Measurements in Pasture and Forage Cropping Systems

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Technical Manual 18

Ethiopian Institute of Agricultural Research
Measurements in Pasture and Forage Cropping Systems

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Preface
Unlike food crops, the progress of technology generation and adoption pasture and forages has been generally low in case of forage crops. Several interacting environmental, biological, social, and economic problems account to this. But lack of properly well-trained and qualified manpower in areas of forage crops research and development is probably the key one. Most research centers are staffed by juniors with little academic background that is not sufficient enough to confidently propose and execute research on the crops. Most often, proposals are written easily by consulting research directories of recent years and get perfected through chains of annual review meetings.

Researchers encounter a number of problems when their proposal is put in to effect on field for data collection. There are no quick reference materials available to be guided with, as in the case of writing proposal. Data are not collected in a systematic manner; even from a well-designed experiment and lost unutilized due to high variability emanating from sampling error and lack of information on the potential utility of the data to extrapolate other vital parameters. Because of this they often frustrate and abandon the institution or learn through time with patience after encouraging a lot of unnecessary wastage on own, country resource and clients' time.

At this junction, we are fully aware that the technical manual is not an exhaustive or conclusive one but stimulates further reading. Most of the parameters given are not new. They have been on use for so long on food crops, but here presented with certain modifications.

Aklilu Mekasha
Alemayehu Mengistu
June 2007
Introduction

Forage crops and pastures may be described in terms of a variety of attributes such as yield, the proportions of the component species, the proportions of the different plant parts for each species, and the chemical composition of the components. All these attributes also change with time so that a description may also include information on rates of change of attributes. A full description of attributes is rarely possible and the research worker has first to choose those most appropriate to the objectives of the particular investigation. In addition, there is a variety of methods available for measuring each attribute and the research worker has to accept that it is not possible to prescribe a ‘best’ method for any given attribute.

The choice for any experiment depends on, the kind of forage crop and pasture, the growth form of the species, the time, labor, and facilities available, the precision required, and the particular facets of the crop and pasture performance under study. Because of these complexities, great care is needed in choosing the attributes to measure and the methods to use, because an inappropriate choice may limit interpretation of the results.

Some form of sampling is usually necessary with most measurements, although in small-plot experiments it is sometimes possible to measure a particular attribute on certain plants or the whole plot. It is not possible to prescribe definite numbers of samples to take when using different methods, because the appropriate number depends upon the variability present in the experiment, the size of treatment difference desired to detect and the confidence level desired in the results.
Indices for pasture and forage crops

If experiences from previous experiments are not available as a guide, it is advisable to carry out a trial sampling to provide estimates of the variation between plots and between samples within a plot. The variation between plot means for any given number of samples per plot can then be calculated, as well as the optimum number of samples per plot required for a specified level of precision.

Bias in the selection of sampling sites must be avoided. Sampling positions should therefore be selected on some random basis, and not be selecting ‘typical’ sites, or by ‘random throws’ of a quadrant. In pasture, an easy way is to choose positions by using plot boundaries as axes and selecting pairs of coordinates from a table of random numbers to define the points. In small plots the quadrat side can be used as a measuring device to locate the point, while in large plots it is usually sufficient to find the point by pacing, with the aid of a compass to maintain direction if necessary, using the plot corner or the previous sample point as the reference. In large grazing experiments, the alternative for a random sampling is to use a systematic arrangement such as a grid with a random choice of the starting point. Stratified random sampling, in which the plot is divided into a number of strata and samples are taken at random within each stratum, is a useful method in large experiments. It ensures that samples are distributed over the whole plot, without losing the benefits of randomization, and it can improve the precision of the overall plot estimate if there is a greater homogeneity of pasture within strata than between strata. Strata are usually obtained by dividing the plot into equal sections and this is particularly appropriate where a consistent site trend in fertility or elevation can be recognized. However, strata can be of irregular shape or size, for instance to coincide with soil or vegetation boundaries within a plot.
With strata of different size, the number of samples per stratum would be proportional to the area.

It is important to keep techniques uniform within replicates, and to minimize bias or variability arising from differences between operators. If more than one operator is being used, then each either should work in a different replicate, or should perform the same number of tasks such as cut the same number of samples in each plot within a replicate. If one person is cutting samples and the other is gathering the cut material, then they should change jobs only when moving to the next replicate. If a sampling takes several days to complete, it is desirable to finish all the operations within a single replicate in one day.
Growth and Development

The development of a plant from germination to maturity can be considered as a series of discrete periods, each identified by an accompanying process of change in the structure, size, or weight of specific organs such as vegetative, root, inflorescence, fruit, and seed. Developmental processes relate to varying degrees of expansion or growth in weight of an organ. A characteristic feature of developmental processes is that they are discrete. Seed either germinates or does not germinate a leaf primordium is visible or invisible. Therefore, they can only be defined in terms of time, and not in length, area, volume, or weight. The duration of a developmental process is usually measured between events that are detected visually. Such events include days to germination, days to emergence, days to heading, days to 50 % flowering, days to 75% flowering, days to physiological maturity etc. Demarcation of the life period of a crop to these distinct stages is better for communication among researchers, development agents, and farmers.

Significance of growth and development studies

Aging time or growth effect is the single biggest variable in herbage quality. It affects herbage yield and quality through its direct effect on plant population, proportion of leaf and stem, herbage biomass yield, nutrient uptake, chemical composition and digestibility. Hence understanding the growth and developmental behavior of a forage crop is useful in determining optimum plant population, optimum time for defoliation, and optimum time and rate for nutrient application.
Optimum plant population

Plant population is a factor of initial seed rate, tillering, and branching of the plant. The optimum plant population required for herbage crop is normally higher than that of a seed crop. Higher plant population than optimum, however, brings out certain modifications in the growth habit of the plant. At higher density competition for light, space, water and nutrient induces alteration in proportion of leaf and stem, rate of plant growth, number of leaf, leaf thickness, leaf orientation, tiller mortality, yield per plant/unit area, fiber content, chemical composition and digestibility.

