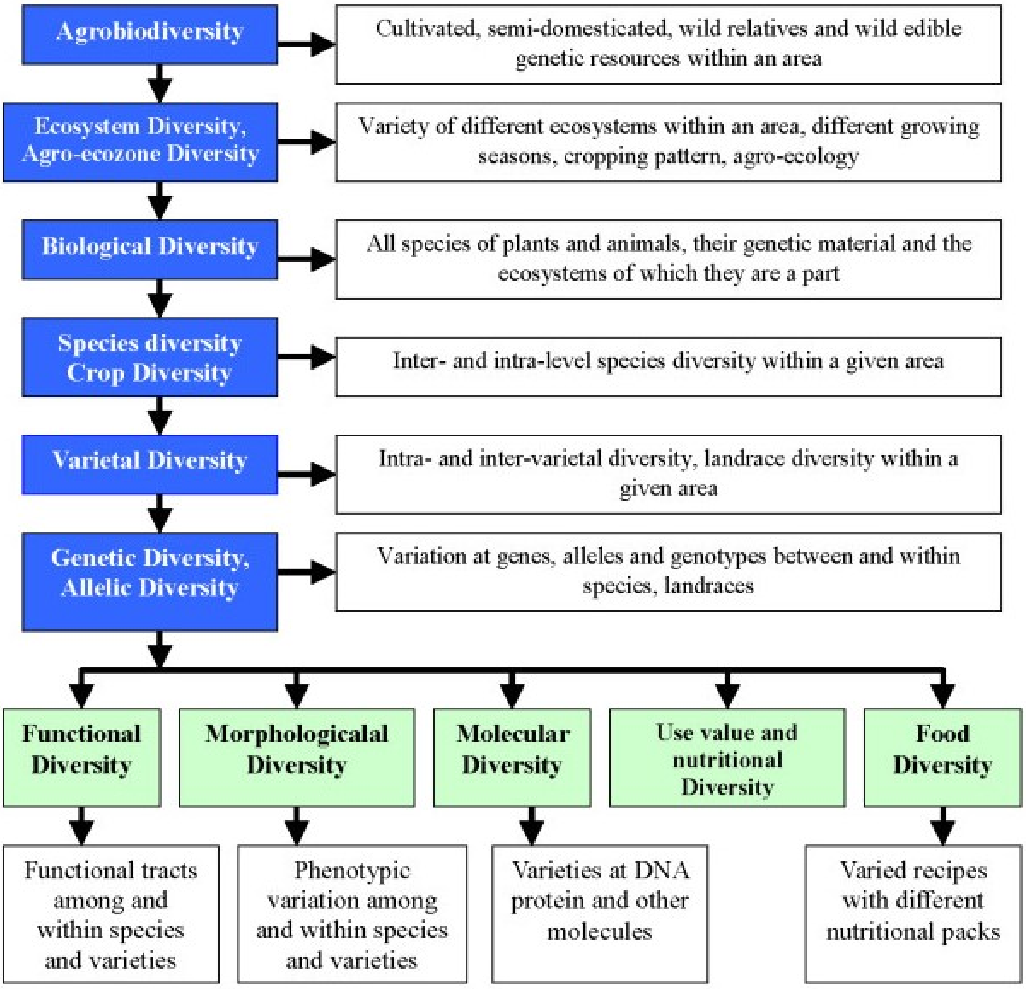

Figure 5. Levels and Types of diversity within crop biodiversity

4. Importance of Classification

Huge diversity at species and genetic levels exists in crop biodiversity. Even subtle differences can be observed in clones. Plants have multifunctional use - values adopted to diverse areas and cultures. It is very tedious, cumbersome, and infeasible to deal with all these plants separately. Grouping is an ancient practice. There are many different methods and reasons for classifying plants and crop species and varieties. Classification helps to reduce the number of entities to deal with. Classification orderly group these diversities based on their resemblance in terms of many criteria. Plant classification is very useful to identify, grow, study, preserve, and manage plant species as well varieties. Classification systems should be simple, accessible, partially useful, scientifically valid, and stable over time and space. Classification of crops may keep changing as an increase in knowledge. The importance and purposes of classification are given below.

