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ISBN: 978-978-789-997-7

Published by:

GA&A Books,
Suite A8, Super Standard Plaza,
Orelope Bus Stop, Egbeda-Idimu Road,
Alimosho, Lagos.

Email: gaaconsult@yahoo.com

Tel: 08029062851; 07046409890

First Published: 2024

Printed in Nigeria

Dedication

This book is dedicated to Almighty God

Acknowledgement

All sources of information and contributions towards the production of the textbook are acknowledged and appreciated.

Foreword

Pastures and Forage Crops Production, as laid out in the National Board for Technical Education (NBTE) curriculum provides a fundamental base for acquiring knowledge, skills and techniques required for production, management and improvement of forage crop production. It equips students with knowledge that are required for translating ruminant animal and other livestock enterprises for higher productivity and profitability. It will drastically reduce farmer and herders clash currently experienced in Nigeria.

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Preface

This textbook, 'Pastures and Forage Crops for Colleges' is written to provide a standard and dependable textbook for Agriculture students in Tertiary Institutions. It extensively covers the National Board for Technical Education (NBTE) Curriculum and the syllabus for Polytechnic students offering Pasture and Forage Crops Production and other related course/field.

This book affords the reader the basic concepts and the principles underlying the techniques and methods for raising producing forages for Livestock Industry. It is a well-researched, factually rich, reader-friendly book, a reliable manual for teachers, students and practitioners. It is thus highly recommended.

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INTRODUCTION

Adequate production of pasture is essential to the growth of livestock business, particularly when the production's objectives are financial gain and environmental sustainability. Plants are, by nature, the main source of energy for all other animal kind, (including humans). Depending on the management style, there is a direct or indirect correlation between cattle performance and the species of pasture. While some livestock, like pigs, poultry, rabbits, and equines (donkeys and horses), are able to consume some fibrous forages, which ferment in the caeca and provide the animals with energy for physiological functions, ruminant livestock, like cattle, sheep, and goats, can only graze or browse the pasture. Of course, because pasture (of whatever species) is a member of the ecosystem, it responds and contributes to the climate, soil, plants as well as humans and animals in the grassland bionetwork. These connections support system equilibrium, which in turn supplies wholesome feed for cattle.

Chapter One

TERMINOLOGIES USED IN PASTURE AND FORAGE PRODUCTION

Pasture: Pasture can be defined in many ways depending on purpose:

- A pasture is a plot of ground that has been planted with forage plants, either naturally occurring or artificially created, with the intention of giving cattle the correct amount and quality of feed.
- The term 'Pasture' may apply to any species of forage that is valuable for feeding livestock.
- Pasture can also refer to the feeding behaviour of animals, such as grazing or browsing on meadows or plants.

Acceptability: Animals' ability to choose and consume a food source; the term is also used synonymously with voluntary intake or palatability.

Acid detergent fibre (ADF): Remaining insoluble material after being extracted using an acid detergent (Van Soest); components of the cell wall minus hemicelluloses.

Acid detergent lignin (ADL): Lignin is found in the residue after the acid detergent has been used to remove it.

Ad libitum: the voluntary intake attained when the animal always has access to nutrition.

Adventitious roots: The secondary root system that emerges from every grass tiller's lower nodes.

Apomixes: This refers to reproduction where viable embryos are created, such as in Guinea corn, but the male and female gametes are not really united.

Browse: A type of range feed made up of twigs with their shoots and leaves that are harvested from shrubs, small trees, and woody vines by livestock or wild herbivores on a selective basis.

Carbohydrate: Complex polyhydroxy, aliphatic aldehydes, and their anhydric polymers, such as glucose, sucrose, starch, and cellulose, whose hydrogen and oxygen contents are typically the same as those of water.

Climax: a completely formed plant community having an unbalanced relationship between the environment and the plant cover.

Concentrates – meals with a high content of fully digested nutrients but no fibre. In theory, any feed that provides the three basic nutrients—protein, carbohydrate, and fat—is categorized as a concentrate if the amount of crude fibre in the feed is less than 18%. Examples include rice bran, copra flour, and cereals.

Crown: refers to the base of tufted grasses.

Cultivars: The agricultural variation is known by its internationally recognized term, cultivars. A cultivated population of plants that differs morphologically, physiologically, chemically, or in other ways is known as a

cultivar. They may go by common, particular, or general names, such as *Desmodium* Greenleaf. Also known as *Desmodium intortum*.

Cured: subjecting forage crop to specific temperature sometimes high temperature (for drying) before storage.

Digestible nutrients the amount of nutrients that are ingested, processed, and absorbed by the animal. Generally speaking, the phrase refers to proteins, carbs and lipids.

Ecotype - a type of plant that has arisen from exposure to a particular environment within a strain or variety.

Fodder: For animal nutrition, coarse grasses like corn and sorghum are gathered along with their seeds and leaves, then cured.

Forage: plant material fed or grazed on by animal.

Glabrous: absence of hair or smooth to touch.

Grassland: Any plant community where the predominant vegetation is made up of grasses and/or legumes.

Grazing capacity: quantity of animals that a certain pasture can sustain over a specific amount of time.

Hemicelluloses: a class of complex carbohydrates that is not as difficult to digest as cellulose.

Herbaceous: relatively woody-tissue-free plant.

In vitro: in a test tube, in glass, outside the organism, or during in vitro digestion.

In vivo: in a living organism, such as an animal or plant.

Lignin: a complicated, less digestible substance than cellulose that strengthens the thicker cell walls of plants.

Pubescence: having short hairs.

Setaceous: possess a bristle texture.

Species - A species is a naturally occurring group of plants that share physical traits (phenotypical similarities), have a common ancestor, and can displace other species of similar plants (Lawrence, 1951).

Varieties: Varieties are divisions and phenotypic variations within a species. To differentiate them from others found in other areas, they are referred to by special names in botanical literature, such as *Panicum maximum* var. Ntchisi. It can be used to describe a population of plants within a species that is distinguished from another by one or more identifiable hereditary traits.

Chapter Two

PASTURE AND FORAGE CROPS IN ANIMAL PRODUCTION

Production of pasture is essential to the growth of any livestock business, particularly when the production's objectives are financial gain and environmental sustainability. Plants are, by nature, the main source of energy for all other species, including humans. Depending on the management style, there is a direct or indirect correlation between cattle performance and the species of pasture. While some livestock, like pigs, poultry, rabbits, and equines (donkeys and horses), are able to consume some fibrous forages, which ferment in the caeca and provide the animals with energy for physiological functions, ruminant livestock, like cattle, sheep, and goats, can only graze or browse the pasture.

There are connections between the climate, soil, plants and pasture species, humans, and animals in the grassland ecosystem. These connections support system equilibrium, which in turn supplies wholesome feed for cattle. The soil is the custodian of nutrients which are in forms that animals cannot utilize. The plant makes use of these nutrients and energy from the sun to convert them into usable products like leaf, cereals, nuts, tubers, stem, roots etc required by animals and humans.

These plant products supplies animals with needed nourishment for continuous existence. After death, both plant

and animals decay and returns the nutrient back to the soil and the cycle continues.

2.1 IMPORTANCE OF PASTURE AND FORAGE CROPS

1. **Provision of feed for livestock especially during the rainy season:** Fresh green fodder made primarily of pasture legumes and grasses is fed to ruminants. In many places, they make up more than 85% of the feed for ruminants. Nutrients in forage legumes can be converted by ruminant animals into meat, milk, wool, bones, organic dung, hides, and skin.
2. **Addition of nutrient to the soil:** Soil microorganisms break down organic debris such as leaves from trees and herbaceous legumes that fall to the ground that can be used to enhance the soil. This is a naturally occurring soil enhancement, contributing to cheaper growth and production of agricultural crops. Certain legumes (such as *Pueraria phaseloides*, *Mucuna utilis* and *Centrosema pebescens*) construct soil by fixing nitrogen through their roots, which raises soil fertility and, as a result, the texture and structure of the soil.
3. **Protecting and conserving the soil:** The majority of herbaceous forages, such as legumes and grass, creep on the ground to cover the soil in a canopy. This lessens evaporation by shielding the soil from direct sunshine; and also keeping raindrops and soil from interacting directly.
4. **Environmental stabilization:** The leaves of pasture plants provide oxygen that is necessary for human respiration and absorb CO₂ from the atmosphere for photosynthesis. This "AIR PURIFICATION" procedure ensures that humans and

animals can live long, healthy lives in a symbiotic exchange of gas.

5. **Source of Medicinal Herbs:** Many pasture legumes, such as pigeon pea, have leaves, stems, roots, seeds, and fruits that are useful herbs for conventional medicine.
6. **Sources of income:** To make money, pasture crops can be planted, harvested, and sold to farmers raising cattle.
7. **Materials for lawn and turf making:** Pasture crops could be used to establish estate lawns around homes and home gardens and enhance the beauty of the environment. They also come in handy for open spaces for human recreation and even competitive sports: polo grounds, stadiums, and other leisure areas.
8. **Employment opportunities for humans:** at least some people have to be engaged in fodder marketing and conservation, tuft growing and management etc.

2.2 DISADVANTAGES OF PASTURE AND FORAGE CROP IN ANIMAL PRODUCTION

It must be remembered that pasture is not just happenstance occurrence: to a large extent, pasture is cultivated or managed for particular purposes. Animal farmers deliberately introduce some species if and when they realize these are going to confer some advantage onto their business, in that their animals would do better by feeding on such species. However, it must be realised that there is always a converse side to every factor of human venture. For instance, some given areas of the surface of the earth just would not take what is cultivable in other areas. Pasture and forages in Nigeria have among others the following specific climatic and geographical disadvantages:

1. Nigeria's climate is not conducive to the growth of some pasture species, which have been found highly beneficial to animals in other areas of the world because of climatic difference. Some pasture species from cold and temperate grasslands have been found just not doing well in Nigeria, particularly in the Sahel regions of the nation.
2. Dense woodlands, particularly in Nigeria's southern regions, make it difficult to construct pastures successfully.

There are also the human factors which confer much disadvantages. Among these are:

1. Farmers' ignorance of the value of deliberately and purposefully producing pasture, particularly in Nigeria during the dry season. Among attendant negative effect is the incessant farmers-herders clash, leading to loss of lives all the time, because herders keep migrating from place to place looking for pasture and as a result, violate farms and other interests.
2. Majority of Nigerian farmers have little interest in producing pasture because the country's natural rangelands are easily accessible. Unfortunately, this is not as true as it used to be.
3. Poor maintenance of our native rangelands. In fact, instead of maintenance, what we have is degrading exploitation – such as bush burning in the dry season so that new and fresh grass could sprout and the cattle could browse. Nobody cares for the after-effect of such bush-burning.

4. Farmers' traditional beliefs have an impact on Nigeria's pasture establishment success. A good example is that of the Fulani (Fullah) group who are of the belief that a nomadic cattle grazing is God-ordained.
5. Inadequate land because of crop competition and a high human population. The south, for example, is perennially 'green'; but the greenness is limited by the woodland nature. So the open places are normally cultivated land or land in fallow. When herders take their cattle to such land, it is an invitation to affray.
6. Farmers using unproductive fields instead of fertile soils to produce pasture. Pasture is crop in its own right, therefore it is important that only productive field should be used for it.
7. Nigerians' ignorance of pastures and the methods used to produce them. Animal farmers in Nigeria are yet to advance to the level of deliberately cultivating pasture for the use of their stock.

Chapter Three

PASTURE AND FORAGE CROPS OF NIGERIA

Nigeria has a sizeable population of animal husbandmen, whether as keepers of domestic animals done as source of peasant income such as are common in the rural areas of the South or as principal business and wealth building such as are found among the cattle herding tribes, especially the Fullah group. With this reality it would be expected pasture production also would have been developed as the society is making advancements. Unfortunately, that is not to be.

Deliberate, coordinated pasture production has never taken root, although this does not mean various governments have not made some attempts. Even before independence, there were efforts by individuals such as a certain Hamisu Kano who in 1950 attempted to transform an abandoned farm settlement into a Cattle Ranch. The colonial masters also tried to create pathways for nomadic herders (in the North). But such moves were more about localization of wild grazing rather than deliberate production of pastures. Recently, the Federal Government attempted to intervene with the RUGA [Rural Grazing Area law (2019/2020)] and its transformation, National Livestock Transformation Plan (NLTP). They both failed due to inherent mistrust and mutual suspicion between the states (ethnic groups) and the cattle herding ethnic groups. The alternative would have been to create pasture reserves in the region(s) predominantly given to cattle rearing. But this

also failed due to cultural reasons, principal of which is the insistence on nomadic life by the cattle Fulani.

Nevertheless, some initiatives especially research have survived the vicissitudes and it can only be hoped that they would be built upon eventually. Kallah (2004) stated that over the years, there has been several attempts on the development of forage resources based on planned programmes, rational technology of utilisation, conservation and management of the resources. Pasture species evaluation (of both exotic and native) in Nigeria started since 1935 in ***Shika Grassland Research Station***, the present ***National Animal Production Research Institute, Shika***. Some of its achievements include identification and classification of forages in Nigeria.

Table 1: Some Pasture species in Nigeria

S/N	Botanical Name	Common Name
1	<i>Andropogon gayanus</i>	Gamba/Gambagrass
2	<i>Anthephora nigritana</i>	
3	<i>Brachiaria brizantha</i>	Signal grass
4	<i>Brachiaria decumbens</i>	
5	<i>Cenchrus biflorus</i>	Karangiya/bargrass
6	<i>Cenchrus sciliaris</i>	Buffel grass
7	<i>Chloris gayana</i>	Rhode grass
8	<i>Digitaria smutsii</i>	Wooly finger grass
9	<i>Panicum maximum</i>	Guinea grass
10	<i>Pennisetum purpureum</i>	Elephant grass
11	<i>Cynodon dactylon</i>	Giant star grass
12	<i>Arachis hypogaea</i>	Groundnut
13	<i>Calopogonium mucunoides</i>	Calopo
14	<i>Desmodium spp</i>	<i>Desmodium</i>
15	<i>Centrosema pubescens</i>	Centro

S/N	Botanical Name	Common Name
16	<i>Glycine max</i>	Soybean
17	<i>Crotalaria macrocalyx</i>	
18	<i>Vignaspp</i>	Cowpea, beans
19	<i>Indigofera bracteolata</i>	Indigo
20	<i>Mucuna pruriens</i>	Mucuna
21	<i>Canajuscajan</i>	Pigeon pea
22	<i>Lablab purpureus</i>	Lablab
23	<i>Stylosanthes fructicosa</i>	Shrubby stylo
24	<i>Microptiliumatro purpureum</i>	Siratro
25	<i>Zorniglo chidiata</i>	Zonia
26	<i>S. guianensis</i>	
27	<i>S. humilis</i>	Townsville stylo
28	<i>S. hamate</i>	

Source: Muhammad and Abubakar (2004)

3.1 CLASSIFICATION OF THE COMMON PASTURE AND FORAGE CROPS

Pastures and forages are classified according to (1) duration of use, (2) Nutrients composition on dry matter, (3) Plant Type

(a) **Basis of duration of use**

- i. **Annuals:** These are plants that survive the dry season as seeds and finish their life cycle in a single growing season. Examples are *Hyparrhenia rufa* (Jaragua), *Pennisetum purpureum* (Elephant grass), *Brachiaria mulato* (Mulato) and *Chloris gayana* (Rhode grass).
- ii. **Biennials:** These are the plants whose life cycle is finished in two seasons. The vegetative growth

season is the first, while the reproductive growth season is the second. For instance, *Cynodon dactylon* (Bermuda grass), *Andropogon tectorum* (Southern Gamba grass), and *Panicum maximum* or *Megathyrsus maximum* (Guinea grass).