Optimum time for defoliation

Defoliation is the removal of more of leafy vegetative aerial plant part either by cutting, grazing animals, insect pests or by any mechanical ways and biological agents. On intensive managed cultivated or naturally managed forage husbandry system, defoliation due to cutting and animal grazing is human controlled. Under such circumstances, the time for optimum defoliation is dictated by considering herbage biomass yield and the nature of chemical composition. At early stages of plant growth, the herbage biomass yield is low; with substantial increase in tonnages as the plant ages because of increase in sugars and cell walls. Nutritional values such as proteins, lipids, minerals, and digestibility deteriorate with advancement in age. The optimum time for defoliation is thus the time when the plants reach certain stage of growth that compromises the trade off between quality and yield. In most forage crops, the time of reaching 50% heading stage is taken as the optimum time for defoliation. This time and the corresponding stage can be fine-tuned to economic level by careful analysis of the growth and development behavior of the crop.
Optimum time and rate for nutrient application

Removal of nutrient from soil under forage crops is higher with frequency of defoliation. As nutrient removal is a function of yield, high yielding forage crops generally remove more nutrients from the soil. The stage at which maximum removal occurs corresponds with the period of establishment, active tillering, and vegetative growth. In most annual grasses, this occurs at emergence early seedling stage and tillering most commonly between 20 and 35 days after sowing depending on species, cultivar type, environment, and management.

The efficiency of fertilizer use decreases with increased rate of application and aging of the crop. Applying excessive amount of fertilizer beyond the level of uptake by the plant at any stage of growth is wastage as it is subjected to loss through fixation, volatilization, and leaching. Hence, analyzing the growth and development behavior of a forage crop is helpful in enhancing fertilizer use efficiency.

Growth Studies

Sampling and data collection

As in any biological studies, data collection is a primary concern in growth and development studies. Data can be collected from a well-designed field experiment in two ways involving either destructive or non-destructive sampling techniques.

Destructive sampling: destructive sampling involves cutting the plant or plant parts for the study of growth. Such parameters related to laboratory chemical analyses, dry matter accumulation through different plant parts, yield, and feeding
trials can only be studied on cut plants or plant parts. In studies involving time series, samples will be taken from new rows each time leaving border rows in between.

**Non-destructive sampling:** here sampling could be done without cutting the plant or its parts. Parameters such as plant height, number of shoots, number of tillers, number of leaves and all developmental parameters can be studied with or without cutting the plant or plant parts. These parameters can also be studied after destructive sampling. In studies involving time series, representative plants will be tagged for the purpose of regular data collection.

**Basic Parameters in Growth Studies**

**Plant height**
In forage crops, plant height is measured from ground to the tip of the longest leaf. Whereas, in seed crops the stalk of the reproductive parts normally grow taller than the longest leaf at maturity and plant height is thus measured from ground to the tip of the spike including awns or panicle or raceme depending on the inflorescence type.

**Number of shoots**
Number of shoots per unit area such as per meter square or per meter row length is expressed by counting all shoot bearing plants including tillers within the unit area or unit row length. Sometimes number of tillers can be considered than taking number of shoots, but in counting number of tillers, one has to exclude the main shoot from which tillers arise.

**Number of leaf**
Number of leaf per unit area is often expressed as dry and green leaves. Dry leaves are not photosynthetically active,
they do not contribute to growth, but can be used to see the treatment effects and dry matter accumulated in leaves.

**Dry matter accumulation/content**
Dry matter accumulation is the amount of oven-dried mass of the herbage accumulated within a certain period. It can also be partitioned to dry matter accumulated through leaf, stem, root, or aerial plant part. It is expressed in terms of gram or kilogram per unit area. Whereas, dry matter content is the proportion of dry matter contained in the herbage expressed as percentage.

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight of sample (g)}}{\text{Fresh weight of sample (g)}} \times 100$$

**Crude protein content**
Crude protein is determined by multiplying the total nitrogen content in percentage—determined by Kjeldhal analysis—by 6.25. This is based on the assumption that on average protein contains 16% nitrogen.

**Digestible dry matter content**
There are a number of techniques for determining digestibility of forage crops. In all the techniques be it in vitro or in vivo, the final estimation of digestibility is based on the following formula.

$$\text{Digestibility (\%)} = \frac{(a - b)}{a} \times 100$$

Where:

- $a$ = dry weight of sample before incubation
- $b$ = dry weight of sample after incubation

**Analyses of growth dynamics**
Growth analysis is a technique for quantifying components of plant growth from a series of mathematical equations. In forage
crops, growth analysis could be based on dry matter accumulation, digestible dry matter accumulation, and crude protein etc. The choice depends on researcher’s interest, nature of the problem to be solved, and treatment effects to be studied. Some of the most commonly used parameters in analyses of growth are given here under with analytical formula.

**Relative growth rate (RGR)**

It is defined as an increase in weight per unit of original weight at a time interval \( t \). It is like gm of dry matter produced by gm of existing dry matter in a day.

\[
RGR = \frac{1}{w} \frac{dw}{dt} = \frac{\ln w_2 - \ln w_1}{t_2 - t_1} = \frac{\log e w_2 - \log e w_1}{t_2 - t_1}
\]

Where,
- \( W \) = dry weight of plant at time \( t_1 \) and time \( t_2 \) respectively.
- \( Dw \) = change in weight
- \( w_1 \) and \( w_2 \) = dry weight of plant at time \( t_1 \) and \( t_2 \) and \( ln \) is natural log
- \( dt \) = time interval

**Leaf area (LA)**

Measurements of leaf area are taken on fresh green leaves while still in full expanded and turgid state. Leaves are cut from culm at colar and about 5 to 10 representative samples of equal number from each of the small, medium, and large sized leaves will be taken categorically and measured for their average width at the wider part and length from the base to the tip. The average leaf area of each category will then be measured with leaf area meter and a factor calculated for each category from the relation ship among length, width, and area. The estimation of leaf area for each category is then by multiplication of category wise average leaf length, width, area and the correction factor. LA is finally determined by summing-up leaf area (LC) of the three categories.
Indices for pasture and forage crops

\[ K = \frac{A}{L \times W} \]

\[ LC = L \times W \times K \times N \]
\[ LA = LC_1 + LC_m + LC_l \]

Where,
- \( A \) = category wise average leaf area (cm\(^2\)) of sample leaves as determined by leaf area meter
- \( LC \) = category wise leaf area (cm\(^2\))
- \( L \) = category wise average leaf length (cm)
- \( W \) = category wise average leaf width (cm)
- \( N \) = category wise number of green leaves
- \( K \) = Correction factor
- \( LA \) = Leaf area (cm\(^2\))

**Leaf area ratio (LAR)**

It may be defined as the ratio of leaf area to whole plant dry weight

\[ LAR = \frac{L}{w} = \frac{L_2 + L_1}{w_1 + w_2} \]