- For easy and quick cultural operations
- For the breeding purpose and to develop new varieties
- For facilitating propagation of crops
- For effective control of pest and diseases
- For cultivating crops suitable to different climatic conditions
- To enhance utilization more efficiently and effectively
- To help communicate similar ecological adaptations and cultural requirements
- To establish plant origins and relationships
- To uniformly categorize the plant species and varieties
- To avoid confusion when referring to a particular plant
- To get information about each group and sub-groups
- To present the full knowledge in a nutshell
- To recognize helpful plants for the advantage of mankind
- To show the relationship between the individual crop
- To systemize the presentation and make the remembrance of the plants easy and convenient
- For identifying and cataloging the large volume of information
- To help identify plants across different cultures and languages

5. Classification Systems on Different Bases

Fruits and vegetables have multifunctional values, adopted in diverse agro-climate, cultural practices, and provide different kinds of nutrients. These large numbers of diversity at species, cultivars, and trait levels have been classified by scientists, farmers, consumers, and businessmen. There are many different means or ways of classifying plants. Broadly there are three systems of classification of fruits and vegetables (Figure 6). They are scientific system, economical system, and operational system. Within each system, many criteria or bases are commonly used to further group the fruits and vegetables genetic resources. For example, under the operational system, fruits and vegetables can be classified based on their life span, climatic requirements, growth habits, physiological characters, plant parts used, leaves shed, longevity, etc.

CLASSIFICATION OF FRUITS AND VEGETABLES		
Botanical	**Economic**	**Operational (field) based on**
Class: Name	**Class:** Example	**Basis:** Example
Kingdom: Plantae (plant)	**Food**: Potato	**Life cycle**: Annual
Division: Magnoliophyta (flowering plant, angiospermae)	**Vegetable**: Cauliflower	**Kind of stem**: Herb
Class: Liliopsida (monocot)	**Fruit**: Apple	**Growth form**: Erect
Order: Liliales (lily order)	**Spices**: Chili	**Climate**: Tropical
Family: Liliaceae (lily family)	**Oil**: Sunflower	**Edible or economical part**: Pod, rood, tuber
Genus: Allium	**Medicinal**: Garlic	**Adaptation**: Cool season, warm season
Specie: Alium cepa (onion)	**Industrial**: Coffee	**Growing season**: Winter
	Commercial: Tomato	**Habitat**: Cultivated

	Plantation: Tea	**Origin**: Exotic
	Beverages: Coffee	**Agroecozone**: Rainfed
	Sugar and starch: Sugar beet	**National list**: Registered
		Red list/ distribution: Endangered
		National priority: Major
		Research priority: NUS
		Conservation strategy: Orthodox

Figure 6. Classification of fruits and vegetables based on different systems and bases

5.1. A Scientific System

A scientific system of plant classification, also called botanical classification is a system of categorizing living beings based on morphological and cytological similarities, place of origin, crossability behavior, floral biology, etc under different taxonomic ranks or taxon. This system uses scientific principles and is therefore universally adopted and applicable. The scientific system of classification employs several criteria which include morphological, anatomical, ultrastructural, physiological, phytochemical, cytological, and evolutionary (phylogenetic) criteria. Pyrame de Candole first introduced the term taxonomy which means classification and naming of plants. Carl von Linne (Linnaeus), a Swedish physician, a father of taxonomy first standardized plant classification by introducing the binomial nomenclature system. Botanical names are binomial and genus and species are underlined or italicized. In this system, plants are given two names, first one is a genus (genera- plural) and the second one is species (sp or spp for plural in short); e.g., the botanical name of mango is *Mangifera indica*, the *Mangifera* being the genus and *indica* denoting the species. This system is most common and this scientific means of classifying plants avoid confusion when referring to a particular plant.

Scientists use mainly seven different taxa or terms (kingdom, division, class, order, family, genus, and species) to categorize the plants (Table 1). Taxa can be grouped as major taxa and minor taxa. The major taxa include kingdom, division, class, order, and family, whereas, the minor taxa include genus, species, and any other classifications taxa. Botanical classification uses hierarchical ranks which are descending (Figure 6). The general features of these eight taxa are:

I. Kingdom: Whether plant or animal
II. Division: Whether the plant bears seed or not.
III. Class: Whether the seed contains one seed leaf or cotyledon (Monocotyledonae) or two (Dicotyledonae)
IV. Order: Based on differences and similarities of vegetative and reproductive structures
V. Family: Based on differences and similarities of vegetative and reproductive structures
VI. Genus: Based on whether the species show close genetic affinities, the subordinate unit of the family
VII. Species: A population of related and interbreeding forms