- iii. **Perennials:** These are plants, like *Acaciaalbida*, *Ziziphus mauritiana*, *Gmelina aborea* (Benchwood, White teak), and *Ficus thonningii* (Mugumo) trees, that grow year-round and produce blooms and seeds for many years without ever dying.

(b) **Basis of nutrients composition on dry matter**

- i. **Non-Maintenance:** These are cereal forages that are collected and/or fed to animals that are fully grown. They have little to no nutritional value and are less digestible. For instance, straw from wheat, rice, sorghum, etc.
- ii. **Maintenance:** These plants are pasture varieties with reduced levels of digestible energy, calcium, magnesium, and crude protein. All grasses, Sorghum, Maize, Bajra, Hybrid napier, and Para grass.
- iii. **Production fodder:** These are wholesome forages that animals are fed in order to produce wool, milk, meat, eggs, and progeny. Examples are Cowpea, all legumes, a blend of legumes and grass, etc.

(c) **Basis of Plant type**

In general, pasture plants are divided into two categories: those that are members of the Leguminosae family and those that are not (grasses and some browse plants)

- i. **Legumes (Leguminosae)** *Papilionaceae*, *Caesalpinoideae*, and *Mosoideae* are the three main families of legumes based on the type and form of their blooms. Their net venation pattern is seen on their large leaves. These herbaceous plants, and the terminal buds are where the blooms are mostly found. Flowers can, however, also grow in other sections of the plant, such as auxiliary branches. Pods of seeds are produced by these flowers. *Mucuna pruriens*, *Alysicarpus vaginalis*, and *Centrosema pascourum* are a few examples.
- ii. **Non- Legumes**
 - a) **Grasses:** These are members of the Gramineae family. Their traits include high energy, low crude protein, rapid growth, and leaves and stems that are cylindrical. The stem is hollow, and the leaves exhibit a parallel venation pattern. They feature tiny, light seeds and a fibrous root structure. The related family members of barley, rye, millet, sorghum, and maize constitute this family.
 - b) **Browse Plants:** These are woody plants that are consumed for their leaves and twigs (soft stems and buds), but leave the woody stem uneaten, for example. *Gmelina aborea* (Gmelina, benchwood), *Tectona grandis* (Teak) among others.



Fig. 1: *Gmelina aborea*

- c) **Weeds:** These are non-planted plant species that invade an area by itself. e.g. *Amaranthus spinosus* (Dagunro in Yoruba) etc
- d) **Shrubs:** Any kind of woody, evergreen, dense plant that branches into a few stems or trunks at the base and is smaller than a tree is referred to as a shrub. Shrubs are easily identified because they are often short and bushy, with little of the stem visible.



Fig. 2: *Chromolaena*



Fig. 3: *Phyllanthus*

3.2 SYSTEMATICS OF CLASSIFICATION OF GRASSES AND LEGUMES

Classification is important in the taxonomy of forage crops because it helps to identify a particular crop in relation to other closely related family members.

Following the rules of biological (Agricultural) sciences, within the families *Leguminosae* (*legume family*) and *Gramineae* (*grass family*) Grass and Legumes are classified systematically by *Tribes, Genus, and Species*.

- **Tribes** are groups based on specific evolutionary (phylogenetic) links.
- **Genus** includes plants that share reproductive structures. This pertains to relationships in ecology, physiology, cytology, genetics, and geography. The first word of a plant's botanical binominal, such as *Chloris gayana*.
- **Species** comprises a naturally occurring group of plants that share morphological traits (phenotypic similarities), have a common ancestor, and are able to displace related species.
- **Varieties** are divisions and physical variations within the species. To differentiate them from species found in other areas, they are referred to specifically in botanical literature, for example, *Panicum maximum* var. *Ntchisi* or *Imperata cylindrical* var. *africana*. It can be used to describe a population of plants within the same species that is distinguished from another by one or more identifiable hereditary traits.
- **Cultivar** is the term for the agricultural type that is widely recognized worldwide. A cultivated population of plants that differs morphologically, physiologically, chemically, or in other ways is known as a cultivar. They could go by common, particular, or general names, such as *Desmodium intortum* or *Desmodium greenleaf*.

3.3 ADVENT OF SCIENTIFIC NAMES

It is an erroneous belief that scientific names are invented with the purpose of impressing and confusing the

amateur. It was also thought that the names should be long, complicated and unintelligible. On the contrary, Swedish naturalist Carolus Linnaeus devised a method, published in the 10th edition of his "Systema Naturae" in 1758, by which the plants are given two names. In order that they should be of international value, Latin or Greek names were used. The first, or generic name, indicated a relationship within a group of species, whilst the second, or specific name, distinguished the related species from one another. Occasionally, the generic name is just the Latin or Greek word for the group, but more often names are composite words drawing attention to some characteristic feature of the species.

3.4 WAYS OF CLASSIFICATION

The early classifications, such as trees, shrubs, herbs, annuals, biennials, and perennials, were based on pre-selected traits like form or habit.

Carolus Linnaeus (1707-1778) transformed the classification of plants by utilizing the sexual system of floral characteristics, particularly the use of pistils and stamens. However, current focus is on the microscopic and sub microscopic characteristics of cellular inclusions, hairs, spores, pollen grains, starch grains, and spines. etc. Classification of plants has gone far beyond the rudimentary, yet highly advanced level, of the days of Linnaeus. Today, discoveries in other closely related fields and advancement in cellular studies have helped scientists to be more precise and descriptive in biological/botanical classifications based on established cytotaxonomic links facilitated by later

discoveries about the role of cytology in determining chromosome number, size and shape, behaviour, and structure during meiosis.

Plant biochemical characteristics, such as essential oils, pigments, alkaloids, flavonoids, glycosides, and non-protein free amino acids, have long been researched and utilized by taxonomists in chemotaxonomy.

Protein immunological investigations provide metrics for taxonomic relationships. Whereas every improvement has the effect of reclassifying plants, this however does not change how adaptable they are or how they react to management techniques.

3.5 ADVANTAGES OF SCIENTIFIC NAMES

In some very specialized fields, practitioners use codes and terms that preclude language barriers. Take aviation as an example: even when he does not ordinarily speak English and cannot communicate in English, a Russian pilot in flight will call the control tower, including the ones in Russia, using codes which are spelt out in the English language. Scientific names serve very much like aviation terms and codes: they are the same for everyone in the field to ensure seamless exchange of knowledge and the fostering of advancement in the sciences.

Specifically, the following are the immediately noticeable advantages of scientific names:

1. All languages use the same names (Greek and Latin based).
2. Consistently there are binomial (two names)
3. When defining a species, binomials are precise.

4. The terminologies are descriptive (as could be confirmed by those versed in Greek and Latin)

5. The choice of names is governed by international rules of botanical nomenclature.

3.6 DISADVANTAGES OF COMMON NAMES (CALLED VERNACULAR, COLLOQUIAL, FOLK NAMES)

1. Common names are called common because they are not based on any scientific premises and therefore depend on language of the place where they are spoken. They may be descriptive though: (sword bean, lemongrass-*Cymbopogon flexuosus*) or bear name of some person (Rhodes grass-*Chloris Gayana*), location (Townsville stylo-*Stylosanthes humilis*) or associated with a habitat (beach grass-*Ammophila spp*). But all these are only as they relate to some particular environment or a people/culture. Thus, common names are restricted to one language or dialect, and perhaps to one locality.
2. Common names are indefinite
2. Unlike scientific names, common names are not regulated by a constituted authority.

3.7 Growth Habit of Forage crops

1. **Bush form:** these are forages with a primary stalk having auxiliary branches growing and side branches sprouting along the main stem e.g. *Cajanus cajan*.
2. **Bunch form:** forages with a single crown that gives rise to multiple stems and new tillers, making it challenging to distinguish between the primary stem and other stems. Examples of this type of plant are *Medicago sativa* and *Stylosanthis guianensis*.

3. **Creeping type:** the stems of these forages trail along the surface of the ground examples are some species of *Vigna*, *Macroptiliumatro purpureum*, and *Calopogonium mucunoides*.
4. **Scrambling form:** these are creeping plants that cling to and grow over vertical surfaces. Additionally, some twine and grow around upright objects, such as *Pueraria phaseoloides* and *Centrosema pubescens*.

Chapter Four

CLASSIFICATION AND MORPHOLOGY OF GRASS

Grasses are a type of flowering plant that belongs to the *Poaceae* family. They are one of the most widespread and abundant plant species on Earth, with thousands of different species, ranging in size from small tufts to tall, towering stalks. Grasses are known for their unique cylindrical stems, called culms, which are usually hollow and jointed. They also have long, narrow leaves that grow in two rows along the stems. The leaves of grasses are typically tough and fibrous, and many species have adapted to withstand grazing and trampling. These plants play a crucial role in various ecosystems, serving as food sources for herbivores and providing habitats for many different organisms. Grasses are also economically important, as they are cultivated as food crops (such as wheat, rice, and corn), used for livestock grazing, and utilized in landscaping and ornamental gardening.

Grasses are resilient and adaptable, able to thrive in a wide range of environments, from grasslands and prairies to savannas and wetlands. Their ability to grow quickly and withstand environmental stresses has made them successful colonizers in many parts of the world. Overall, grasses are a fascinating group of plants that contribute to the beauty and functionality of our natural landscapes, while also playing a significant role in agriculture and food production.

4.1 Features of Grasses

- Grasses belong to the family *Gramineae*.
- They are Herbaceous (non-woody), divergent in size, shape and growth habit.
- They are Monocotyledonous i.e. possess one seed leaf.
- They have fibrous rooting system with light and small seeds.
- They are characterized by high energy, low crude protein, fast growth rate, cylindrical stems and leaves.
- They are made up of two main parts: shoot or tillers (aerial parts) and roots (subterranean parts) with the reproductive parts included at flowering.
- The leaves have parallel venation pattern and the stem is hollow.

Brachiaria ruziziensis, *Sorghum almum* (Columbus grass), *Digitaria smutsii* barley, rye, millet, *Andropogon gayanus* and maize are a few examples.

4.2 Classification of Grasses

The Gramineae family, now known as Poaceae, is one of the largest families of flowering plants, encompassing around 12,000 species. Within this vast family, there are several important subfamilies, each with its own distinct characteristics. Some of the notable subfamilies include commonly found in the tropical environment includes:

1. **Panicoideae** This subfamily includes economically significant grasses such as maize (corn), sugarcane, sorghum, and switch grass. These grasses are often cultivated for food, forage, or biofuel production. They includes Tribes of *Maideae* (*Zea*, *Euchlaena*, *Tripsacum*), Tribes of *Andropogoneae*

(*Andropogon*, *Hyparrhenia*, *Sorghum*, *Lasiurus*, *Themedia*) and Tribes of *Paniceae* or *mellinidae* (*Panicum*, *Brachiaria*, *Digitaria*, *Mellinis*, *Pennisetum*, *Cenchrus*)

2. **Pooideae**: This subfamily includes grasses commonly found in temperate regions, including wheat, barley, oats, and ryegrass. Many of these grasses are important for agriculture and as turf grasses.

3. **Chloridoideae**: Grasses in this subfamily are often found in arid and semi-arid regions. Examples include Bermuda grass, buffalo grass, and Rhodes grass. They include tribes of *Eragrostae* (*Eragrostis*, *Dactyloctenium*, *Eleusine*) and tribes of *Chlorideae* (*Chloris*, *Cynodon*)

4. **Bambusoideae**: This subfamily includes bamboos, which are economically important for their uses in construction, furniture making, and as a food source in some cultures.

5. **Arundinoideae**: Grasses in this subfamily are typically found in wetland habitats. Examples include giant reed (*Arundodonax*) and common reed (*Phragmites australis*).

6. **Oryzoideae**: This subfamily includes rice, one of the most important cereal crops worldwide and a staple food for a large portion of the global population.

7. **Festucoid**: Festucoid grasses are characterized by their diverse range of ecological adaptations and are commonly found in various habitats around the world

8. **Temperate grasses**. They include tribes of *Agrostideae* (*Agrostis*, *Alopecurus*, *Phleum*), *Festuceae* (*Festuca*, *Dactylis*, *Lolium*, *poa*), *Triticae* (*Agropyronspp*), *Aveneae* (*Avena*, *Arrhenetherum*), *Bromeae* (*Bromus*).

4.3 MORPHOLOGY OF GRASSES

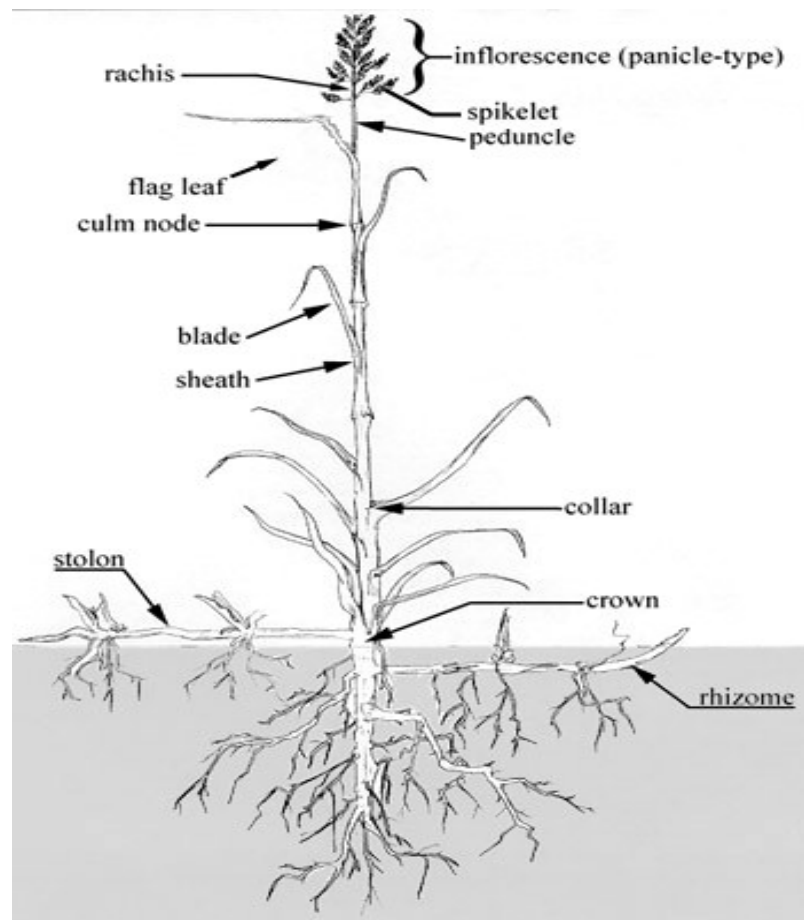


Fig. 4: Diagram of a grass

Grasses are made up of two main parts:

- Tillers, or shoots, which are aerial portions that include the reproductive parts when they flower.
- Roots (subterranean parts)

1. Aerial Parts

The shoots comprise the leaves and the stem (haulm, culm).