Where:
- \( L_1 \) and \( L_2 \) = leaf area (cm\(^2\)) at time \( t_1 \) and \( t_2 \)
- \( w_1 \) and \( w_2 \) = dry weight (g) of plant at \( t_1 \) and \( t_2 \)

**Unit leaf rate (ULR)**

It may be defined as rate of increase in dry weight per unit leaf area, assuming that both dry weight and leaf area are increasing exponentially.

\[ ULR = \frac{w_2 - w_1}{l_2 - l_1} \cdot (ln l_2 - ln l_1) \]

Where:
- \( w_1 \) and \( w_2 \) = dry weight (g) of plant
- \( l_1 \) and \( l_2 \) = leaf area (cm\(^2\)) and \( ln \) is natural log
**Specific leaf area (SLA)**

It may be defined as the ratio of leaf area to its dry weight

\[ SLA = \frac{L}{W} = \frac{1}{2} \left( \frac{L_1}{W_1} + \frac{L_2}{W_2} \right) \]

Where:
- \( L_1 \) and \( L_2 \) = leaf areas at time \( t_1 \) and \( t_2 \)
- \( W_1 \) and \( W_2 \) = leaf dry weights at time \( t_1 \) and \( t_2 \).

**Specific leaf weight (SLW)**

It may be defined as the ratio of leaf dry weight to its area. Useful it reflects cell density with higher SLW being an indication of more number of cells per unit leaf area and better nutritional value of the crop.

\[ SLW = \frac{W}{L} = \frac{1}{2} \left( \frac{W_1}{L_1} + \frac{W_2}{L_2} \right) \]

Where:
- \( L_1 \) and \( L_2 \) = leaf areas at time \( t_1 \) and \( t_2 \)
- \( W_1 \) and \( W_2 \) = leaf weights at time \( t_1 \) and \( t_2 \).

**Leaf area index (LAI)**

It is the ratio of leaf area to the ground area. It is useful to know the photosynthetic surface area of the crop per unit of its ground area. Plants with higher LAI generally intercept more solar energy and accumulate more dry matter.

\[ LAI = \frac{\text{Leaf area } \text{cm}^2}{\text{Ground area } \text{cm}^2} \]
Crop growth rate (CGR)
CGR indicates at what rate the crop is growing i.e. whether the crop is growing at faster rate or slower rate than normal. It is expressed as gm of dry matter produced per day

\[ \text{CGR} = \frac{w_2 - w_1}{t_2 - t_1} = \frac{dw}{dt} \text{ g dry matter} \frac{m}{day} \text{ land area day}^{-1} \]

Where:
- \( w_1 \) and \( w_2 \) = dry weight (g) of plants at time \( t_1 \) and \( t_2 \), respectively.
- \( \text{CGR} \) = total dry matter productivity per unit land area over a certain time span.

\[ \text{CGR} = \text{NAR} \times \text{LAI} \]

Since LAI is simply a ratio of leaf area to land area, it becomes a fulcrum between NAR and productivity.

Dry matter partitioning (DMP)
It is Partitioning of total dry matter in to different components. It is useful to know the share of leaves, stem, inflorescences, roots etc. in the total dry matter yield.

\[ dL = \frac{L}{W} \times 100 \]

Where:
- \( dL \) = dry matter (g) of leaf
- \( L \) = leaf dry matter (g) and
- \( W \) = total dry matter (g) of plant.

Leaves to stem ratio (L: S)
Leaves to stem ratio is the ratio of dry weight of leaves to the dry weight of stem. Higher leaves to stem ratio is generally an indication of better nutritional value of the crop.

\[ \text{L: S} = \frac{\text{Dry weight of leaves (g)}}{\text{Dry weight of stem (g)}} \]
Developmental Analyses

Days to 50% germination
After sowing, seeds imbibe moisture and put forth radicle and plumule. The coming out of these organs first from the seed is known as germination. Under field condition, it is difficult to determine days to germination since germinating seeds are still covered by the soil. Days to germination and germination percentages are thus determined under laboratory condition using Petri dish or germination chamber.

Days to 50% germination is thus the number of days taken from watering seeds to the date in which 50% of the seeds germinated.

\[
\text{Germination \%} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds watered for germination}} \times 100
\]

Days to 50% emergence
Emergence refers to the coming out of germinated seedlings to the soil surface. The plant put forth leaves and no more depends on seed reserves after emergence as it develops sufficient number of seminal roots and leaves. The date from sowing to when 50% of the plants show two distinct leaves is taken as days to 50% emergence.

Days to 50% heading
It is the number of days taken from planting to the date in which 50% of the plant’s panicle emerges out of the flag leaf booting. In case of plant community, it is the number of days in which 50% of the plants come to heading in such a way. It is also called as days to 50% earring.
**Indices for pasture and forage crops**

**Panicle emergence rate (PER)**
Panicle emergence rate indicates the rate at which panicle emerges from the flag-leaf booting. Panicle emerges due to the forces of inter-nodal elongation. Care has to be taken not to confuse with panicle initiation. In most grasses, panicle initiation occurs just after or at tillering time.

\[
\text{PER} = \frac{pl_2 - pl_1}{t_2 - t_1}
\]

*Where:*
\[pl_1 \text{ and } pl_2 = \text{ length of emerged panicles at time } t_1 \text{ and } t_2\]

**Rate of flowering (FR)**
This parameter indicates whether most of the tillers or branches flower in quick succession or not. In other words, it indicates synchronous flowering. It is expressed as number of flowers that appear per day.

\[
\text{PR} = \frac{Fr_2 - Fr_1}{t_2 - t_1}
\]

*Where:*
\[Fr_1 \text{ and } Fr_2 = \text{ number of flowers that appear per plant at time } t_1 \text{ and } t_2, \text{ respectively.}\]

**Days to 50% flowering**
It is the number of days taken from planting to the date in which 50% of the plants' flower. Flowering is related to the development of pollen. It occurs after that of heading. Nevertheless, many people often confuse days to heading with that of days to flowering and use the two terminologies interchangeably substituting one with the other. In grasses, days to 50% heading are generally considered as the optimum time for defoliation.
**Days to maturity**

It is the number of days taken from planting to the date in which plants attain maturity. It is useful only for seed crops. It helps to determine when to harvest the crop for seed production. In most perennial forage grasses, and it is difficult to determine this stage since tillers with varies stage of growth and development may be found at any time as far as moisture is not limiting.