The fruits and vegetables belong to the kingdom Plantae, which are further classified into two subkingdoms, Phanerogamae (flowering and seed-bearing plants) and

Cryptogamae (non-flowering and non-seed-bearing plants). More than 80% of all species in the plant kingdom are flowering plants. The majority of the fruits and vegetables are vascular plants and angiosperms and belong to the Dicotyledonae class. All vegetables are from Angiospermae. The division Angiospermae has two classes, Monocotyledoneae and Dicotyledoneae. Any fruit or vegetable crops can be classified from kingdom to variety based on the resemblance of characteristics. During the classification of fruits and vegetables, scientists most commonly deal with family, genus, species, and cultivars. Cultivar which may be either variety or landrace is very important in production. It is a plant derived from a cultivated variety that has originated and persisted under cultivation, or developed through a breeding system.

Rank (suffix)	**Example - Maryland Butterfly Pea (trait)**
Kingdom (ae)	Plantae
Subkingdom (ae)	Phanerogamae (flowering and seed-bearing)
Phylum or Division (phyta)	Magnoliophyta [= angiosperms], (true flower, seeds enclosed within fruits)
Subphylum or Subdivision (phytina)	Magnoliophytina
Class (opsida)	Magnoliopsida [= dicots]
Subclass (idea)	Rosidae
Order (ales)	Fabales
Suborder (linear)	Fabineae
Family (aceae)	Fabaceae [or Leguminosae]
Subfamily (oideae)	Papilionoideae
Tribe (eae)	Phaseoleae
Subtribe (ineae)	Clitoriineae
Genus–Intergeneric Hybrid	*Clitoria*
Subgenus	*Clitoria* subg. *Neurocarpum*
Section	*Clitoria* sect. *Neurocarpum*
Series	*Clitoria* ser. *Americana*
Species–Intrageneric Hybrid	*Clitoria mariana*
Subspecies	
Variety	*Clitoria mariana* var. *mariana*
Cultivar Group	
Forma–Cultivar	*Clitoria mariana* ‘Mexicana’

Table 1. Hierarchical (botanical) classification of butterfly pea

5.2. Economical System

This system of classification considers use-values, economical values of plant species, and relationship with a human. Species may belong to different groups based on location and purpose of growing. For example, potato may belong to the food category in some locations where it is a staple crop, but in other areas, it may belong to tuber vegetables where other crops are stable. Major groups under this system are food crop (potato), vegetable (cauliflower), fruit (apple), spices (chili), oil crop (sunflower), industrial crop (rubber), medicinal crop (garlic), beverage crop (coffee), commercial crop (tomato), plantation crop (tea) and sugar and starchy crop (beetroot), etc. These classes are not in any order and do not depend on each other.

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Bibliography

Acquaah G. 2009. *Horticulture*: *Principles and Practices*, 4th Edition. Pearson Education, Inc., Upper Saddle River, New Jersey 07458. Pearson Prentice Hall. [Explains the botanical and operational classification of horticultural plants with examples]

Beentje, H., & Williamson, J. (2010). The Kew Plant Glossary: *An illustrated dictionary of plant terms*. Richmond, Surrey: Kew, UK. [Simple definition of many plant-related terminologies with illustration]

ePIC (2021) Plant identification Database, Kew Royal Botanical Garden. Available at: http://epic.kew.org/searchepic/searchpage.do (accessed March 2021). [Digitized information about plants and easy search varied collections, bibliographies, nomenclatures and checklists, publications, and taxonomic works]

Hanelt, P. (ed). 2001. *Mansfeld's encyclopedia of agricultural and horticultural crops*. Springer, Berlin. [Provides taxonomy, updated scientific names, common names, economic use, and distribution of economically important plants]

IARC. 2003. IARC *Handbooks of Cancer Prevention. Volume 8. Fruit and Vegetables*. International Agency for Research on Cancer, IARC Press: Lyon. [Define fruits and vegetables in multiple prospects and classify fruits and vegetables based on different criteria]

International Plant Name Index (IPNI). 2021. http://www.ipni.org/ [Web database which provides nomenclatural information for the scientific names of Vascular Plants from Family down to infraspecific ranks].