- The stems consist of jointed, spherical, or cylindrical nodes divided by internodes.
- Internodes may have holes in its interior (e.g. *Brachiaria mutica*), which are filled with white pith (e.g. *Zea mays*, *Sorghum vulgare* and *Hyparrhenia spp.*) or they may be solid e.g. *Axonopus scoparius*.
- Stems may be pubescent or glabrous.
- Buds found at the nodes give rise to shoots, which then create side branches.
- Stolon stems are creeping in nature and emerge above the earth and produce roots and new shoots at their nodes. *Digitaria pentzii*, *Cynodon nlemfuensis*, are a few examples of grasses that have stolons.
- Leaves are arranged in alternate rows across the stem.
- The midrib is usually prominent with faint lateral veins.
- The leaf sheath has free edges and chlorophyll.
- The leaf blade can have a filiform (thread-like) or setaceous (wiry and bristle) appearance.
- Leaves could be smooth or rough

Ligule is an appendage that is typically placed up against the culm at the point where the leaf blade and sheath meet. It can be used for identification and comes in a variety of sizes, shapes, and textures. It can be a membrane, a fringe of hairs, or a rigid ring.



Fig. 5: Grass leaf

Auricles are ear-like projections found at the base of the leaves of some species'. They can be noticeable and encircle the stem, tiny and insignificant or nonexistent, without chlorophyll and without any purpose, yet they are used in taxonomic identification.

Collar indicates the point where the leaf blade, which is sometimes discoloured, meets the upper surface of the sheath. The leaf splits at this point.

Prophyllum: is a two-keeled organ (a reduced leaf) covering the bud in the axil of the sheath.

2. Subterranean Parts

Primary roots are the first roots to emerge from the germination seed. In the early stages of growth, primary roots can branch and supply water and mineral nutrients to seedlings. Subsequent roots, which have the potential

to grow quite large, take their place and aid in holding onto soil particles to stop erosion. The roots that grew from the nodes of tillers or creeping stems are known as secondary or adventitious roots.

Secondary roots of grasses, also known as fibrous roots, are thin and threadlike roots that spread horizontally in the soil to anchor the grass plants and also to absorb water. These roots are important for the overall health of the grasses, helping them to survive in various environmental conditions. Grasses, such as wheat, rice and maize, have fibrous root systems that play a crucial role in their growth and development.

4.4 Reproductive Organs

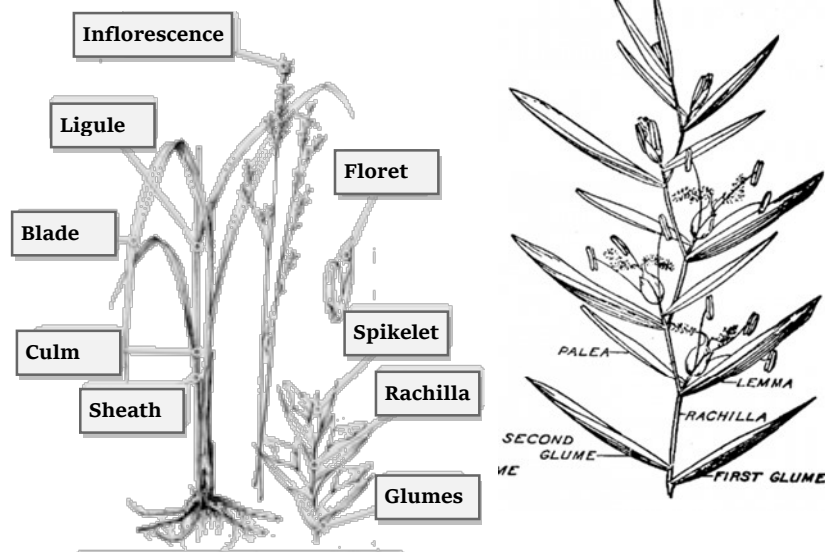


Fig. 6: Reproductive organ of grass

The Stamens and Pistils that make up the modified shoots are the floral organs.

Inflorescence: The term "inflorescence" refers to the floral organs. There are two types of inflorescences: **axillary** and **terminal**.

Spikelet: The spikelet, which is the fundamental unit of the inflorescence, is made up of flowers that are typically found in clusters or groups. One to several florets, two glumes, and an axis (rachilla) make up a typical spikelet. The lower and upper bracts of the perfectly formed floret, called the *palea* and *lemma*, respectively, encapsulate the flower. Because of the way the lamina is structured, the seeds are protected and may even find a way to disperse. The palea is narrower and shorter than the lemma.

Inflorescence types

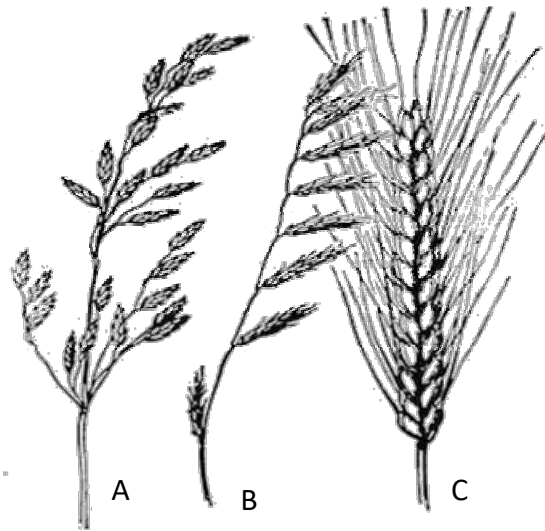


Fig. 7: Different types of inflorescences

A = panicle, B = raceme, C = spike

Inflorescence types are classified as:

1. **Spike**: when the spikelets are without stalks or are
 - a. Situated on an **Unbranched** axis (rachis) e.g. *Lolium*, *Triticum*, *Secale*, *Hordeum*, *Agropyron*;
 - b. **One-sided** e. g. *Cteniumelegans*, **Digitate** or finger like e.g. *Chloris* and *Cynodon Spp* or **Racemose** found on a central axis such as *Dactyloctenium* and *Leptochloa spp*.
2. **Raceme**: Species such as *Digitaria*, *Paspalum*, and *Brachiaria* have pedicels that run parallel to their axis. Spikes are less common than racemes.
3. **Panicle**: Having a branching inflorescence with several side branches and a central axis, spikelets have short stalks e.g. *Panicum*, *Sporobolus*, and *Sorghum* spp. have open and loose panicles; *Centrusciliaris* and *Setariaanceps* have thick panicles that resemble spikes; and *Pennisetum purpureum* has "false-spikes," which are spike-like panicles with branches hidden by spikelets.

The Flower

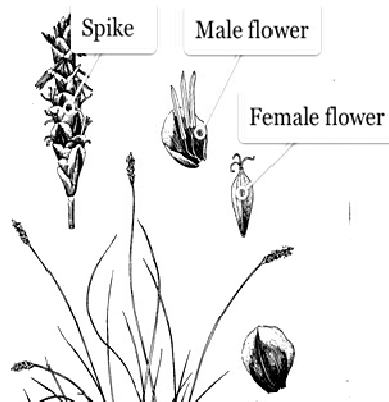


Fig. 8: Flower of grass plant

The gynoecium, or female parts, and the *androecium*, which has three or one to six stamens each, make up the floral organs. The pollen grains are housed in the two-celled anther, which is supported by a thin filament on each stamen that is composed of two cells. The colours of the anthers might be yellow, purple, reddish, or speckled. Outside the stamens, at the base of the flower are the lodicules. With the exception of some members of the tribe *Maydese*, most grasses have complete (hermaphrodite) flowers, meaning that each floret has both pistils and stamens.

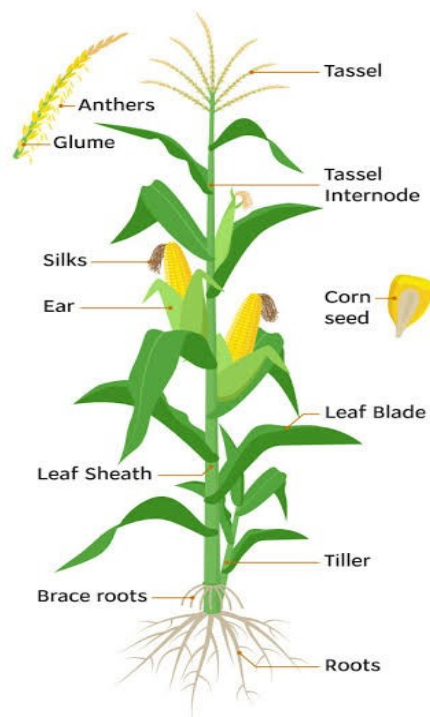


Fig. 9: Maize plant

Zeamays: solitary male and female on the same plant.

Table 2: Major Species of Grasses

S/N	Genus	Names	Scientific name
1	<i>Panicum</i> with over (500species)	Common guinea	<i>Panicum maximum</i> var. typical
		Green panic	<i>Panicum maximum</i> var. trichoglume
		Blue panic	<i>Panicum antidotale</i>
		Makarikari grass	<i>Panicum coloratum</i>
		Tall panic	<i>Panicum dactylon</i>
2	<i>Pennisetum</i>	Elephant or Napier grass	<i>Pennisetum purpureum</i> cv. Capricon
		Kikuyu grass	<i>Pennisetum clandestinum</i> cv. Whittet
3	Brachiaria	Signal grass	<i>Brachiaria decumbens</i> cv. Basilisk
		Para grass	<i>Brachiaria mutica</i>
		Ruzi grass	<i>Brachiaria ruziziensis</i>
4	Cenchrusspp	Buffel grass	<i>Cenchrus ciliaris</i> cv. Doela
		Birdwood grass	<i>Cenchrus setigenus</i>
5	Chloris	Rhodes grass	<i>Chloris gayana</i> cv. Pioneer
6	Cynodon	Bermuda grass / green couch	<i>Cynodon dactylon</i>

		African star grass	<i>Cynodonplectostachyus, Cynodon nlemfuensis</i>
7	Digitaria	Pangola grass	<i>Digitariadecumbens</i>
8	Melinis	Molasses grass	<i>Melinis minutiflora</i>
9	Paspalum	Common paspalum	<i>Paspalum dilatatum</i>
		Bahia grass	<i>Paspalum notatum</i>
		Scorbie grass	<i>Paspalum vaginatum</i>
		Plicartulum	<i>Paspalum setaceum</i>

4.5 Description of some Grasses

1. *Axonopus compressus*



Fig. 10: Carpet grass

Common names: Broad-leaf carpet grass,
Savannah grass

Description

- It is a stoloniferous, glabrous, perennial plant that grows to a height of 25-75 cm.
- Its leaves measure 5-20 cm in length and 9-12 mm in width.
- The inflorescence is made up of two-three erect, sessile, and slender spikes, with the spikelets measuring 2.2-2.5 mm in length.
- About 297,000 seeds are contained in one kilogram.

2. *Brachiaria mutica*



Fig. 11: Buffalo grass

Common names: Para grass, Buffalo grass, Water grass

Description

- *Brachiaria mutica* is an exotic, hairy, perennial grass that spreads quickly by surface runners and profusely roots at nodes.
- The stems are rhizomatous with ascending branches; culms hollow, succulent, glabrous, with hairy inter-nodes;
- The inflorescence is open panicle, 6–20 cm long;
- The leaf blade is linear, dark green, 30 cm long, and 6–16 mm broad. Seed density is roughly 1,000,000/kg.
- The grass grows well among legumes such as *Aeschynomene*, *Centrosema*, and *Calpogonium*.

3. *Chloris gayana*



Fig. 12: Rhodes grass

Common name: Rhodes grass

Description

- It is fine stemmed, leafy, perennial, erect, rhizomatous or spreading, stoloniferous grass.
- Culms are 0.6 to 1.2 m tall with long and stout internodes.
- Leaf blades are 15-30 cm long and 3-5 mm wide, tapering to fine pointed tips.
- The linear leaves have flat or folded glabrous blades, tapering at the tip.
- Inflorescence is spreading with 10-15 cm long, spikelets crowded, straw coloured on ripening.
- The open-handed seed head contains two to ten one- or double-sided racemes that are between four and fifteen centimeters in length.

- The spikelets (more than 32) feature two awns and are heavily imbricated.
- The fruit is a longitudinally grooved caryopsis.
- It produces profuse amount of seeds with seed count amounting to 7,250,000 to 9,500,000/kg.

4. *Cynodon dactylon*



Fig. 13: Bermuda grass

Common names: Bermuda, Lawn, Bahama, Wire and Devil grass

Description

- It is a leafy perennial stoloniferous with many branches and runners; each stolon can become a different plant when removed, making it the easiest and quickest to grow.
- It is quite varied how long a stalk is.

- The plant has soft, short leaves, 2–8 spikes that are 2–5 cm long, digitally arranged on the tips of erect peduncles.
- Seeds contain 448,900 seeds/kg

5. *Heteropogon contortus*



Fig. 14: Spear grass

Common names: Spear grass, Tangle head

Description

- It is an erect or decumbent grass, 0.9 to 1.0m tall, densely tufted, perennial, and quite tasty; its base is mostly leafy.
- Racemes are terminal, erect, 4.8cm long with noticeable dark brown awns (3–12 cm long), which are cooperatively twisted together to create a bundle at maturity.

- Leaves are robust, linear, up to 60 cm long and 3.7 mm broad, frequently hairy with bulbous base.

6. *Panicum maximum*



Fig. 15:Guinea grass

Common names: Guinea grass, Green panic

Description

- It is a tall, erect, perennial tussocky grass with a large number of tillers and short, strong rhizomes.
- The leaf blade is 60 cm long, 2.5 to 3.8 cm wide, and light green. The culms are 1.8 to 2.7 m tall, with densely hairy nodes and pubescent leaf sheaths.
- The inflorescence is an open panicle that is between 175,000 and 220,000 seeds per kilogram. It is 50 cm long and 10 to 30 cm wide, and it is heavily split with stiff branches in whorls.

7. *Andropogon gayanus*



Fig. 16: Gamba grass

Common name: Gamba grass

Description

- Gamba grass is a tall, perennial, tussock grass that thrives on a range of soils in locations with 600–1100 mm of rain and a 5- to 6-month dry season, with stems reaching up to 2 meters in height.
- It allows for poor fertility; but not overgrazing or waterlogging. It has thick cord roots that store starch and anchor the tussock; near the surface,
- The root is Fibrous roots (creating the vigorous early growth/post dry season reaction to first rains).
- During the dry season, it employs its vertical roots with the ability to draw water from a depth.
- The leaves are hairy on both surfaces, especially when young. Leaves can be up to 1m long, green, turning bluish when stressed by moisture, with a prominent white midrib. Leaf is hairy at base and the sheath is up to 20 cm long.

- The leaves may appear to have petioles because the leaf blade is reduced almost to the midrib above the ligule
- The seed head is carried on tall, strong culms. The inflorescence is a false panicle (synflorescence) composed of paired racemes (rames) 4-9 cm long, bearing about 17 spikelet pairs; the spikelets are sessile and have a long (~30 mm) conspicuous awn. Caryopsis, light brown to brownish black, 2-3 mm length, 1 mm wide, approximately seeds are about 890,000/kg.