**Yield Analyses**

Yield is the most important variable, which forage and pasture agronomists are striving to improve while maintaining and possibly improving other quality parameters. DMY, CPY, and DDMY are the three most aspects of yield calculated on bases of basic parameters under section 2.3.2. The choice of unit of reporting yield depends on the quantity of yield. For yield greater than 10 q/ha the unit of choice could be tons /ha and for less than 1.0 q/ha the unit of choice could be kg/ha.

**Dry matter yield (DMY)**

Dry matter yield is the oven-dried mass of herbage expressed in terms of t/ha or in q/ha and rarely kg/ha. Dry matter yield is estimated by multiplying the estimated green forage yield with dry matter content of the herbage.

\[
\text{Dry matter yield (q/ha)} = \frac{\text{Green forage yield (q/ha)} \times \text{dry matter content (%)}}{100}
\]

**Crude protein yield (CPY)**

Crude protein yield is the amount of crude protein harvested, expressed in terms of q/ha or kg/ha. Crude protein yield is estimated by multiplying the estimated dry matter yield with the crude protein content of the herbage.
Crude protein yield = \( \frac{\text{dry matter yield (q/ha)} \times \text{crude protein} \%}{100} \)

**Digestible dry matter yield (DDY)**

Digestible dry matter yield is the amount of digestible dry matter harvested, expressed in q/ha or kg/ha. Digestible dry matter yield is estimated by multiplying the estimated dry matter yield with the digestible dry matter content of the herbage.

Digestible dry matter yield (q/ha) = \( \frac{\text{dry matter yield} \times \text{digestible dry matter} \%}{100} \)

**Green forage yield (GFY)**

Green forage yield is the amount of green herbage harvested/cut, expressed in terms of t/ha or in q/ha. Green forage yield per ha is estimated based on green herbage harvested/cut from sampling area. Under field condition, the appropriate unit of measuring herbage cut from sampling area is kilogram and that of the sampling area is square meter. The green forage yield expressed (q/ha) and (t/ha) is therefore estimated by the following equation.

\[
\text{Green forage yield} = \frac{10000 \text{ m}^2}{Y \text{ m}^2} \times \frac{Z \text{ kg}}{100} \\
\text{Green forage yield} = \frac{10000 \text{ m}^2}{Y \text{ m}^2} \times \frac{Z \text{ kg}}{1000}
\]

*Where:*

- \( Z \) = yield obtained from sampling area (kg/m²)
- \( Y \) = area of the sampling site/quadrant (m²)
Harvest index (HI)

Harvest index is the ratio of economic yield to biological yield. Economic yield is the yield in which we are interested. In seed crops, the interest is seed. Nevertheless, in forage crops the interest could be for crude protein yield, digestible dry matter yield, or other. In all the cases, however, biological yield refers to the entire yield including the economic yield. In forage crops, GFY and DMY can both be taken as a biological yield. Nevertheless, since GFY is subjected to variation with moisture status of the crop, it is less reliable estimation of yield, and may not be advisable to use for HI calculation.

\[
HI = \frac{\text{Economic yield}}{\text{Biological yield}}
\]

\[
HI = \frac{\text{Seed yield}}{\text{Total biological yield}}
\]

\[
HI = \frac{\text{CPY}}{\text{DMY}} \times 100 \quad \text{or} \quad \frac{\text{CPY}}{\text{GFY}} \times 100
\]

\[
HI = \frac{\text{DDY}}{\text{DMY}} \times 100 \quad \text{or} \quad \frac{\text{DDY}}{\text{GFY}} \times 100
\]

Where:
- CPY = crude protein yield (q/ha)
- DDY = digestible dry matter yield (q/ha)
- DMY = dry matter yield (q/ha)
- GFY = green forage yield (q/ha)

Nutrient use Analyses

Forage and pasture agronomists apply fertilizers of different form and origin to increase yield based on soil test. Since nutrients are made available to plants through mineralization of slow release and application of ready to take-up fertilizers, how much to apply is rather based on the efficiency of the plant to take-up and use the applied nutrient for production of targeted
yield. The estimation of nutrient use is based on determination of the uptake and recovery of the nutrient.

**Nutrient uptake/ removal (U)**
The uptake or removal of any particular nutrient from soil (whether applied externally as fertilizer or not) is determined by the following equation. The equation does not differentiate whether the nutrient in plant tissue is recovered from the applied fertilizer or from the soil.

\[
U = \frac{Y \times N}{100}
\]

*Where:*
- \( U \) = the uptake or removal of a nutrient (kg/ha)
- \( Y \) = the dry matter yield (kg/ha).
- \( N \) = the percentage of a nutrient contained in plant tissue (determined in laboratory by chemical analysis).

**Apparent recovery (AP)**
The apparent recovery of any particular nutrient is the ratio of that portion of the applied nutrient absorbed by the crop to the total nutrient applied. It tells how much percentage of the applied nutrient is recovered or taken up by the plants. The equation takes into account the difference in uptake by plants in the control plot to which a nutrient is not applied and that to which the nutrient is applied.

\[
AP \% = \frac{AT - AC}{AD} \times 100
\]

*Where:*
- \( AP \) = apparent recovery of a nutrient
- \( AT \) = uptake from the nutrient treated plot (g/ha)
- \( AC \) = uptake from control plot to which the nutrient is not applied (kg/ha)
- \( AD \) = amount of the nutrient applied (kg/ha)
Nutrient use efficiency (NUE)

Also called agronomic nutrient use efficiency of forage crop for a particular nutrient is useful to know the amount of dry matter or any yield produced by a unit of the applied nutrient. The equation takes in to account the yield difference between the control plot to which a nutrient is not applied and that to which the nutrient is applied.

\[
NUE = \frac{DMT - DMC}{AD}
\]

Where:
- \(NUE\) = the agronomic use efficiency for a particular nutrient
- \(DMT\) = dry matter yield from the nutrient treated plot (kg/ha)
- \(DMC\) = dry matter yield from the control plot (kg/ha) (to which the nutrient is not applied).
- \(AD\) = amount of a nutrient applied (kg/ha)

Physiological nutrient use efficiency (PNUE)