Jayachandran BK and K Rajmohan. 1999. *Dictionary of Horticulture*. Anmol Publications Pvt Ltd, New Delhi. [Explanation of many horticultural terms]

Joshi BK and R Shrestha, eds. 2019. Working Groups of Agricultural Plant Genetic Resources (APGRs) in Nepal. Proceedings of National Workshop, 21-22 June 2018, Kathmandu; NAGRC, NARC, Nepal. https://www.researchgate.net/publication/334052118_Working_Groups_of_Agricultural_Plant_Genetic_Resources_APGRs_in_Nepal_Proceedings_of_National_Workshop_21-22_June_2018_Kathmandu [Describes plant and crop groups based on different bases]

Joshi BK, HB KC and AK Acharya, eds. 2017. Conservation and Utilization of Agricultural Plant Genetic Resources in Nepal. Proceedings of 2nd National Workshop, 22-23 May 2017, Dhulikhel; NAGRC, FDD, DoA and MoAD; Kathmandu, Nepal. https://www.researchgate.net/publication/348049968_Conservation_and_Utilization_of_Agricultural_Plant_Genetic_Resources_in_Nepal_Proceedings_of_2nd_National_Workshop. [Explains botanical and field classification along with common and scientific names of different crops]

Nakasone, H.Y. and R.E. Paull. 1998. *Tropical Fruits. Crop Production Science in Horticulture* 7. CAB International Publishing, Wallingford, U.K. [A good introduction to the biology and culture of many of the subtropical and tropical fruit crops grown throughout the world]

Poehlman, J.M., and Sleeper, D.A. (1995) *Breeding Field Crops*, 4th eds. ISU Press, Ames, Iowa. [Describe plants group based on genetics and mode of pollination]

Rubatzky, V.E., and Yamaguchi, M. (1997) *World Vegetables - Principals, Production, and Nutritive Values*, 2nd edn AVI Publishing, Westport, Connecticut. [Describes the importance of classification along with botanical and other classification systems]

Spooner, D. M., R. G. van den Berg, W. L. A. Hetterscheid & W. A. Brandenburg. 2003. Plant nomenclature and taxonomy. A horticultural and agronomic perspective. *Horticultural Reviews* 28: 1–59. [Provides a glossary, explain details of botanical classification of cultivated crops, including variety, hybrid, etc]

The plant list (TPL). 2021. http://www.theplantlist.org/. [A working list of all known plant species, searchable by genus or species name and to know the botanical classification of plant species].

USDA (2021) Plants Profile. Available at: http://plants.usda.gov (accessed March 2021). [Online plant database for searching different taxon]

Welbaum, G. E. 2015. *Vegetable Production and Practices*. CAB International Publisher. [Describes vegetables, their botanical and operational classification]

World Flora Online (WFO). 2021. www.worldfloraonline.org. [*An Online Flora of All Known Plants*, open-access database with search facility by species, genus, or family name].

Biographical Sketch

Bal Krishna Joshi, a Senior Scientist in Nepal Agricultural Research Council, did Master degree in Horticulture Science with a minor in Statistics from North Carolina State University, USA; Master degree in Plant breeding and genetics from Tribhuvan University, Nepal, and PhD in Plant breeding and genetics from Tsukuba University, Japan. He has published over 300 articles and edited 25 books and proceedings. He is serving as an Editor-in-Chief of the *Journal of Nepal Agricultural Research Council* since 2018. He had contributed as a resource person many times in statistical, plant breeding, biotechnology, and agrobiodiversity training. He has also been involved in teaching Plant breeding, Genetics, Biotechnology, and Statistics in different universities. Dr. Joshi is working on the conservation and utilization of agrobiodiversity following four strategies (*ex-situ, in-situ,* on-farm, and conservation breeding). About 80 good practices and initiatives, many of which were developed in his leadership are now in action in Nepal. Biotechnological tools and geographical information systems have been effectively utilized for the management of agrobiodiversity in Nepal. Some of them are school field genebank, community seed bank, aqua pond genebank, livestock farm genebank, temple garden, community field genebank, household genebank, microbial genebank, potato park, insect field genebank, red zoning, and red listing, etc. Dr Joshi had received 12 different awards including National Technology Award, Distinguished Scientist, and Science and Technology Youth Award. His details can be accessed from his Google scholar profile at https://scholar.google.com/citations?user=65DOKzMAAAAJ&hl=en; and Researchgate profile https://www.researchgate.net/profile/Bal_Joshi