8. *Sorghum bicolor*



Fig. 17: Guinea corn

Common name: Guinea corn

Description

- Growing up to 5 meters tall, the sorghum plant is an erect, tall annual grass. The adventitious roots of sorghum can reach twice as deep into the earth as the top 90 cm layer.

- While some varieties are produced only for grain, others have been created for the production of fodder, and some are dual-purpose, sorghum (*Sorghum bicolor* (L.) Moench) is utilized for both grain and forage
- The solid, upright stalks of the plant range in height from 0.6 to 5 m and diameter from 5 to 30 mm.
- The broad, glabrous leaves resemble those of maize, although they are broader and shorter.
- Generally glabrous leaf sheaths; flat, linear, apex tapering leaf blades that are (12–) 30–60 (–135) cm long and 1–5 (–13) cm wide; margins are scabrous, the midrib is conspicuous and pale, and the ligule is setaceous, measuring 1.5–5.5 mm.
- Up to 6000 spikelets can be found in the panicle-shaped inflorescence, which is around 60 cm long.
- The Panicle is erect, occasionally recurved, usually compact in grain sorghums and more open in forage types;
- Sessile spikelet: broadly obovate, 4–6 mm long, 3–4.5 mm wide, glumes pubescent, lemma of upper floret without awn;
- Pedicellate spikelets is usually sterile, rarely staminate, narrowly lanceolate, 4–5 (–6) mm long;
- Caryopsis is ellipsoid to obovoid or globose, dorsiventrally compressed, 3–4mm diameter, white, yellow, orange, reddish or reddish brown, exposed distally through glumes at maturity.
- Each kilogram of seeds contains up to 25,000–60,000 grains.

9. *Pennisetum purpureum*



Fig. 18: Elephant grass

Common names: Elephant grass, Napier grass, Bana grass, Barner grass.

Description

- Elephant grass is a major tropical perennial grass, robust, rhizomatous, tufted, very similar in appearance to sugarcane (*Saccharum officinarum*) but its leaves are narrower and its stems are taller.
- It is a very versatile species that can be grown under a wide range of conditions and systems.
- It is one of the highest yielding tropical grasses.
- The culms are coarse, perennial, and may be up to 4-7m in height, branched above.
- The leaves are flat, linear, hairy at the base, up to 100-120 cm long and 1-5 cm wide, with a bluish-green colour.
- The inflorescence is a stiff terminal bristly spike, up to 15-20 cm in length, yellow-brown to purplish in colour.

Chapter Five

CLASSIFICATION AND MORPHOLOGY OF LEGUMES

Legumes are a diverse family of plants belonging to the *Fabaceae* family, commonly known as the pea, bean, or legume family. They are characterized by their unique ability to fix atmospheric nitrogen in symbiosis with nitrogen-fixing bacteria present in nodules on their roots. This nitrogen fixation process enriches the soil with nitrogen, making legumes valuable components of sustainable agriculture and ecosystem health.

Legumes encompass a wide variety of species, including beans (such as kidney beans, black beans, and chickpeas), peas (including garden peas and snow peas), lentils, peanuts, soybeans, alfalfa, clover, and many more. These plants are cultivated for various purposes, including food, feed for livestock, green manure, cover crops, and ornamental purposes.

5.1 Features of Legumes

- Legumes are dicotyledonous; their embryos have two cotyledons, or seed leaves. Leguminosae (Fabaceae) family, have broad leaves and net venation pattern.
- Their flowers are mostly found at the terminal buds, though they can also be found in other areas of the plant, such as auxiliary branches.

- Pods are produced that enclosed the seeds by their flowers. A few examples are *Mucuna pruriens*, *Arachis hypogaea*, *Calopogonium mucunoides*, *Vigna unguiculata*, and *Centrosema pubescence*.
- They have the ability to fix atmospheric oxygen to the soil

5.2 Classification of Legumes

Three (3) categories, or subfamilies, can be distinguished within the legume family:

1. **Mimosoideae:** This subfamily includes mostly trees and shrubs with bipinnately compound leaves and small, often inconspicuous flowers arranged in dense heads or spikes. Examples include species of *Acacia*, .



Fig. 19: Mimosoideae flower (Mimosa, and Albizia)

2. **Caesalpinoideae:** This subfamily includes trees, shrubs, and some herbaceous plants. The flowers are

typically showy and often have long. Examples include species of the genera *Cassia*, *Caesalpinia*, and *Bauhinia*



Fig. 20: Caesalpinoideae flower

3. **Papilionaceae:** This is the largest subfamily and includes many economically important legume crops such as peas, beans, lentils, peanuts, and chickpeas. The flowers of species in this subfamily typically have a distinctive butterfly-like shape, with a large upper petal (the "banner") and two lateral petals ("wings") that enclose two lower petals fused together to form a "keel". Woody or herbaceous plants that have a characteristic butterfly-shaped or papilionate flower.

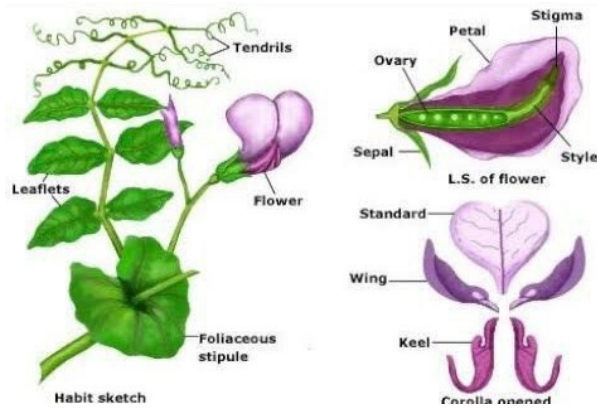


Fig. 21: Papilionaceae flower

There are 17 recognized Papilionoideae tribes. Significant ones are;

1. Aeschynomeneae
2. Indigofera
3. Trifolieae
4. Gentisteae
5. Sesbanieae
6. Psoraleae
7. Stylosantheae
8. Desmodieae
9. Phaseoleae.

5.3 Morphology of Legumes

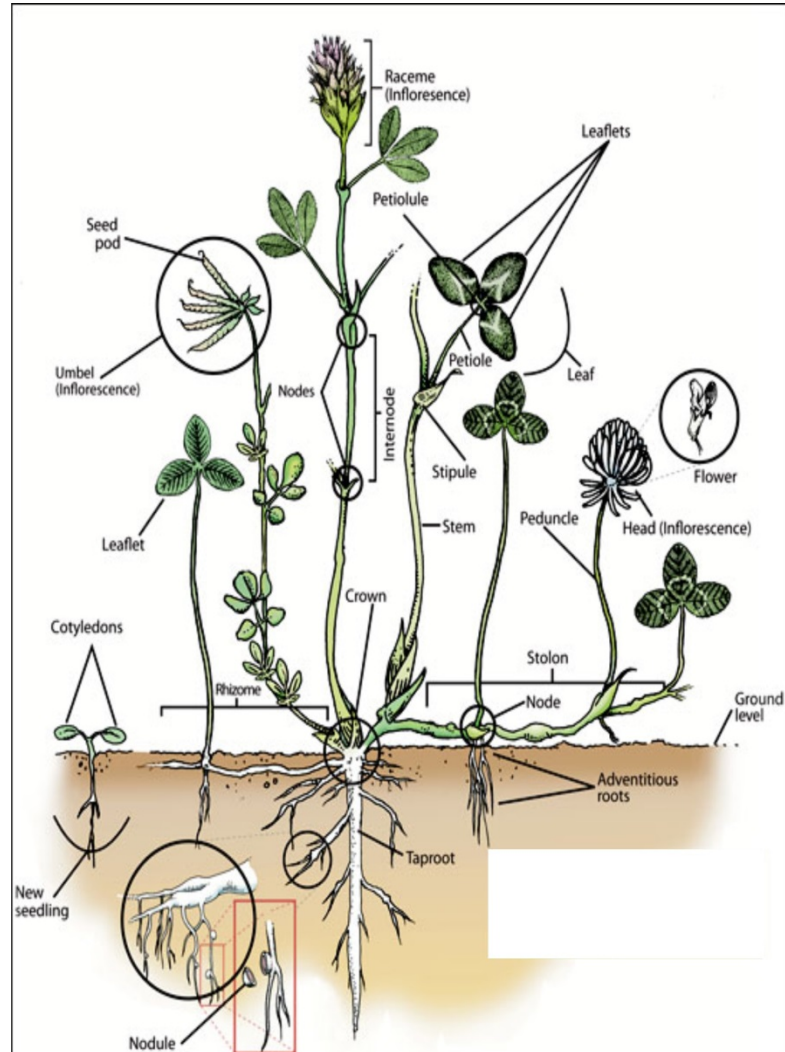


Fig. 22: Diagram of Legumes

While there are clear physical distinctions amongst the legumes, some share similar and uniform general traits.

Legumes are made up of Vegetative part and Reproductive parts

5.4 Vegetative part

The vegetative part of legumes can be further broken into the Aerial part as well as the subterranean part.

1. Aerial parts

The above-ground component consists of a primary stem with axillary branches, usually complex leaves, stipules, and inflorescences.

Tillers can occasionally emerge from the base region of the stem (crown), and stems also grow axillary branches.

The stems are joined, hollow and have internodes and nodes. They could have hairs covering them or they could be glabrous. Stems that are herbaceous have chlorophyll. The leaves have three or more leaflets, each with its own stem (petiolule), on a single leaf stalk (petiole).

The leaves may be "palmately" compounded, meaning that the petiole ends in leaflets that are directly linked to it (*Centrosema pubescense*), or they may be "pinnately" compounded, meaning that the petiole extends into a long, slender structure that has leaflets (*Clitoria ternatea*).

The distinctive trait of the legume family is the presence of pulvinus.

Stipules are leaf-like projections that vary in size and form and are used to distinguish between species. They are located at the base of the primary leaf stalk.

The stipules and leaflets might have hairs or be smooth.

Unlike the parallel venation of grasses, the leaves have a netted pattern of veins.

2. Subterranean parts

Majority of legumes have an active primary root system with secondary branches that sprout from it.

The main roots can reach a depth of 6 to 8 meters in the ground.

Leguminous plants have Rhizobium bacteria in their roots which proliferate and expand to produce nodules on the roots that vary in size, shape, and arrangement.

5.5 Reproductive Part

1. Inflorescence

- The *Mimosoideae* family produces dense heads of flowers or small globular, spike-like inflorescences, with the floral elements typically organized in sets of four.
- The long, colourful filaments of the many stamens make the flowers stand out.
- The flowers of the *Caesalpinoideae* family have overlapping petals and emerge in clusters or racemes, such as *Leucaena leucocephala* and *Acaciaspp.*
- In most cases, the stamens are separated, such as in *Gleditschia*, *Ceratonia*, and *Cassia* species.
- The flowers of the *papilionaceae* family are organized in racemes, like in *Desmodium* spp., in heads, like in *Trifolium* spp., or spike-like racemes, as in *Medicago sativa*.
- Every flower has a peduncle, or small stalk, of its own.
- The inflorescence may be terminal or auxiliary.

2. The flower

- The corolla has three different types of petals; the largest and most showy petal "standards" or "banner," which is the uppermost or outer petal, secondly, the wing petals with slender stalks called the "claw" and an expanded portion and lastly the keel, which is made up of two petals folded together and partially hidden by the wing petals, with the expanded portions more or less united at the outer margin into a boat-shaped structure.
- At the base of the flower, the five-toothed calyx creates a tube.
- The ten stamens that make up the androecium can have their filaments joined. The keel encloses the pistil and stamens.
- The superior ovary is an elongated structure that is made up of one carpel with one ovule, one row, or several ovules. The strominal tube surrounds the superior ovary.
- The nectar resides at the bottom of the corolla.
- A bent style surmounts the ovary and the stylar tip broadens into the stigmatic surface.

3. Fruit and Seed

- Some seeds break open and dehisce, such as *Macroptiliumatro purpureum* and *Centrosema pubescens*.

- Some ripened ovary forms a fruit of varying shape, like *Crotolaria spp.*, which are non-dehiscent.
- The reserve food in the cotyledon is kept in pods, which can either be hairless or glabrous.
- The testa, also known as the seed coat, encloses each seed.
- Hilum indicates the ovarian walls' attachment point.

Table 3: Some Tropical Legumes

S/N	Genus	Names	Scientific name
1	<i>Calopogonium</i> (climbing and perennials)	Calopo	<i>Calopogonium mucunoides</i>
2	Centrosema (climbing and perennials)	Centro	<i>C. pubescens</i>
			<i>C. pascorum</i>
			<i>C. brasilanum</i>
3	Desmodium (perennial and annual)	Green leaf Desmodium	<i>D. heterophyllum</i>
			<i>D. intortum</i>
		Silver leaf Desmodium	<i>D. uncinatum</i>
4	Lablab (annual, erect)	Lablab	<i>Lablab purpureus</i>
5	Lotononis (perennial herb, creeping stems)	Lotononis	<i>Lotononisbainesii</i>
6	Macroptilium (perennial trailing or creeping stolons, rooting at the nodes)	Siratro	<i>Macroptiliumatro purpureum</i>
7	Macrotyloma(trailing and twining, perennial herb, drought tolerant, not tolerant to waterlogging)	Horse grain	<i>Macrotyloma uniflorum</i>
		Archer axillaris	<i>Macrotyloma axillare</i>

Table 3: Some Tropical Legumes

S/N	Genus	Names	Scientific name
8	Medicago(erect, perennial, drought tolerant, frost tolerant, intolerant to waterlogging)	Leucerne	<i>Medicago sativa</i>
9	Pueraria (Vigorous climber, dense hairs, drought tolerant)	Puero	<i>Puerariaphase oloides</i>
10	Stylosanthes(Herbaceous, erect and perennial)	Cook stylo	<i>S. guianensis</i>
		Caribbean stylo	<i>S. hamate</i>
		Townsville stylo	<i>S. humilis</i>
		Shrubby stylo	<i>S.scabra</i>
11	Trifolium(creeping, annuals and perennial, drought tolerant (grows in spring))	White clover	<i>Trifoliumrepens</i>
		Kenya white clover	<i>T. semipilosum</i>
12	Glycine (perennial, climbing and trailing, twinning)	Glycine	<i>Glycine wightii</i>
		Soyabean	<i>Glycine max</i>
13	Vigna (annual or perennial, pulse)	Cowpea	<i>Vignaun guiculata</i>
		Dalrymple vigna	<i>Vignainteola</i>

5.6 Description of some Legumes

1. *Stylosanthes humilis*



Fig. 23: Stylo

Common names:

Townsville stylo, townsville lucerne

Description

- Townsville stylo, [(*Stylosanthes humilis* (Kunth))], is a low-growing annual (sometimes perennial) legume. It might grow to a height of 50–70 cm.
- It has a taproot, and in situations when it is severely grazed or experiences high levels of wetness, it may generate adventitious roots a few inches from the taproot.
- The stems are erect, hairy, slender, and having numerous branches; nevertheless, in situations with

high moisture content, they may become prostrate before rooting from the nodes.

- The leaves are trifoliate, with slender, pointed leaflets that measure 15 mm in length and 3.5 mm in width at the terminal position. Most leaflets are glabrous.
- When pollinated, inflorescence, spikes containing five to fifteen bright yellow flowers develop into hairy, one-seeded, articulated pods with hooked, yellow-to brown seeds.