It is that part of the recovered nutrient used by plants for production of a unit of yield. Just like NUE, the equation takes in to account the yield difference between the control plot to which a nutrient is not applied and that to which the nutrient is applied. The difference however, between NUE and PNUE lies in that the estimation of PNUE is based on the amount of the nutrient recovered by the plant - which is expected to be from the nutrient applied externally to the soil as fertilizer; whereas, NUE is estimated based on the amount of the nutrient applied externally as fertilizer to the soil.

\[
PNUE = \frac{DMT - DMC}{AP}
\]

Where:
- \(PNUE\) = Physiological use efficiency for a particular nutrient
- \(DMT\) = dry matter yield from the nutrient treated plot (kg/ha)
<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$DMC$</td>
<td>dry matter yield from the control plot (kg/ha) (to which the nutrient is not applied).</td>
</tr>
<tr>
<td>$AP$</td>
<td>amount of a nutrient recovered by the plant (kg/ha)</td>
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Measurements in Pasture and Grass-Legume Mixed Cropping Systems

Pasture Measurement

Pasture is a dynamic biological plant community made up of one or more species of grasses, legumes, or mixture of both. Pastures are established at low seed rate by either broad casting or drilling seeds at certain spatial arrangement, but they lose the pattern of planting as they age because of self-seeding and tillering. Pasture crops seed may also be broadcasted on established for enrichment. Unlike studies in pot and small plot field experiments, studies in pasture thus posse special problems of taking representative samples and associated measurements for which pasture measurement is treated separately under this section.

Seedling emergences and establishment
Measurements are usually made directly by counting numbers of seedlings or plants within a plot or a sampling unit. The results will then be expressed on a unit area basis. Alternatively, visual assessments of density or canopy cover can be made on an arbitrary scale, e.g. 0 to 5, or 0 to 10, depending on the variation encountered from plot to plot. Such assessments can be put on to a quantitative scale by making counts on a number of sample areas that have been rated previously; photographic standards can also be used.
The size of quadrant to use will vary inversely with the density of the seedlings or plants to be counted, and may range from 20 x 20 cm to 50 x 50 cm frames for most pastures. As a general guide, five samples per plot may suffice for small plots; say of 100m² or less, unless the pasture is very uneven, while plots of about 0.5ha would require twenty to fifty samples.

**Botanical composition**

Botanical composition can be expressed as the proportions of pasture components based on weight, number of individuals, frequency of occurrence, or area covered by each species.

**Percentage dry weight**

Proportion of species on a weight basis is generally the most useful measure where the main interest is in pasture production. Where samples are cut for yield determination, botanical composition can be determined by hand-separating the sample into its component species. This gives the most precise result, and although the task is time-consuming, it is the most satisfactory method to use in many small-plot experiments.

The sample needs to be sorted as soon as possible after cutting so that it does not dry out and break up on handling. If the time between cutting and sorting is likely to be more than 1 or 2 hr, samples may be put into polythene bags, securely fastened at the top with a rubber band, and stored in a cool, shady place; samples have been kept satisfactorily in this way for up to 48 hr. If the delay in sorting is longer, samples can be kept in cold storage at 4°C for several weeks. When cutting is done with hand shears, it is often possible to cut different species separately, i.e. to sort as one cuts. Hand sorting will be made easier if every effort is made when cutting and gathering the sample to keep the components oriented as they are in the
pasture, i.e., to keep all plant bases together and stems parallel; there is then more chance of picking out whole plants together instead of having to pick out single stems, tillers or leaves.

Because hand sorting is such a slow process, it is often not possible in large experiments to deal with enough samples for the sampling to be adequate. Various estimation techniques provide alternatives. Visual estimates on a percentage basis can be made on the sample before or after cutting. Such they are all morphologically similar, than if there are many species of diverse types. Training by estimating and hand sorting is essential, as is regular checking whenever the method is used, but some operators can develop a high degree of skill. An alternative is the dry-weight-rank method of in which the observer has only to estimate which species take first, second and third placing are calculated for each species and these are multiplied by weighting factors to give dry-weigh percentages.

The method has been used extensively on a variety of pastures. However, there is an assumption implicit in the method that there is no consistent association between first placing by a species and a particular level of yield, e.g. that when species A occupies first place, then yield is usually high, whereas yield is low when species B is first. Such situations do arise, we have used a modification in which the yield of each quadrant is estimated, and component ranks are then weighted for yield.

**Number, frequency, and area**
Botanical composition expressed in these terms is concerned mainly with the pasture as an association of species and individual plants. Such measurements can be used to describe a pasture and to measure changes in population due to treatments or time.
Indices for pasture and for age crops

**Number:** is concerned with counts or estimates of plant units that can be recognized as individuals. It is usually expressed either as number per unit area (= density), or on a relative basis as a percentage of total plant numbers present. This measure is very useful at the germination and establishment phases as described earlier. However, it can also be used to record regeneration of annual species, and long-term changes in density of perennial species that can be easily identified as individuals.

**Frequency:** is concerned with occurrence or distribution of species in a pasture. It is particularly useful in recording long-term botanical changes or treatment effects, and in revealing vegetation patterns due to such things as soils, elevation, or aspect. It is measured by recording the presence of species within quadrants, and is normally expressed as a percentage of the total number of quadrants examined. The criterion for presence needs to be defined precisely. This may be that a plant must be rooted within the quadrant, and with a pasture composed of perennial species; frequency is then not greatly affected by current seasonal conditions or by the current defoliation regime. However, with trailing species, it is often convenient to accept vegetative presence as the criterion, but it should be realized that such presence is more affected by recent plant growth than is rooted presence. Frequency recordings can easily be taken at the same time as dry-weigh-rank estimations.

Quadrants of 0.05 to 1.0m² are used for measuring frequency, and the appropriate size has to be worked out for each pasture. It is obvious that frequency will increase as quadrant size increases, so that more species will have high frequency in large quadrants. It also follows that some species of low frequency may never be recorded if quadrants are very small. The quadrant should be large than the areas of bare ground that
occur between plants. If more than two species are recorded as having 100% frequency, then the quadrant is probably too big. Because frequency is so dependent on quadrant size, it is essential to keep the size constant for any experiment. It also follows that comparisons cannot be made between the results of analyses in which different sized units have been used.

**Area:** is concerned with the amount of ground surface covered by the plants, and so the term ‘cover’ is sometimes used. Area covered may refer to the plant canopy or to the vassal area of the plant. Canopy cover is very much influenced by the immediate past history of seasonal conditional and management, and is not very useful in pasture evaluation. Basal cover is less subject to these recent influences and hence is more useful in describing a population; it can be estimated within quadrates, or by means of a point-quadrant, with hits on plant bases only recorded.