2. *Glycine max*



Fig. 24: Soybean

Common names: Soybean forage, forage soybean, soybean hay, soybean straw

Description

- Soybeans, are a key legume crop farmed for their oil and protein-rich seeds. They are also used to make silage, hay, and important feed for grazing.

- It is a tall leguminous plant that can reach a height of 1.3 meters. In ideal soil conditions, its taproot can reach a depth of 2 meters, while its secondary roots can reach the top 15-20 centimetres of the earth.
- *Rhizobiumja ponicum* is frequently the cause of the nodules on roots.
- The flowers are *papilionaceous*, with a corolla that is 5 to 7 mm long and colours ranging from white to pink, purple, or bluish.
- The leaves are trifoliate, with leaflets that are oval to lanceolate and typically broad in some varieties.
- The fruits are made up of two or three pods that hold spherical, golden seeds that can range in colour from yellow to black.

3. *Desmodium scorpiurus*



Fig. 25: Samoan clover

Common names: Samoan clover, scorpion ticktre foil

Description

- It is a prostrate perennial legume that grows up to 50 cm long, and spreads easily from its trailing, ascending, or procumbent hairy stems.
- It has Trifoliolate, complex leaves.
- The elliptic, round or oblong-shaped, hairy leaflets are 0.5-4.5 cm in length and 0.2-1.8 cm in width.
- The pink or light purple flowers are papilionaceous.
- The fruits are hairy, cylindrical, four centimeter-long pods that are constricted around the seeds.
- The Latin name "scorpiurus" refers to the pods' potential to twist and resemble scorpion tails.
- The seeds are round, 2.3mm long and 1mm broad, and have a light brown hue.

4. *Mucuna pruriens*



Fig. 26: Velvet bean

Common names: Velvet bean, Mauritius velvet bean, Bengal bean,

Description

- It is an annual or occasionally a transient perennial.
- It grows vigorously, up to 18 m in length, and can trail or climb.
- It has a taproot and many lateral roots that are 7–10 m long. The stems are thin and have a hint of pubescence.
- In general, the leaves are trifoliolate, alternating, and slightly hairy. They measure 5–15cm in length and 3–12 cm in width.
- The inflorescence is a drooping axillary raceme that is covered in numerous white to dark purple flowers.
- Clusters of ten to fourteen pods are produced following flower pollination. With two to six seeds, they are robust, curved, and measure 10 to 12.5 cm in length. They have hairs that are either orange or greyish-white that can severely irritate the skin.
- The colour of the velvet bean seeds varies; they might be glossy black, white, or brownish with black mottling. The seeds are 0.5 cm thick, 1.2 to 1.5 cm long, and oblong-ellipsoid in shape.

5. *Pueraria phaseoloides*



Fig. 27: Peuro, Kudzu

Common names: Tropical kudzu, puero

Description

- Kudzu is a fast-growing, densely packed vine that is used in tropical regions for animal feed, green manure, and cover crops. It has hairy, slender stems that can grow up to 10m in length and 0.6cm in diameter.
- It is deeply rooted, reaching a depth of 2m. The stems may sprout several branches after rooting from the nodes. It grows in tangled swards up to 60–75 centimetres in height and possess trifoliolate leaves borne on hairy, 3–11cm long petioles.

- It has dense brown hairs covering the immature branches.
- The apical leaflet is triangular to ovate, cuneate at its base, shallowly lobed, and 2-20cm long by 2-16cm broad.
- The leaflets are thin, dark green on their upper surface, pale green on their below one, and pubescent. The lateral leaflets measure 6-7cm in length and 6-7cm in width. They are oblique, rounded, and obtuse at the base.
- The 15-30cm long axillary raceme that serves as the inflorescence is dotted with tiny, deep purple to mauve flower. After being fertilized, the flowers develop into linear, cylindrical, straight, or slightly curved pods, or fruits. 10 to 25 black, oblong, 3mm long seeds are contained in the 4-11cm long and 3-5mm wide pods. The pods have very little hair. When they are young and green at maturity.

6. *Lablab purpureus*



Fig. 28: Lablab

Common names: Lablab, lablab bean, hyacinth bean, field bean, pig-ears

Description

- It is a herbaceous plant that twines, climbs, trails, or stands upright reaching a maximum length of 3-6 meters.
- Its leaves are alternating and trifoliate; the plant has a strong, glabrous or pubescent trailing stem and a deep taproot.
- The leaflets have an acute tip and are rhomboid in shape, measuring 7.5–15cm long by 8–14cm wide.
- The underside bears small hairs, while the upper surface is smooth. The flowers are white to blue or

purple in colour, approximately 1.5cm long, and usually papilionaceous in shape.

- The inflorescences are multiple flowered racemes carried on elongated peduncles.
- The lablab fruits are linear, 4–15cm long by 1–4cm broad, smooth, and beaked pods that hold two to eight seeds each. The ovoid, laterally compressed Lablab seeds (beans) have a noticeable linear hilum.
- Depending on the cultivar or variety, lablab beans can range in colour from white to dark brown, with some even being black.

7. *Medicago sativa*



Fig. 29: Alfalfa

Common names: Alfalfa, lucerne

Description

- Alfalfa has erect or decumbent stems up to 1m high, glabrous or hairy in the upper parts.
- Its leaves are trifoliate, with obovate leaflets, 10–45mm long and 3–10mm broad

- Its roots are deep, reaching 4 m, but can reach 7-9 m in well-drained soils.
- The fruits are 2-8 seeded curly pods that turn brown from green;
- inflorescences are oval or spherical racemes with 5-40 yellow, blue, or purple flowers.
- Alfalfa comes in a variety of cultivars that are chosen for particular traits, such as drought resistance, winter hardiness, tolerance to high grazing (like the Spanish "Mielga" cultivars), or resistance to pests and diseases.

8. *Vigna unguiculata*



Fig. 30: Cowpea

Common names: Cowpea, asparagus bean, black-eyed pea.

Description

- Depending on the cultivar, this annual herbaceous legume can be ascending and erect or prostrate and creeping. It is planted for its edible seeds or as fodder.
- Climbing cultivars can reach a height of two meters, whereas prostrate varieties reach only around 80 centimetres.
- The trifoliate leaves have oval leaflets that are 4–11cm in width and 6–15cm in length.
- The papilionaceous flowers are arranged along auxiliary clusters and might be white, yellowish, pale blue, or violet in colour. Pods are erect or pendulous, and they usually grow in pairs in a V-shape.
- They are cylindrical, ranging in length from 6 to 20cm and in width from 3 to 12mm, and they hold 8 to 20 seeds. White, pink, brown, or black seeds are possible.

8. *Calopogonium mucunoides*



Fig. 31: Calopo

Common names: Calopo, wild ground nut

Description

- Depending on the cultivar, this annual herbaceous legume can be ascending and erect or prostrate and creeping. It is planted for its edible seeds or as fodder.
- Climbing cultivars can reach a height of two meters, whereas prostrate varieties reach only around 80 centimetres.
- Its trifoliate leaves have oval leaflets that are 4-11 cm in width and 6-15 cm in length.
- There are two to twelve tiny blue or purple blooms on the inflorescence, which is a slender, hairy raceme that can grow up to 20cm in length.
- The papilionaceous flowers are arranged along axillary clusters and might be white, yellowish, pale blue, or violet in colour.

- Pods are erect or pendulous, and they usually grow in pairs in a V-shape. They are cylindrical, ranging in length from 6 to 20cm and in width from 3 to 12mm, and they hold 8 to 20 seeds. Seed colour may be white, pink, brown, or black.
- The fruits are 2-4cm long, 3-8 seeded with hairy pods.

10. *Cajanus cajan*



Fig. 32: Pigeon pea

Common names: Pigeon pea, no-eye pea

Description

- Grown for its edible seeds, it is one of the most popular tropical and subtropical legumes.
- It is an erect, short-lived perennial leguminous shrub that typically reaches a height of 1-2 m, but it

can grow as high as 2–5 m. It develops a fast taproot quickly, reaching a depth of 2m.

- The stems are angular, branched, and have a woody base with trifoliate, alternating leaves which are pubescence.
- The oblong, lanceolate leaflets measure 2-4cm in width and 5-10cm in length.
- At the tips or axils of the branches, the flowers (five to ten) are arranged in racemes. The papilionaceous flowers are typically yellow in colour.
- Purple streaks can also be present.
- The fruit is a 5 to 9cm length by 12 to 13mm wide pubescent pod. It contains two to nine tiny, occasionally hard-coated, brown, red, or black seeds.

11. ***Centrosema pubescens*,**



Fig. 33: *Centro*

Common name: Centro or butterfly pea

Description

- Centro is a perennial herb that grows up to 45cm (17.5in) in height. The root system can extend up to 30cm below the surface, usually in conjunction with the nitrogen-fixing bacterium *Rhizobium*.
- Leaves are trifoliate, with elliptical leaflets approximately 4 cm × 3.5 cm (1.6in × 1.4in), dark-green and glabrous above, but whitish and densely tomentose below.
- Flowers are usually pale violet with darker violet veins, born in axillary racemes.
- Stems grow and branch rapidly, producing a dense mass of branches and leaves on the soil.

- Fruit is a long, flat pod that is dark brown; 7.5–15cm (3.0–5.9in) in length, with a maximum of 20 seeds inside.
- When ripe, the spherical, dark brown seeds have a diameter of around 4mm (0.16 inches).

12. Caribbean stylo (*Stylosanthes hamata*)



Fig. 34: Caribbean Stylo

Common names: Caribbean stylo, verano stylo,

Description

- It is a semi-erect, annual or short-lived perennial tropical legume, up to 75 cm high.
- Its stems are slender, multi-branched, without bristles, unlike the Townsville stylo, *Stylosanthes humilis*, which has many bristles.
- The leaves are trifoliate with shiny, lanceolate leaflets, 19-37mm long and 3-6mm broad.

- The inflorescence is a compact oblong spike bearing 8 to 14 small, yellow, hairy and papilionaceous flowers.
- The single-seeded pods are erect and segmented.
- The upper segment is glabrous and hooked, 6-7 mm long including the length of the hook. The seeds are kidney-shaped, dark brown, mottled and 2-2.5 mm long.

13. *Desmodium intortum*



Fig. 35: Desmodium

Common name: Green leaf desmodium (E)

Description

- It is a huge, ascending and trailing perennial plant with shorter internodes. It has root at the nodes and a

deep tap root with pubescent stems branch that are frequently reddish brown in colour.

- Generally, the upper surface of leaves has flecks ranging from reddish brown to purple.
- Leaflets are circular, 2–7cm long, 1.5–5.5cm broad, and have a length–width ratio of 1.4 to 1.
- Born in pairs, the inflorescence is fairly compact and has deep violet to pink blooms. There are eight to twelve seeds in the curving pod. There are 755,000 seeds per kg.

Chapter Six

FACTORS AFFECTING NUTRITIONAL VALUE AND PRODUCTIVITY OF PASTURE

6.1 Forage Quality

Forage quality is the degree to which an animal's nutritional requirements is met when fed the forage and it is measured in terms of the animal's ability to grow, provide milk, or make wool. When forage is an animal's only source of nutrients and is provided without limits (ad libitum), the quality of the forage can be determined. It is influenced by the animal's intake and forage's nutritional value, which includes its chemical composition and digestibility. Additionally, the species and class of the animal influences forage utilization, since forage may be more valuable to a certain kind of herbivore than another.

Animal performance, including growth and milk production, is determined by the animal's capacity for production, the amount of dry matter (DM) it eats, and the nutritional content of that DM. Thus, feed intake and feed nutritive content are the two forage-related parameters that impact animal performance.

These elements work together to define the forage's quality.

6.2 Factors Affecting Forage Nutritive Value

1. Genotype

Legumes have higher concentrations of total digestible nutrient (TDN) and crude protein (CP) than grasses. They generally have a higher nutritional value hence their incorporation into livestock diet is important. Although it is unsafe to generalize about the nutritional content of grasses, tropical or warm-season grasses like Bermuda grass usually have lower nutritive values than temperate or cool-season grasses like rye and ryegrass. The nutritional value of fodder varies greatly, nevertheless, both within and between grass genera and even between variants of the same species.

2. Maturity

The nutritional content of forage is significantly influenced by the stage of growth at the time of usage, whether as hay, haylage, or grazed fodder. The stem buildup and the deposition of poorly digested lignin in both the leaves and the stems, the nutritional value of the forage starts to decrease throughout the regrowth period. The physiological stage of growth can be used to determine the maturity of cool-season grasses and legumes. However, weeks of regrowth are a better measure of maturity for warm-season grasses, as flowering may start soon after regrowth commences. With respect to maturity effects on perennial grasses, the most dramatic difference is the decrease in voluntary intake between six and eight weeks, after eight weeks of regrowth, forage nutritive value will generally be less than needed for livestock maintenance.

3. Season

Africa experiences diverse climatic zones, ranging from arid and semi-arid regions to humid areas. The nutritional value of pasture can vary significantly between these zones. In arid regions, where water availability is limited and vegetation is sparse, the nutritional value of pasture tends to be lower. In contrast, humid regions with abundant rainfall can support more productive pastures with higher nutritional content.

Rainfall plays a crucial role in determining the growth and quality of pasture. In areas with seasonal rainfall, the onset, duration, and intensity of rains can significantly influence the nutritional value of pasture. Droughts are a common occurrence in many parts of Africa and can have a severe impact on the nutritional value of pasture. During droughts, the lack of rainfall limits grass growth, leading to a scarcity of high-quality forage. As the drought progresses, the available forage becomes more mature, fibrous, and less nutritious, which can negatively affect livestock nutrition. Temperature and Sunlight: High temperatures and intense sunlight can cause rapid evaporation and drying of grasses, resulting in reduced nutritional content.

4. Management

- a. **Pre-Harvest Management:** Weed control and regular cutting are important aspects of pre-harvest management for maximizing the nutritional content of forages.
- b. **Post-Harvest Management:** It is possible to reduce post-harvest reductions in the quality of silage or hay

by managing forages carefully. Hay must be properly cured to less than 15% moisture content and rain damage must be avoided as part of post-harvest management. The nutrient value of pasture is reduced by weathering-induced nutrient leaching. As a result, wherever feasible, hay bales should be kept beneath a barn or tarp. In order to properly manage silage, it must be protected from rain, allowed to wilt to 60%–70% moisture when needed, packed at a density of approximately 40lb/cubic foot (as fed), sealed silos (or wrapped haylage bales) as soon as the forage is harvested, and fed out at a rate that prevents heating (above 12 inches per day).

- c. The development of yeasts and moulds can also lower the nutritional content and acceptability of forage, which in turn lowers the amount of feed that animals eat. Yeast produces mycotoxins which can impair animal performance and result in illnesses in both humans and livestock.
- d. **Management of Grazed Pastures:** To maximize the nutritional content of fodder, pastures should be managed to maintain a leafy canopy that is free of weeds and not too old. The most crucial element in balancing the amount of forage and the needs of the animals is a proper stocking rate. N fertilizer use will raise forage CP and may also help with enhanced forage intake and animal performance.

5. Anti-Quality Factors

Anti-nutritional factors interfere with feed utilization directly or through their metabolic products, affecting the health and productivity of animals. Therefore, the accumulation of these compounds in forage is dangerous. Proper ensiling may reduce concentrations of these compounds to safe levels, but it is recommended for pastoral farmers to undertake periodic testing to ensure their forage is always at safe levels.

6.3 FACTORS AFFECTING PASTURE PRODUCTIVITY

- a. **Soil fertility** – A soil with low fertility will definitely not support adequate productivity. Soil fertility can however be improved by enrichment through organic or inorganic fertilizer.
- b. **Rainfall** – Adequate supply of water naturally from rainfall is required for pasture productivity but there may be need for artificial supply of water through irrigation in areas of low rainfall or during the dry season.
- c. **Topography** – Topography plays a significant role in determining the suitability of pasture land for grazing animals. Slopes, elevation, aspect, and soil characteristics can all impact pasture productivity. Steep slopes may limit access for livestock and machinery, increasing erosion risk. Higher elevations can affect temperature and precipitation levels, influencing the growth of pasture grasses. South-facing slopes receive more sunlight and warmth, promoting better grass growth. Soil depth, texture,

and drainage also impact pasture quality. Overall, topography influences water availability, temperature, and soil conditions, all of which affect pasture productivity.

- d. **Shrubs and Weeds** – These are unwanted plant materials that compete with pasture for nutrients, moisture and air, thus affecting their germination, growth and productivity.
- e. **Grass/legume mixture** – The ratio of grass to legumes must be balanced to ensure complete soil cover and balanced graze.
- f. **Bush burning** – Annual bush burning usually affects growth of pasture and this should be avoided.
- g. **Overgrazing** – Overgrazing of pasture by grazing animals should be avoided. Also uprooting of herbage should be avoided as this leads to erosion.

Chapter Seven

AQUATIC PLANTS

Like terrestrial plants, there are plants that grow in water, swamps, seas, rivers, streams, lakes, lagoons and other water bodies. These types of plants are referred to as Aquatic plants. They are photosynthetic organisms that grow wholly or partly in water either rooted in the mud or floating without anchorage.

Aquatic plants are also named macrophytes or hydrophytes and constitute the primary producer of the aquatic food chain, stabilizing shorelines, filtering water, and contributing to overall biodiversity. They live in diverse aquatic environments, ranging from the freshwater to marine habitats. These plants have unique features that allow them to thrive in water, including specialized structures for buoyancy, nutrient absorption, and gas exchange. They encompass a wide range of species, from floating plants like water lilies to submerged plants like seaweeds and pondweeds.

7.1 Classification of Aquatic Plants

Aquatic plants can be classified based on their growth habit and different ecological niche occupied within the aquatic environments.

- a) **Algae:** They are the most common type of aquatic plants. They are found in oceans as they have no true roots, leaves or stems. These types of algae are known as seaweeds. They are really small and are important part of the ocean food chain.
- b) **Floating Plants:** These plants float on the water's surface, and their roots hang below in the water. They do not anchor in the substrate and rely on buoyancy. However, they do have roots that absorb the water and nutrients from the water, while photosynthesizing directly with the sun. Their roots are firm and remain flat to absorb more water. E.g. water hyacinth, lilies.
- c) **Submerged plants:** These plants grow entirely underwater, and their leaves and stems are submerged. They extract nutrients and carbon dioxide directly from the water.
- d) **Emergent plants:** These plants have their roots submerged in water, but the majority of their stems and leaves extend above the water surface. They are often found along the edges of bodies of water.

7.2 Description of Common Aquatic Plants Found In Nigeria

1. Water Hyacinth (*Eichhornia crassipes*): A floating aquatic plant with thick, shiny leaves and lavender to violet flowers.
2. Water Lettuce (*Pistiastratiotes*): Another floating plant with rosettes of light green leaves.
3. Water Lily (*Nymphaea spp.*): These have beautiful, large, round leaves and showy, fragrant flowers. They can be found in various colours.

4. Water Fern (*Azolla spp.*): Small, free-floating aquatic ferns with tiny leaves that can cover the water's surface.
5. Elephant Ear (*Colocasia esculenta*): Although not exclusively aquatic, elephant ear plants are often found in wetland areas with their large, heart-shaped leaves.
6. Papyrus (*Cyperus papyrus*): An emergent aquatic plant with tall, thin stems and umbrella-like clusters of long, thread-like leaves.
7. Water Grass (*Echino chloa spp.*): Common in aquatic environments, water grasses have long, narrow leaves and may form dense mats.
8. African Water Fern (*Bolbitis spp.*): A submerged or emergent fern with finely divided leaves.

7.3 Importance of Aquatic Plants

Aquatic plants serve various important roles and have several common uses in different sectors. Here are some of the most notable uses of aquatic plants:

1. **Water Filtration:** Aquatic plants, especially submerged species like water hyacinth and water lettuce, are effective in filtering and purifying water by absorbing nutrients and contaminants. They play a crucial role in improving water quality.
2. **Habitat and Ecosystem Support:** Aquatic plants provide habitat and food for a diverse range of aquatic organisms, including fish, amphibians, insects, and microorganisms. They contribute to the overall biodiversity and stability of aquatic ecosystems.

3. **Oxygen Production:** Through photosynthesis, aquatic plants release oxygen into the water, contributing to dissolved oxygen levels necessary for the survival of aquatic organisms. Oxygenating plants like Elodea and Hornwort are particularly important for this purpose.
4. **Erosion Control:** Emergent and marginal aquatic plants, such as cattails and bulrushes, play a role in stabilizing shorelines and preventing erosion. Their root systems help bind soil together and reduce the impact of water movement.
5. **Agricultural Uses:** Some aquatic plants, like watercress and lotus, are cultivated for human consumption. These plants are rich in nutrients and are used in salads, soups, and various traditional dishes in different cultures.
6. **Phytoremediation:** Certain aquatic plants are employed in phytoremediation, a process where they absorb and accumulate pollutants from the water, helping to remediate contaminated environments. Examples include water hyacinth and duckweed.
7. **Ornamental and Landscape Purposes:** Water lilies, lotus, and other aesthetically pleasing aquatic plants are often used in ornamental ponds and water gardens to enhance landscaping and provide visual appeal.
8. **Aquaculture and Fisheries:** Aquatic plants contribute to the health of fish populations by providing shelter, breeding grounds, and food sources. In aquaculture, some plants are intentionally cultivated to create a balanced ecosystem in fish ponds.

9. **Biofuel Production:** Certain aquatic plants, like algae and duckweed, have the potential to be used for biofuel production. These plants can be harvested and processed to extract oils for biodiesel or bioethanol production.
10. **Traditional Medicine:** In various cultures, certain aquatic plants have been used for medicinal purposes. For example, extracts from water hyssop (*Bacopamonnieri*) are used in traditional medicine for cognitive enhancement.
11. **Educational and Research Purposes:** Aquatic plants are essential subjects for ecological research, environmental studies, and educational purposes. They serve as model organisms for understanding plant adaptations to aquatic environments.

Understanding and appreciating the ecological, economic, and cultural roles of aquatic plants can contribute to their sustainable management and conservation.

7.4 Aquatic Weeds Used as Fodder for Animals

Certain aquatic plants are used as fodder for animals. These plants are often rich in nutrients and provide a valuable source of feed for livestock. Here are some examples:

1. Water Hyacinth (*Eichhornia crassipes*):



Fig. 36: Flower of *Eichhornia crassipes*

Also known as *Pontederia crassipes*. Water hyacinth is a perennial, free floating herb found in freshwater environments. It dwells on the surface of rivers, canals, lakes, and ponds and can be rooted in muddy shallow waters. While water hyacinth is considered as invasive species in many regions due to its rapid growth, which is disruptive of water transportation, the plant has its use as fodder for animals. Lots of researches have been conducted on its application as a feed item for cattle. It is particularly high in protein content and can be fed to cattle, goats, and other livestock after proper processing. Animals are typically fed the aerial portion (leaves and stems without roots) or

just the leaves. It can be fed to animals fresh, dried, ensiled, chopped, ground or whole.



Fig. 37: Picture of *Pontederia crassipes*

- 2. Duckweed (*Lemna spp.*):** Duckweed is a small, free-floating vascular aquatic plant that grows rapidly. It can be found all over the world in fresh or brackish waters. The duckweed family, *Lemnaceae*, have five genera with about 40 species. The five genera are *Lemna*, *Landoltia*, *Spirodela*, *Wolffia* and *Wolffiella*. Their morphology is incredibly simple, as they have no stems or genuine leaves and are often composed of a single or a few flat, oval-shaped, tiny fronds. Most species reproduce through vegetative propagation, with plants clustering in colonies and forming green mats on the water's surface. Floating duckweed mats frequently contain multiple species, such

as Lemna and Wolffia. Highly rich in protein it can be used as a supplementary feed for poultry, fish, and livestock. Duckweed can be dried and incorporated into animal feed formulations.



Fig. 38: Picture of *Lemna minor*

- 3. Azolla (*Azolla spp.*):** Azolla is a water fern that develops on the surface of water that is stationary or moving slowly. It consists of a small, branching, floating stem with roots that dangle down in the water and alternately arranged leaves. An anthocyanin pigment present in the plant gives the fern a reddish-brown colour due to some conditions. Azolla plants are polygonal or triangular in shape and float on the water's surface as individuals or as mats. They resemble a dark green to reddish carpet, with the exception of *Azolla nilotica*, which lacks the red anthocyanin pigment. Azolla has a symbiotic relationship with nitrogen-fixing cyano bacteria, *Anabaena azollae*

making the plant a nitrogen-rich feed. This aquatic plant has a historical role in agriculture as it has been used for centuries as a bio-fertilizer and green manure for the rice crop due to its N-fixing abilities. The promotion and research of azolla as a livestock feed has increased due to its greater protein content (19-30%) compared to most green fodder crops and aquatic macrophytes, which is beneficial to animal nutrition. Azolla can be a useful protein supplement for various animals, including ruminants, pigs, poultry, and fish. It can be fed to livestock either fresh or dried.



Fig. 39: Picture of *Azolla species*

4. **Water Cress (*Nasturtium officinale*):** Watercress is a semi-aquatic plant that grows in shallow water and belongs to the family Brassicaceae. It is often confused for the garden cress which grows rooted in soil. In contrast, water cress has floating roots that grow freely in natural spring and highly appreciated in the

Mediterranean as part of salads, soups and cuisine due to its peppery and slightly tangy taste. It is considered as a weed in Africa and not cultivated on a commercial scale, unlike other countries where its medicinal and life-healing properties are highly appreciated. It is rich in vitamins and minerals; containing more calcium than milk, more vitamin C than orange and more iron than spinach. It is locally known as **ipara-omi** in Yoruba Language. It can be fed to various animals, including rabbits, goats, poultry and fish.



Fig. 40: Picture of *Nasturtium officinale*

- 5. Pondweeds (*Potamogeton spp.*):** Pondweeds are perennials with underwater leaves scattered on long flexible stem that are rooted to the bottom. Some have

floating leaves that are different from the submerged ones. The submerged leaves are usually translucent and thin while floating leaves have broad, opaque, leathery textured leaves. It can be found both in fresh and brackish water. *Potamogeton* species reproduce majorly through asexual propagation via rhizomes, shoots and turions. It has been reported to have high protein, carbohydrate, nitrogen and potassium content but with low level of micro-elements. It can however be fortified. Some species of pondweeds are palatable to livestock and can be grazed directly or harvested and used as fodder. They are majorly found in freshwater bodies and can contribute to the nutritional needs of animals.



Fig. 41: Picture of *Potamogeton* species

- 6. Reed Canary Grass (*Phalaris arundinacea*):** While not fully aquatic, reed canary grass is often found in wetlands and along water edges. It is a tall growing perennial grass with rhizomatous root. It is used for pasture, hay and

erosion control. It is drought and flood tolerant. It grows aggressively, majorly the first aquatic plant during the growing season and thus have the best result for pasture system. Animal grazing on it perform better than those grazing on some other pastures and its hay are more preferred by horses. Reed canary can be planted with legumes. It has flowers that occur on a narrow panicle. Flowers are greenish to purplish in colour, densely clustered in a single floret.



Fig. 42: Picture of *Phalaris arundinacea*

It's important to note that the use of aquatic plants as fodder may require proper processing, drying, or ensiling to improve palatability and nutrient retention. Additionally, care should be taken to avoid the introduction of invasive

species when utilizing aquatic plants for animal feed. Other aquatic macrophytes used as fodder in Nigeria include Hippo grass (*Vossia cuspidata*), Antelope grass (*Echinocloa pyramidalis*), Seashore paspalum (*Paspalum virginatus*), Burgumillet (*Echinocloa stagnina*), Common wild sorghum (*Sorghum arundinaceum*), Para Grass (*Brachiaria mutica*) and Swamp rice grass (*Leersia hexandra*). Always consult with local agricultural experts and follow appropriate guidelines for feeding practices.

Chapter Eight

PASTURE AND FORAGE CROP ESTABLISHMENT

The establishment and upkeep of pastures contribute significantly to the improvement of the quality of grass and legume feed, which is essential for the growth and well-being of livestock.

A well-managed natural pasture may be able to quickly adjust to its new surroundings because it has the correct amount of air, nutrients, moisture, and soil structure. Nonetheless, favourable weather conditions and proper management techniques are required. Whether they are foreign or native species, poorly managed pastures will not develop well.

Through the process of photosynthesis, only plants are able to produce their own food. Plants are the primary source of food for livestock, either directly or indirectly. Through biochemical processes (catabolism and metabolism), livestock transform these plants into protein. The plant can be used by animals as food, fodder, forage, etc. They are found in an area referred to as pasture.

8.1 Importance of Pasture Establishment

- It improves native or natural grasslands by introducing new species through planting,

transplanting, or soil enrichment through fertilizer, which increases yield.

- It results in the rehabilitation of pasture that was previously established.
- It improves already-cultivated land to enable efficient output.
- It causes forested land to be developed.
- It contributes to feed availability throughout the year.
- It contributes to improving animal health and lowering the cost of feed.

8.2 Types of Pasture (Based on Duration)

Pastures are classified based on duration as Temporary, Semi-Permanent or Permanent.

A. Temporary Pastures

A pasture is considered temporary if it is created with the plan to turn it into a farm within a few years. The kind of cattle business the farmer wishes to start and the resources at his disposal will determine this. The decision of the farmer on the duration of use of these pastures will also be influenced by the quantity of animals on the farm. To prevent harm to the environment, the farmer must use caution while selecting the species of pasture to be established.

These are pastures created as part of a rotation system, either to supply feed for animals or for non-feeding objectives including moisture conservation, erosion prevention, and disease and insect management. Additionally, they might contribute nutrients to the soil, increasing its fertility. It is possible to utilize both annual

and perennial plants, but they must be readily eliminated. Because they have been established on healthy soils, they have a high production. They last endure for three to five years.

Establishment of Temporary Pastures

On regions that are already fertile, reasonably plain, and free of rocks, temporary pastures are constructed. Ploughing, harrowing, levelling, and ridging should be done to ensure the site is ready. Prior to sowing, the appropriate number of seeds have to be acquired from a trustworthy source. Establishing field crops and the agronomic process are comparable. Nonetheless, timely fertilizing and weeding are essential, particularly in the first year of establishment.