**Yield**

**Cutting techniques**

In most small-plot experiments, dry-matter yield is determined by cutting, drying and weighing samples. Sometimes the whole plot can be cut, after removing borders, but more commonly, yield will be estimated from sample areas. Quadrant sizes of 0.5 and 1.0m² are suitable for most tropical pastures, and an open-ended frame is useful because it can be slid easily into position among tall or twining species.

A common procedure for small plots (up to 50m²) is to take a single sample if the plot is uniform, and two or more if it is variable. For larger plots, greater numbers are required, but a point is eventually reached, especially in grazing experiments,
where the number of quadrants required involves too much time and labor.

For cutting quadrant samples, hand shears are much more adaptable than most other devices; they can be used for plants of widely differing growth forms and sizes, they give good control of cutting height, and individual species can be cut separately.

Unless samples are cut to ground level, which is only possible when using hand shears, material will be left below cutting height, and this cannot be overlooked. For example, it would be important when comparing a prostrate species with an erect one and in grazing experiments, the material below a 10 cm cutting height may at times represent most of the feed on offer to the grazing animal. Estimates of residual pasture below mower height can be made with quadrants and hand shears.

If an estimate of within-plot-sampling variation is required, the individual samples will have to be dried and weighed separately. Otherwise, all the samples from plot may be bulked together, which often means that it becomes necessary to sub sample. In such cases the total sample should be weighed after harvest, and a weighed sub sample is by quartering; the sample is mixed, spread out, and divided roughly into four quarters; two opposite quarters chosen at random are discarded and the other two detained and combined; the process is repeated until the desired sub sample size is reached. However, this method is seldom practicable with tall grasses and trailing legumes. An alternative is to take a number of small grab samples of up to twenty-five at random, either along the length of the strip before the sample is raked up, or from the bulked material. Sub-samples of about 1 kg are a convenient size.
A final point concerning large samples is that there is often a large bulk of material remaining after the sub-sample has been taken, and it is sometimes advocated that this material should be returned to the plot to avoid undue removal of plant nutrients. Fertility losses, however, are important only where the sample size constitutes a high probability better to spread the material thinly over the whole plot, or to discard it completely.

For transport to the laboratory, large samples can be either put into sacks. Sub-samples can be put into paper bags or plastic bags, the latter being preferable if fresh weights cannot be recorded immediately in the field.

**Measuring yield of leguminous, shrubs, and Trees**

Shrubs and trees present special sampling problems. In general, it is not very meaningful to sample entire plant tops, because this will usually include inedible woody stems. A definition of the edible portions to include in the yield sample is therefore necessary, and observations on the way livestock graze the particular species can provide a guide. With *Leucaena leucocephala* we have sampled all leaf plus stems less than 6mm in diameter.

When shrubs branch and intermingle, it is impracticable to set out a sampling area on the ground and cut all material above this. For this reason we have used a single plant as the smallest sampling unit, and large samples consist of whole numbers of plants, e.g. five plants, or all the plants whose main stems originate within a given sample area.

**Growths and utilization**

The previous section has dealt only with measurements of yield at a particular time, but often the pasture agronomist/scientist will wish to measure growth or utilization. Such measurements
introduce a time factor, and it needs to be recognized that a number of processes will be operating simultaneously. The amount of pasture present will increase because of plant growth, but to offset this will be losses from senescence, seed fall, weathering processes, consumption by wildlife, insects, and grazing animals, and losses from the activities of the grazing animals. Hence, true growth is rarely measured in practice, but rather the net affect of a number of processes; also, the longer the time interval between samplings, the greater will be the departure form true growth. Nevertheless, such measurements provide useful data for comparisons between species or management treatments and for convenience, use the term 'growth' in the discussion, that follows.

Where experiments are conducted under a mowing regime, measurements of growth can be obtained from areas that are pre-trimmed at the beginning of the period and then cut back to the same height at the end of the period. This is a reasonable assumption in many instances, but may be unacceptable when comparing species with different growth forms, or when comparing swards in which structure has been varied by different management treatments. In such cases, it is better to measure growth from the differences between samples taken at the beginning and end of the period, cuts being made at ground level in each instance. The same procedures can be used for evaluation experiments in which plots are defoliated at intervals by rapid, intensive grazing, although it will usually be necessary to now after grazing to bring the whole area back to a uniform height.
Mixed Grass and Legume Cropping Systems

Mixed grass and legume cropping is a common culture among annuals and perennials. The most common practice is cultivating annual grasses such as maize, sorghum, teosinte, oat, triticale, wheat, and barley with annual legumes like vetch, cowpea, lablab, and soybean. Perennial grasses such as napier, rhodes, panicum, and buffle with perennial legumes including desmodium, siratro, alfalfa, and stylos and less commonly perennials with annuals. In case of annuals, the purpose may be to harvest both component crops as green feed or one of the component crops for green feed and the other for grain with residue/straw being feed. Annuals are more suitable rather for cut and carry feeding and silage making whereas, perennials are for grazing, hay, and as green feed. Mixed cropping of these crops has certain advantages over mono cropping. Some of the most common advantages of such culture include: improvement in soil fertility and reduction in fertilizer needs; improvement in the nutritional value of companion crops and for making balanced ration; it also improves feed intake and performance of animals as well as efficiency of land use. These benefits however, can be achieved only if the two or more companion crops are less competitive. The forage crops in mixed culture can be established sown as either intercrop, mixed, etc. The performance of such crops grown in such culture with certain spatial arrangements can therefore be assessed in terms of competition and yield advantage.
Indices for pasture and forage crops

Assessment of Competition and Yield Advantages

Land equivalent ratio (LER)
LER is the relative land area under sole crops that is required to produce the yields achieved in intercropping.

\[ LER = \sum_{i=1}^{n} \frac{Y_i}{Y_{ij}} \]

Where:
- \( Y_i \) = the yield of \( i^{th} \) component from a unit area of intercrop expressed as a fraction of the yield.
- \( Y_{ij} \) = the yield of that component grown as sole crop over the same area and \( n \) is number of crops involved.

The LER is indicative of competitive relationships between the species. In case LER is less than one, there is mutual inhibition; if it is equal to one, there is cooperation and if LER is greater than one, there is compensation. When LER is compared at uniform overall plant density of the sole and intercrops then it is known as Relative Yield Total.