Merits and Demerits of Establishing Temporary Pastures:

- The farmer can include animal production into pastures
- Chemicals are used less frequently to control insects, pests, and diseases on the farm
- The soil becomes more fertile
- They are readily eliminated

The following disadvantages could prevent these pastures from being established:

- They might not accomplish the goals for which they were created
- Farmers might have to pay more for fertilizers, particularly for grass species
- They might not be able to tolerate extensive defoliation or livestock grazing.

B. Semi-permanent Pastures

These are pastures that were set up as a component of a rotation system, usually as a result of a cropping phase break. There are a number of reasons why the cropping phase may end, including a sharp drop in crop prices, an epidemic, poor soil fertility, or a change in the farmer's mind. For this reason, cattle production is only temporarily incorporated into these pastures—typically for five to ten years—before the pastureland is once more turned over to cropland.

Establishment of Semi-Permanent Pastures

Establishing semi-permanent pastures requires rich, well-drained, and soil that is not undulated. Agronomic measures that are advised should be followed to ensure the site is well-prepared. Plots of leguminous 28 forages, such *Mucuna pruriens*, should closely trail plots that were previously planted with cereal crops.

Advantages and Disadvantages of Establishing Semi-Permanent Pastures

- The freedom to return to crop cultivation whenever one pleases
- Sufficient protection of the soil from direct heating by sunlight.
- Appropriate conservation of soil organisms, which enhances soil health
- An increase in farmers' income from the sale of fodder or other crops.

Disadvantages of establishment of semi-permanent pastures:

- These pastures can occasionally be potential sources of pests on the farm
- Some might be challenging to remove with common tools like hoes.
- Some might not establish well, particularly if they are mismanaged and compete with other crops.

C. Permanent Pastures

The species that have underground rhizomes and stolons are the ones that define permanent pastures. These organs serve as storage and help these pastures withstand hardship. After these pastures become well-established, there is no need to reseed them. These pastures may consist of a single species or a mix of species pasture. Their establishment takes place on rich, non-wet, and non-stony soil. The site needs to be properly prepared using the advised agronomic practices. These pastures are tough to remove once they've taken hold.

Advantages and Disadvantages of Establishing Permanent Pastures

- Their underground organs help preserve the soil's structure
- They supply livestock with a large amount of forage
- They are resistant to natural and man-made hazards like fire outbreaks and drought
- They are easily able to cover a large area of land due to their rapid seed production
- Farmers can earn additional revenue from the sale of harvested forage.

8.3 Drawbacks affecting the establishment of pastures:

- They are highly expensive to build and maintain
- Livestock may be compelled to graze on a single type of pasture without choice
- They may act as possible hosts for some disease vectors, such as snails, etc.

The process of establishing pastures usually follows a set timeline which should be adhered to strictly. This comprises:

1. Site selection: This may vary depending on the area where the pasture will be planted. Nonetheless, the location should be suitable for growing field crops, and it should be level and not rocky.
2. Land clearing: Either by hand, with chemicals, by machine, or by burning should be used to accomplish this. When making a choice, one should, however, determine the cost-benefit ratio of these approaches.
3. Ploughing: it is the procedure that turns or loosen or breaks the soil into smaller forms before planting. During this process, weeds and other unwanted plants already growing on the site are incorporated into the soil and contribute significantly to the organic content of the soil.
4. Harrowing: This is the second phase of land preparation, during which the soil is further broken down into tiny particles. Rough harrowing is necessary.
5. Use of Herbicide: Chemicals called herbicides possess the ability to eradicate weeds and their seeds.

5.2 Types of herbicides

1. Post emergence/contact herbicides: This kind of herbicide is used to eradicate weeds that have already sprouted e.g Gramoxon.

2. Pre-emergence herbicide: It is the kind of herbicide used to kill soil-borne weed seeds.
3. Specific herbicide: It is the kind intended to eradicate a specific type of weed.
4. Systemic herbicide: This kind of herbicide kills the specific portion of the weed. The leaf, stem, or root.

On farms, herbicide can be sprayed using a "knapsack sprayer.

8.5 Importance of Soil Tillage

Tillage is the preparation of soil for planting and the cultivation of soil after planting¹. It is the manipulation of the soil into a desired condition by mechanical means.

- This enhances soil aeration.
- It improves nutrition absorption.
- It facilitates root penetration with ease.

A. Seed/Seeding

Seedbed preparation- The best way to prepare seed bed is to prepare the land well. For large-seeded legumes, this can be accomplished by levelling, harrowing, ploughing, and creating ridges.

- B. Seed treatment: Fungicides and insecticides should be applied to pasture seeds prior to sowing. Hot water treatment is sometimes used to treat seeds in order to induce dormancy. This is referred to as scarification. Additionally, to aid in germination and establishment, some pasture seeds, like *Lablab purpureus*, are injected with a rhizobium strain of bacteria. Nonetheless, the amount of seeds to be used (seed rate) needs to be calculated per hectare. For grass

species, the seeding depth must be shallow (2 cm), while for legumes, it must be medium (5-7 cm).

8.6 Planting/Sowing Methods

There are three ways to plant or sow pasture seeds:

- ii) Planting,
- iii) drilling, and
- iv) broadcasting

Large-seeded legumes like *Lablab purpureus* and *Mucuna pruriens* are the principal ones that are planted. For the best plant population, these pasture seeds are sown using the available inter- and intra-row spacing (25 cm × 75 cm). Drilling does not include intra-spacing; instead, a single, continuous hole is bored through the seeds uniformly. The seeds are dispersed on the field for broadcasting. For grass and legume seeds with tiny seeds, drilling and broadcasting techniques are used. Sometimes, especially on windy days, it is best to employ a carrier agent when planting, like sand, fertilizer, or sawdust, to help seeds land where they are supposed to.

Seed quality: Physical quality, genetic quality, seed viability, and seed rate are all taken into account when determining seed quality.

- a. Physical quality: this implies that the seed is complete. The seed's appearance is important since it will affect its ability for germination. Therefore, before purchasing or planting the seed, it is essential to

determine whether the seed has damage or is properly developed.

b. Genetic quality: The following genetic factors have a significant impact on pasture performance:

- Rapid growth
- Resistance to the area's unfavourable climate.
- Resistance to pests and diseases
- Resistance to the pressure of grazing
- Rapid regeneration following grazing.

Seed viability

Germination is the ultimate goal of seed sowing. The viability of the seed is based on the rate of germination. The ability of the seed to survive is referred to as seed viability. It indicates whether or not the seed is a living.

Therefore, if high-quality pasture establishment is to be achieved, seed viability needs to be checked.

Viability test

The percentage germination rate, as its name suggests, is the proportion of seeds that sprout for each unit of seeds sown. For example, 60% germination is attained if 100 seeds are sown and only 60 of them germinate.

Why seed viability test?

All seeds are expected to produce new plants when sown on the field. Hence, seed must be of high quality and viability at the beginning of the storage and during storage. Seeds with high initial viability are capable of surviving longer storage period. Poor and improper storage conditions

may affect the viability and quality of seeds. It is therefore important to carry out viability test of seeds before seeds are packaged for storage or sales, during storage and before planting.

How to determine seed viability/percentage germination

Viability test is demined majorly through germination test, sometimes biochemical test is also carried out. The latter is not as accurate as the former.

Process of Germination test

- (i) Gather a known sample of seeds and set them in a Petri dish
- (ii) Make sure there's an absorbent (cotton wool or paper absorbent) that can take up water
- (iii) Add water;
- (iv) Let it sit in the sun for five days.
- (v) Keep track of how many seeds germinate.

Once all of the seed is sown in the grazing area, 60% of the seeds will have germinated if you choose 100 seeds and 60 of them germinate. This will enable you to raise the seed supply even further in order to compensate for the 40% of seeds that will not germinate.

Seed quantity: Many factors affect how much seed should be spread in a particular plot of land, hence it is impossible to determine the precise or exact amount of seed per kilogram, however it can be guessed.

These elements consist of the following:

- i) Seed viability (germination rate)
- ii) Seed dormancy; and
- iii) Predator issue.
- iv) Replanting;
- v) Erosion and Irrigation.
- vi) The pasture crop species.

Plant density: This is a reference to the number of plants in a specific land area. It can be expressed as follows:

$$\frac{\text{number of seed per stand} \times \text{spacing} \times 10,000 \text{ha}}{\text{Area of land}}$$

A 100m² plot of ground may hold roughly 60 kilogram of *Andropogon gayanus* seed, however in order to account for the previously mentioned conditions, an additional 20% of the 60kg should be planted. Thus, an estimated 72 kilogram of *Andropogon gayanus* seed are needed for a 100m² plot of land.

8.7 Post-Planting Operations

It is anticipated that some procedures will improve grassland species germination and lead to improved fodder output and quality.

The following are some of these operations:

1. Weeding:

This can be done mechanically using tractor-coupled tools like a weeder, chemically with herbicides, or

manually with hand hoes. Depending on the severity of the weeds and the management, weeding should be done two to three weeks after planting. For better outcomes, weeding in commercial pasture production is done mechanically.

2. Fertilizer Application

Fertilizer: is any substance that is applied to the soil with the intention of enhancing plant growth. Fertilizer can be organic or inorganic.

- (a) Organic fertilizer: It is the kind of fertilizer that comes from either plants or animals. Examples include plant waste, animal excrement, and industrial waste.
- (b) Inorganic fertilizer: It is the kind of fertilizer made of inorganic substances. Compound and single fertilizers are two examples.
- (c) Compound fertilizers: Fertilizers that contain many elements are referred to here. N.P.K. fertilizer is one example.
- (d) Single fertilizer: fertilizer with only one element.
- (e) Urea, superphosphate, and other examples are given.

For the pasture to expand more quickly, fertilizer needs to be added to the soil.

8.8 Irrigation

Irrigation refers to the artificial application of water to the soil. Artificial application of water to the soil is needed to provide moisture which is essential to the plant growth. It is necessary during prolonged drought to save dry land crops and for out of season production of crops.

Advantages of Irrigation

1. Irrigation provides the moisture to the soil.
2. Irrigation plays a vital role in increasing food production.
3. Proper irrigation prevents drought conditions which affect food production.
4. Irrigation also reduces the wastage of water.
5. Fertilizer can be applied through the irrigation.

Types of irrigation

1. **Surface irrigation:** When the water is distributed or supplied over the soil surface by gravity is known as the surface irrigation. It is the most common irrigation technique which is used by most of the farmers in their field. It is also known as Flood irrigation.

Advantages of surface irrigation

- They have relatively low energy requirements in routine operations.
- This type of irrigation technique can be developed at the farm level with minimum investment.

2. **Sprinkler irrigation:** It is also known as the Overhead irrigation. Application of irrigation water is similar to natural rainfall. Water is sprayed into the air through sprinklers. This type of irrigation system is mostly suitable for the row, field and tree crops.

Advantages of sprinkler irrigation

- Water is applied in a consistent manner.
 - Suitable for leaching salts from saline soils.
 - There is no risk of runoff or erosion.
3. **Drip irrigation:** Drip irrigation was discovered in Israel by Simcha Blass, and the water flow rate per dripper is typically 1-4 lit/hr. The water diffuses through the soil due to capillary action. The main pipeline, submains, laterals, and emitters are all part of it drip irrigation system.

Advantages of drip irrigation

- No land levelling is required.
 - It can save up to 70% of water and even more.
 - Herbicides and fertilizers are applied to the crop by solubilising into the irrigation water, which is referred to as Herbigation (Herbicide+Irrigation) and Fertigation (Fertilizer application through irrigation).
4. **Subsurface irrigation/Subsoil Irrigation:** in this system, water gradually wets the root zone by capillary movement through subterranean perforated pipes and deep ditches at 15-30 m intervals.

Defoliation:

This is the process of chopping off plant shoots in order to enhance growth and produce high-quality fodder. Depending on the species, the habitat, and management, pasture species may undergo defoliation two to three times year.

Chapter Nine

PASTURE MANAGEMENT

A livestock farmer's main objective is to turn a profit. A few elements are deftly applied to two fundamental biological processes in order to accomplish these goals: the grazing animals and the pasture sward, or the available herbage for grazing.

Pasture is managed using a few cultural customs. They consist of stock water development, reseeding, irrigation, fertilizer application, weeding and grazing.

Stock Water Development:

Where there is water available, animals will gather to graze. The effectiveness of grazing will be improved on a pasture field with evenly distributed water.

Re-seeding:

Introducing new seeds to an established pasture are what this entails. It is done in pastures that have been lost due to weeding, erosion, and overgrazing.

Irrigation:

Due to evapo-transpiration inside the grazing field's microclimate, there is a greater amount of soil water loss during the dry season. This can result in low forage productivity. Farmers water the field so that plants can use it as a solution to this issue. We call this procedure irrigation. It is important to design an effective irrigation

system that will improve the availability of sufficient water throughout the pasture land.

Fertilizer application:

To increase soil fertility, fertilizers either organic or inorganic are typically added to the soil. When there are insufficient nutrients in the soil to support pasture plants.

Fertilizer that is inorganic might be either simple or complex. Compound fertilizers, such as N. P. K. (nitrogen, phosphorus, and potassium), are examples. Inorganic fertilizers include superphosphate and urea. For optimum pasture growth all essential nutrients must be present in sufficient amounts. If any nutrient is deficient, pasture growth will be limited by this deficiency, even if all other nutrients are in abundance.

Soil testing is a vital part of fertilizer use. Savings can be made by using fertilizers only when and where they are needed. Using fertilizer on steep country with shallow, infertile soils is less likely to be economic. Some fertilizers and farming practices can gradually acidify the soil, particularly the poorer sandy ones.

If fertilizers are used correctly, they can decrease the amount of pollutants in runoff and leaching.

9.1 Factors to consider before fertilizer application

- The soil's nutrient level: Soil testing in the laboratory is the main way to determine the fertility of a soil. Soil tests are required to prevent the under or oversupply of nutrients, monitor changes in nutrient levels over time and help decide which areas to fertilize.
- The soil's response and pH level (acidity and alkalinity): pH is a measure of how strongly acid or alkaline a substance is. Soil pH measurements are made in a 1:5 solution in water (pH_w) or calcium chloride (pH_{Ca}) or as

a field test using soil test kits (test papers). Acid soils with pH below 5 requires less nitrogen fertilizer. Because nitrogenous fertilizers cause the soil to become more acid. Fertilizers such as ammonium phosphate, ammonium sulphate, mono ammonium phosphate, and diammonium phosphate decrease soil pH while Urea, ammonium nitrate and anhydrous ammonia are less acidifying.

- The pasture field's size: Bigger sized pasture field require large quantity of fertilizer than small sized pasture. To prevent wastages and inappropriate use of fertilizer, it should be evenly applied.
- Forage crop's nutrient requirements in the field: Forages often shows deficiency symptoms of nutrients when they are limiting or absent in the soil. These deficiency symptoms help the farmers to know the type of fertilizer to apply. For example, pasture deficient in nitrogen are patchy and often show a pale green-yellow colour.

9.2 Mineral application

Mineral salt is used for grazing distribution. The animals focus more on the region where the salt is present. They graze more as a result of it stimulating their appetite.

9.3 Weeding:

This entails clearing the pasture field of non-forage plants, or plants that animals do not eat. It can be accomplished chemically (using herbicides) or mechanically (using machines).

9.4 Fencing

In terms of grazing distribution and control, fencing establishes ownership. Fences can significantly increase livestock grazing efficiency. The first step in planning livestock fencing is determining the purpose and goals of the fencing program. Livestock protection and confinement are not the only reasons to consider fencing. An effective rotational or other intensively managed grazing system can be an affordable way to provide forage to grazing livestock and reduce herd nutrition costs year-round. Fencing needs vary depending on the type of grazing management system and livestock species, class, and age. Determine the operation size, number of animals, type of forage system, and number of paddocks needed before investing in fencing materials is necessary.

Types of Fencing

There are two types of fencing systems:

1. **Fixed fencing system:** In this type of fencing, the fencing materials are permanently fixed and are intended for a long term usage e.g. use of perennial trees as fence.

Advantages Fixed fencing system

- Minimum daily labour
- Low maintenance
- Low cost per acre on large installation

Disadvantages Fixed fencing system

- High cost per acre on small installations
- Limited management flexibility

2. **Flexible fencing system:** this types of fencing systems include a temporary boundary fence consisting of woven or barbed wire or electrified, high-tensile smooth wire to ensure that livestock are restrained on the ranch. These fencing materials are adjustable and moveable.

Advantages of flexible fencing system

- High management flexibility
- Low cost per acre on small installations

Disadvantages of flexible fencing system

- More labour
- High maintenance

Fencing of pasture can be in form of Perimeter fencing or Internal fencing

Perimeter fencing: This demarcates the pasture from other vegetation or farm land.

Internal fencing: This divides the pasture into individual paddocks, making it simple to manage the animals while they graze.

9.5 Grazing and Grazing Management

Grazing is the process by which ruminant, etc. animals eat grass in the field. Grassland's botanical composition reflects both past and present grazing pressure. As grazing

pressure increases, more green grass growth would be encouraged and dominate the sward.

A number of the grasslands have completely changed as a result of the increased grazing pressure brought about by the introduction of domestic animals; others have improved thanks to clever livestock management.

Grazing management is the intelligent and deft regulation of two fundamental biological systems: the grazing animal and the pasture sward, or the available herbage for grazing.

A livestock enterprise's manager or producer works to control the number of animals in order to make the most effective use of a variable herbage supply. Variables impacting either system will ultimately affect the amount of output per animal (meat, milk, wool, reproduction, and hides) as well as the yield of pasture per hectare.

9.6 GRAZING SYSTEMS

- **Zero grazing:** This type of grazing involves cutting the fodder to feed livestock that is housed or contained in a certain area. Zero grazing might take the form of preserved food (hay, silage, etc.)
- **Direct system:** animal grazing straight on the pasture is one of the techniques used. Grazing practices that are examples include creep grazing, block grazing, paddock grazing, continuous grazing, and mixed grazing.
- **Continuous grazing:** This is a technique in which the livestock are given permission to graze over a sizable region for a considerable amount of time, perhaps two to three months.
- **Paddock grazing:** This is an extremely structured approach to rotational grazing, with the grazing area

divided into roughly 21-28 permanent fences and equal-sized paddocks. The goal is to graze one paddock every day, with the rotation around the area ending as soon as the first paddock is once again ready for grazing.

- **Block grazing system:** The system's objective is to allow for rotational grazing by dividing the grazing area into many sizable chunks. For a brief time typically one to seven days, a single block of grass is grazed by numerous animals, after which it is relocated to another block to allow for regrowth. The block is suitable for grazing once again after roughly 20 to 28 days. For conservation purposes, the excess blocks from grazing are cut.
- **Strip grazing:** This entails using an electric fence to provide a new herbage strip once or twice a day.
- **Mixed grazing:** This term is used to describe the grazing practices of various livestock species, such as sheep and cattle, on the same land, regardless of whether the two animals graze the same area at the same time.
- **Creep grazing:** Creep grazing is the technique of letting young animals, such as calves or lambs, graze in a region that is inaccessible to their dams. It improves young stock's effective use of the grass and effective parasite control.
- **Rotational Grazing:** This is the grazing system where animals rotate between different grazing areas before returning to the formal grazing area for a set amount of time. Here, there are no fences around the meadows, so the animals are free to graze anywhere in the area.

Chapter Ten

FODDER CONSERVATION AND PRESERVATION

Fodder: This is forage that has been harvested with the intention of preserving it and providing it to the animal at a later time.

Preservation: Preservation is the process of preventing the fodder from becoming bad. Preservation is about maintaining the quality of fodder for the animals.

Conservation: Conservation is the process of storing forages in a conducive environment while keeping their nutritive qualities intact. The word conservation and preservation become twin terms that must go together if the full weight of their meaning is to be realised and appreciated.

10.1 Objective of fodder conservation and preservation

The main goal of fodder conservation is to ensure that animals have a steady supply of fodder for the entire season.

When there is no available fodder for grazing, cattle are fed on conserved fodder. An important consideration when forage grasses emerge as a grazing excess is to remove the crops as soon as possible to enable re-growth for additional grazing.

Cutting green crops triggers biochemical changes that, if left unchecked will lead to material breakdown and the release of heat and effluent. Although, there are methods of preventing progressive degradation which includes acidification, dehydration and chemical techniques.

Acidification

If the material is under anaerobic (oxygen-free) condition, deterioration ceases when the pH of the substance drops below 4.2–5.0 (depending on the moisture content of the material e.g. Silage).

Dehydration

When the substance reaches 85% dry matter, degradation ceases. Dehydration occurs naturally in the field and during the process of making hay.

Chemical preservatives: Certain chemicals have the ability to stop the deterioration process, keeping the materials nearly in their original chemical condition after they are sliced. Research is currently being carried out to find appropriate compounds that will economically conserve herbage without limiting animal intake, interfering with rumen fermentation, or ending up in animal products.

10.2 Different Methods of Forage Preservation and Conservation

Forage preservation and conservation basically aims to produce at low cost, a stable product suitable for ruminant animal feeding and other non-ruminant herbivores with minimum loss of nutritive value. It also bridged the gap between the feed requirement of the animals and the production of the forages. Two major methods are used to conserve and preserve forages:

1. Silage

Silage is a fermented green leaf feed. The process of ensilage involves keeping green feed in a succulent state in acidic conditions. By limiting the flow of oxygen during the

silage-making process, microorganisms manage the fermentation process. These microbes are separated into the following groups:

The desirable bacteria: The good bacteria are mostly of the lactobacillus and streptococcus species, which are capable of converting carbohydrates into lactic acid. The crop is chopped mechanically, the silo is quickly compressed, and the air is kept out, all of which promote the even distribution of germs.

The crop's moisture level determines the pH at which this process happens; the wetter the fodder, the lower the required pH and the greater the amount of lactic acid that must be produced.

Undesirable bacteria: These are the ones that convert carbohydrate into carbon (IV) oxide and water, obligate carbohydrate and lactic acid to form butyric acid. *Clostridium sporogenes* break down amino acid to ammonia and amines, some of which are toxic to the livestock.

It is possible to prevent *Clostridal* activity in silage by:

- Cutting the grass's moisture content, as this will require less acid to keep it from decomposing.
- Making sure there are enough carbohydrates present for lactic acid bacteria, or adding acid to help decrease the pH.
- Preventing contamination from animal dung or soil, as they both have high clostridium levels.
- Attaining a high packing density in a silo is important because it determines the porosity at which air moves into the silo and subsequently the amount of spoilage

that occurs during storage and feedout. Silage density is largely influenced by packing intensity.

- Different types of silage silos require different packing strategies and target densities for appropriate ensiling. In general, a shorter processing time will result in higher silage densities due to a decreased stiffness of the material.
- Good sealing with plastic sheets and concrete barriers will keep the carbon dioxide in and prevent oxygen from entering the silo. Oxygen barrier film technology, compared to standard polyethylene films, has proven to further reduce DM losses and increase aerobic stability from the outer layers of silos.
- Additives like *lactoba cillus* can help in every phase of silage making by enhancing the ensiling process and the quality of the silage..

Features of good silage

- Its colour is pale green rather than brown.
- It has sweet smell like yogurt.
- It is highly stable and may be stored for years if needed, as long as no action is taken to allow oxygen to enter the contents.

Features of bad silage

- It looks dark brown.
- It has rancid smells.
- It is unpalatable to the stock.
- It is mouldy and dry.
- It has a higher pH.

- It is unstable and cannot be stored for more than a few months

The crop should have a high carbohydrate content to offer a substrate for fermentation and a low moisture content to minimize the amount of materials that need to be acidified for the optimal fermentation throughout the silage-making process. For these reasons, crops that might wilt fast are prioritized for cutting. Grass should be wilted from its typical moisture content of roughly 80% down to 70-75% and that the sugar level should be at least 30% at the time of cutting.

Differences between Silage and Haylage

The main difference between silage and haylage is the initial dry matter (DM) concentration level at which the forage is clipped and packed to achieve optimum anaerobic and fermentation conditions. Three different moisture levels can be achieved: high-moisture silage ($\leq 30\%$ DM), medium-moisture silage (30% to 40% DM), and low-moisture (wilted) silage (40% to 60% DM). Low-moisture silage is referred to as haylage. When baled and wrapped, haylage is referred to as baleage. High-moisture silages are more prone to potential seepage losses (that is, effluent or leachate from the silo), undesirable secondary fermentation (resulting in butyric acid, which results in a rancid smell), and high dry matter losses (silo shrink). On the other hand, preservation as haylage depends more on achieving adequate packing (high density) to maintain anaerobic conditions. Achieving high density at packing is more difficult in drier forage. Nevertheless, high density is critical in haylage to maintain

anaerobic conditions because microbes are less active and fermentation is lower in haylage than in higher moisture silage.

10.2.1 Silos used for ensiling

A silo is a structure used for storing agricultural produce and fermented forages. It is effective in the storage of silage because it maintains the anaerobic nature of the conserved forages.

There are three types of silos used for silage making:

1. Bunker Silo: This silo types consist of a layer of concrete or asphalt to protect from soil contamination and a polyethylene plastic sheet covering the silage (sometimes the wall as well). The bunker silo is a variant with two or three concrete wall sides (Figure 43). This silo type is the least expensive but also has a large surface exposed to the air. Consequently, adequate lining of the inside walls with plastic is needed to avoid outer layer forage damage, in addition to the plastic sheet for the top. Sealing is most critical to ensure good preservation and forage quality. Plastic films must be at least 5 mm thick and be UV-resistant. Tires or gravel-filled bags must be used to keep plastic sheeting in place. The forage crop should be packed to form progressive wedges and maintain a minimum slope of 1 (rise) to 3 (run) to avoid tractor rollover. The forage should be spread in a thin layer (no more than 6 inches deep) as much as possible to aid the compaction process.



Fig. 43: Bunker silo

2. Pressed silo bags: Pressed bags are becoming increasingly used, because they provide the advantage of flexibility in terms of storage and movement of stored silage (Figure 44). The bagging machine regulates silage density in the bag, and achieving a smooth bag surface requires expertise. Pack as tightly as possible without creating an irregular surface (ripples), which creates air passages that can spoil much of the material being ensiled. This type of silo requires constant checking of each bag's integrity so that punctures are quickly fixed and no air comes inside the silo.



Fig. 44: Silo bag

3. Towers Silage silos are cylindrical structures which could be 10-90 ft in diameter and 50-275 ft tall. The losses in DM during ensiling tend to be lower in tower silos compared to other types. Oxygen-limiting tower variants, primarily unloaded from the bottom, are available to limit spoilage even further.



Fig. 45: Tower silo

2. HAY

Hay can be defined as animal feed produced through dehydration of green forage to moisture content of between 15-20% which is low enough to inhibit activities of plant microbes and enzymes and without deterioration of nutrients. It remains the most widely used conservation strategy.

The following guidelines are followed when preparing hay successfully:

- Before harvesting, the grass needs to be in the proper development stage. It may be tempting to wait to trim grass until very heavy, mature crops have developed because doing so boosts the grass's overall yield and lowers its moisture content. Mature hay, however well-made, has poor feed value and low intake characteristics; digestibility diminishes at a rate of one-third ($\frac{1}{3}$) to one-half ($\frac{1}{2}$) of a d-value unit/d once the seed head has formed.
- The amount of losses ought to be minimized. Losses may occur from the following sources:
 - (a) Respiration losses may occur in the field as the herbage continues to respire after cutting. Rapid drying will minimize this loss which can amount to 1-5% of the dry matter yield.
 - (b) Mechanical losses occur if herbage is fragmented into pieces by machinery too small to be picked when the hay is collected from the field for storage. Mechanical loss tends to become higher greater as the herbage

becomes drier and when the action of the machine is abrasive. A mechanical loss of 10% is acceptable.

- (c) When the cut material is exposed to rain, nutrients may leach out. Hay is best created and hauled from the field when there is no rainfall, but prolonged periods of heavy rain can cause up to 15% loss of dry matter and significantly more loss of soluble nutrients.
- (d) Due to dust and mould, some of the hay itself might not be edible. When hay is produced in unfavourable conditions, both of these issues emerge. Up to 15% of the dry matter may be lost, which emphasizes how crucial it is to produce hay in an environment with favourable weather.

There is a quick initial loss of moisture when grass is cut and a large swath is exposed to the sun and wind. This is because water from the outer cells of leaves and stems is lost, along with external moisture. At this point, drying can occur in the absence of significant sunlight as long as the relative humidity in the environment is low.

If the grass is cut with a flail mower or immediately passes through a crimper conditioner, the rate of drying may be accelerated; however, grass treated in this manner is more susceptible to weather-related damage, and the materials used to make flail mowers may experience up to 50% mechanical loss in the event of prolonged wet weather. When inclement weather poses a risk to the drying process, materials should be wind-rowed to expose the smallest possible area to the rain. It is also a good idea to rake up grass at night to reduce the effect of dew, making sure that

the ground and swath surface are dry before the materials are re-spread the following morning.

The weather, appropriate machinery use, swath conditions, maturity stage, amount of grass present, time of year, and desired moisture content during field transportation all affect how quickly grass dries.

Baled: Hay is usually baled, but it shouldn't be until it's ready for storage. That is, at roughly 20% moisture content. Hay is often baled at a moisture level higher than this and then allowed to cure in the field. The bale can lose very little more moisture on the field, but in the event of rain, the bale will absorb a significant amount of moisture. Baling should generally be thought of as the initial stage of the transfer into storage procedure. It is not recommended to bale grass until the foliage has dried completely before storing it.

Good hay quality is determined by its colour, which should be a vibrant green or yellow, its pleasant scent, and the lack of dust.

Occasionally, nearly dry hay is brought inside a structure and exposed to forced airflow to finish drying and dehydrating it. This process is known as barn hay.

Disadvantage of hay

- ❖ The weather greatly affects the process of hay making as it requires sunshine for wilting and drying. During dry season, the process of hay making is faster and quicker than wet season.

- ❖ Hay is highly inflammable and has the ability to start a fire just as any stick of dry grass would, either accidentally or through the activities of some arsonist.

To ascertain the moisture content of the hay, a handful of forage is twisted tightly and release. If it is brittle and falls apart (too dry) or stays wadded up or slowly untwists (too wet) it is not yet ready for baling. Hay that springs open and fluffs out upon release is at right moisture concentration and is ready to be baled. If hay is too dry, wait until the humidity increases in the evening before baling to avoid loss of leaves and breakage.



Fig. 46: Baled Hay

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