Relative yield total (RYT)
Is the ratio of yields obtained in mixture to that of yields in sole stand? RYT is necessary to know which crop combination gives higher forage yield. The yield advantage is not only measured on unit area, but also based on unit population, which is estimated by RYT. The application is in replacement series of experiments. High RYT above unit imply that the two species are not strictly competing for the same limiting factor.
\[
R_Y T = \frac{Y_{ab} + Y_{ba}}{Y_{aa} + Y_{bb}}
\]

\[
R_Y T = R_{Ya} + R_{Yb}
\]

\[
R_{Ya} = \frac{Y_{ab}}{Y_{aa}} \quad \text{and} \quad R_{Yb} = \frac{Y_{ba}}{Y_{bb}}
\]

Where:

- \(Y_{ab}\) = yield of component 'a' in the mixture
- \(Y_{ba}\) = yield of 'b' in the mixture
- \(Y_{aa}\) = yield of 'a' in sole stand at 100% population
- \(Y_{bb}\) = yield of 'b' in sole stand at 100% population
- \(R_{ya}\) = the relative yield of a
- \(R_{yb}\) = the relative yield of b

**Relative crowding coefficient (RCC)**

RCC is used in replacement series experiments. Each component has its own coefficient, which gives a measure of whether that component has produced more, or less yields than expected. For component 'a' in a 50 by 50 ratio mixture with component b, it can be written as

\[
R_{ab} = \frac{\text{Mixture yield of 'a'}}{\text{Pure stand yield of 'a' - mixture yield of 'a'}}
\]

\[
R_{ab} = \frac{Y_{ab}}{Y_{aa} - Y_{ab}}
\]

For a mixture differing from 50 by 50 proportion, it can be generalized as

\[
R_{ab} = \frac{Y_{ab} \times Z_{ab}}{(Y_{ab} - Y_{ab}) \times Z_{ab}}
\]

Where:

- \(Z_{ab}\) = the sown proportion of the component 'a' in combination with 'b'
- \(Z_{ba}\) = the sown proportion of component 'b' in combination with 'a'
Indices for pasture and forage crops

\[
Yab = \text{yield of 'a' in combination with 'b'}
\]

\[
Yaa = \text{yield of 'a' in sole stand at 100\% population}
\]

If "a" component has the coefficient less than one, it has produced less yields, if it is equal to one, the yield obtained is the same as expected and if it is greater than one, the yield is more than expected and is advantageous, but if it is less than one then disadvantageous.

Aggressivity (A)

Aggressivity gives a simple measure of how much the relative yield increase in component 'a' is greater than that component 'b'.

\[
Aab = \frac{\text{Mixture yield of 'a'}}{\text{Expected yield of 'a'}} - \frac{\text{Mixture yield of 'b'}}{\text{Expected yield of 'b'}}
\]

\[
Aab = \frac{Yab}{Yaa \times Zab} - \frac{Yba}{Ybb \times Zba}
\]

Where:

\[
Yab = \text{yield of component 'a' in mixture with 'b'}
\]

\[
Yba = \text{yield of component 'b' in mixture with 'a'}
\]

\[
Yaa = \text{yield of 'a' in sole stand at 100\% population}
\]

\[
Ybb = \text{yield of 'b' in sole stand at 100\% population}
\]

\[
Zab = \text{sown proportion of 'a' in combination with 'b'}
\]

Indications at different values of A

<table>
<thead>
<tr>
<th>Value of A</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>equally competitive crops</td>
</tr>
<tr>
<td>+ ve</td>
<td>dominant component</td>
</tr>
<tr>
<td>- ve</td>
<td>dominated component</td>
</tr>
</tbody>
</table>
Assessment of Land use and Productivity

In areas where multiple forage cropping is practiced along with field grain crops, it is often referred to as Agro-pastoralism. Whereas, in case pasture production is well integrated with horticultural crops, it is referred to as Horti-pastoralism. Likewise if, it is linked with forestry, and then it is called Silvo-pastoralism. However, in case where land is completely kept under pasture meant for extensive grazing then it is referred to as Pastoralism. Based on these kinds of land use, forage, and pasture crops could be grown in association with other agricultural businesses or forage crops after forage crops in certain spatial and temporal arrangement, i.e., sequentially or in rotation. Under such condition, the following indices are useful for land use assessment.

**Cropping index (Cropping intensity)**

The number of crops grown per annum on a given area of land multiplied by 100 gives cropping index.

**Diversity index (DI)**

It measures the multiplicity of crops planted in a single year by computing the reciprocal of sum of squares of the share of gross revenue received from each individual farm enterprises in a single year.

\[
DI = \frac{1}{\sum_{i=1}^{n} (Y_i/\sum_{i=1}^{n} Y_i)^2}
\]

Where:

- \( n \) = is total number of enterprises (crops of farm products)
- \( Y_i \) = gross revenue of \( i^{th} \) enterprise produced with in a year.
Indices for pasture and forage crops

**Cultivated land utilization index (CLUI)**
This is calculated by summing the products of land area planted under each crop, multiplied by the actual duration of that crop, and divided by the total cultivated land area times 365 days.

\[ CLUI = \frac{\sum_{i=1}^{n} a_i d_i}{A \times 365} \]

Where:
- \( n \) = total number of crops
- \( a_i \) = area occupied by \( i^{th} \) crop
- \( d_i \) = days that \( i^{th} \) crop occupied \( a_i \) and
- \( A \) = total cultivated land area available during 365 days.

**Relative yield index (RYI)**
Relative yield index is the percentage of the ration of mean yield of a crop in specific region or district to that of mean yield of the same crop for the country.

\[ RYI = \frac{\text{Mean yield of a crop in specific region}}{\text{Mean yield of the crop for the country}} \times 100 \]

**Relative spread (RS)**
Relative spread is the ratio of area of the crop expressed as percentage of the total cultivated area in the region or district to area of the crop expressed as percentage of the total cultivated areas in the country.

\[ RS = \frac{\text{Area of the crop expressed as % of the total cultivated area in the region}}{\text{Area of the crop expressed as % of the total cultivated area in the country}} \]
Handling Samples

Drying

Fresh weights are unreliable as a measure of yield since the moisture content of samples varies between species, with time of day and with the maturity, it is best to express results on an oven-dry basis. In practice it seems preferable to dry at 100°C where dry-matter determination is the main objective, and 60°C where chemical analysis are of prime importance, using forced-draught ovens in both cases. In drying, individual samples should be loosely packed so that hot air circulation around samples. The drying temperature may affect some chemical determinations and therefore the analyst should be consulted. It should be realized that plant respiration continues after cutting, and that this can result in a loss of dry matter and a change in chemical composition. For comparative purposes, this may not be serious, but it is nevertheless desirable that the interval between cutting samples and drying should be kept to a minimum—not exceeding 3 or 4 hr.

In the absence of drying facilities, air-dry weights are the only alternative. Air-drying can be accomplished in open-weave bags hung in a dry, well-ventilated place until they attain constant weight. Such samples give reasonable comparative estimates of dry matter.

Weighing

Where field weighing is required, spring balances are often adequate. Spring balances need to be tested regularly for accuracy, and during weighing there should be periodic checks.
of the zero setting and of the weight of the container, especially if it becomes wet. The capacity of the spring balance should be matched to the size of sample being handled. For example, the sensitivity of most spring balance with a capacity of 25 kg is only about 50 g, so that satisfactory results cannot be expected with samples ranging from 0.5 to 5.0 kg.

Modern knife-edge balances with a single pan on top are the most satisfactory devices for weighing samples in the laboratory. They are robust and can be carried from room to room without risk of damage, and they can be used in the field, when batteries can substitute for mains power supply. However, they are sensitive to air movement in the field, especially when large trays are used to hold samples.

Data Recording

The points listed below are those, which we believe should be incorporated into any system for recording and handling data.

Each experiment should have a number and an associated statement of title of the experiment, the aims of the experiment, the treatments, the design, location, year, season, and the measurements to be made. The recording system adopted should include sufficient information to permit another research worker to understand exactly what has been done. Adequate information should be written on bags containing samples or on labels enclosed with the sample; for examples the experiment number or code, date of sampling, plot and/or treatment identification number, description of sample and unit of measurements. The information should be sufficient to allow the sample to be identified accurately if it should accidentally be mislaid and subsequently found.
These labels or bags should be kept until the results have been completely entered up in the records because this can assist in checking data, which appear to be faulty, e.g. two weights with the same plot number. In this connection, it is an added safeguard to record sample weights on bags or labels as well as on record sheets. Each experiment should have a notebook for entering records of events during the course of an experiment, e.g. sowing date, dates of application of treatments, dates of mowing or grazing, when fertilizer was applied, climatic occurrences such as frosts, periods of moisture stress, and so on. Memories are unreliable.

Recording systems should be as simple as possible. They should be designed to avoid transferring figures more often than necessary, because copying only increases the chances of making mistakes. It is wise to keep a record of the way in which various calculations are done, so that subsequent re-checking is easier.

If regular observations are to be made on any experiment, it is useful to prepare a functional record sheet for such observations. This can make calculations easier and lessens the chance of some record being omitted. Where computers are used for handling data, it is often possible to record data directly on to computer sheets, thus avoiding unnecessary transcription. Original data records should also be retained until some time after the results have been written up and published or distribute it may be necessary to re-check. As far as possible, data should be tabulated regularly so that unexpected trends can be recognized quickly and, if necessary, investigated at once. It may be necessary to undertake extra sampling to explain trends, and it may be too late if calculations are left until the end of the year.
Sample exercise

Two forage oat varieties, namely A and B were planted on first of June by drilling the seeds in 5-meter row length at spacing of 25 cm between rows. Urea fertilizer was applied @ 120kg/ha. For growth and development analysis, samples were taken from 0.5-meter row length successively at 30 days interval i.e. at 30, 60, 90 and 120 days after sowing. Based on the information given in Table calculate: LAI, LA, RGR, LAR, SLA, SLW, CGR, DMY, U, AP, and NUE. Hint: assume K as = 0.7

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Variety</th>
<th>30DAS</th>
<th>60DAS</th>
<th>90DAS</th>
<th>120DAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Height(cm) A</td>
<td>27</td>
<td>72</td>
<td>111</td>
<td>113</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>25</td>
<td>62</td>
<td>140</td>
<td>147</td>
</tr>
<tr>
<td># of shoot A</td>
<td>47</td>
<td>74</td>
<td>42</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>42</td>
<td>62</td>
<td>43</td>
<td>47</td>
</tr>
<tr>
<td># of small leaf A</td>
<td>10</td>
<td>30</td>
<td>22</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>15</td>
<td>25</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td># of medium leaf A</td>
<td>60</td>
<td>100</td>
<td>41</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>72</td>
<td>98</td>
<td>47</td>
<td>39</td>
</tr>
<tr>
<td># of large leaf A</td>
<td>20</td>
<td>54</td>
<td>22</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>16</td>
<td>61</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Av. Length of small leaf(cm) A</td>
<td>5</td>
<td>8</td>
<td>11</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>4</td>
<td>7</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Av. Length of medium leaf(cm) A</td>
<td>10</td>
<td>15</td>
<td>18</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>12</td>
<td>15</td>
<td>19</td>
<td>23</td>
</tr>
<tr>
<td>Av. Length of large leaf(cm) A</td>
<td>15</td>
<td>24</td>
<td>29</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>16</td>
<td>23</td>
<td>30</td>
<td>39</td>
</tr>
<tr>
<td>Av. Width of small leaf(cm) A</td>
<td>1</td>
<td>1.5</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>1</td>
<td>1.5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Av. Width of medium leaf(cm) A</td>
<td>2</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>2</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Av. Width of large leaf(cm) A</td>
<td>3.5</td>
<td>3.5</td>
<td>3.7</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>3</td>
<td>3.5</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>DM. Acc. Leaf(g) A</td>
<td>4</td>
<td>26</td>
<td>33</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>3</td>
<td>15</td>
<td>44</td>
<td>68</td>
</tr>
<tr>
<td>DM. acc. stem(g) A</td>
<td>3</td>
<td>15</td>
<td>44</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>2</td>
<td>16</td>
<td>44</td>
<td>74</td>
</tr>
<tr>
<td>% N content A</td>
<td>4.6</td>
<td>3.8</td>
<td>3.0</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>4.9</td>
<td>4</td>
<td>3.1</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Based on your result answer the following questions

1. Which variety showed higher LAI, RGR, LEAF AREA, LAR, SLA, SLW, CGR, Dry Matter Yield, U, AP, NUE, and why so this happened.
2. Why number of shoot and leaves decreased with age of the crop? Give your scientific reasons.
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