Pasture Improvement Research in Eastern and Southern Africa

Proceedings of a workshop held in Harare, Zimbabwe, 17-21 September 1984
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Editor: Jackson A. Kategile

Cosponsored by the Southern African Development Coordination Committee, Gaborone, Botswana, and the International Development Research Centre, Ottawa, Canada
Abstract: The proceedings contains reviews by national scientists on pasture research done primarily in Eastern and Southern Africa (Ethiopia, Kenya, Tanzania, Burundi, Zambia, Zimbabwe, Lesotho, Botswana, Mozambique, and Madagascar). The application of the results obtained and lessons learned are highlighted and used in setting of national priorities for research areas for the future. Critical reviews on current pasture research methodologies are included in the proceedings. The research methods discussed are germ-plasm collection, storage, and dissemination; and germ-plasm introduction and evaluation, nutritive evaluation of pastures, grazing experiments, and range monitoring. Specific guidelines on methodologies are outlined and these are useful to pasture agronomists, animal nutritionists, and range-management scientists.

Two case studies of pasture-research regional networks in Asia and Latin America were presented and discussed. A strategy for future pasture research coordinated through a regional Pastures Network for Eastern and Southern Africa (PANESA) was discussed and agreed upon.


Deux études de cas ont fait l'objet d'une présentation suivie d'une discussion : il s'agit des réseaux régionaux de recherche sur les pâturages en Asie et en Amérique latine. Après discussion, on a convenu d'une stratégie de la recherche sur les pâturages, dans les années à venir; la coordination de cette stratégie sera assurée par une section régionale du Pastures Network pour l'Afrique orientale et méridionale (PANESA).

Resumen: En las actas se recogen ponencias presentadas por científicos de diferentes países sobre las investigaciones en pastos que se han realizado principalmente en el África oriental y meridional (Etiopía, Kenia, Tanzania, Burundi, Zambie, Zimbabwe, Swazilandia, Lesotho, Botswana, Mozambique y Madagascar). Se destaca la aplicación de los resultados y experiencias obtenidos, muy útiles para determinar las prioridades de las investigaciones futuras en las diferentes naciones. En las actas se recogen también ponencias críticas sobre las metodologías empleadas actualmente en las investigaciones sobre pastos. Se analizan los siguientes métodos de investigación: recogida, almacenamiento, diseminación, introducción y evaluación de germoplasma; evaluación del valor nutricional de los pastos; experimentos de pastoreo; y control de dehesas. Se resumen directrices y metodologías específicas de gran utilidad para agrónomos especializados en pastos, expertos en nutrición animal y científicos especializados en gestión de dehesas.

Se presentan y analizan dos estudios de casos de las redes regionales de investigación en Asia y Latinoamérica. Se discutió y aprobó una estrategia para realizar investigaciones sobre pastos en el futuro que serán coordinadas por la Red de Investigaciones sobre Pastos para África Oriental y Meridional (RIPAOM).
CONTENTS

Foreword 7

Participants 9

Keynote Address 15

Session I State of Research Work in Eastern and Southern Africa 23

Pasture Research in Zimbabwe: 1964-84
   J.N. Clatworthy 25

Highlights of Pasture Research in Malawi: 1975-84
   B.H. Dzowela 59

Pasture Research and Development in Ethiopia
   Lulseged Gebrehiwot and Alemu Tadesse 77

Pasture Research in Burundi
   Gaboryaheze Astère 92

Survey of Pasture Research in Madagascar
   J.H. Rasambainarivo, R. Razafindratsita, and M. Rabehanitriniony 102

Review of Range and Pasture Research in Botswana
   D.R. Chandler 115

Review of the Use of Improved Pasture Species in Mozambique
   Jonathan Timberlake and António Catalão Dionisio 143
Pastures in Lesotho  
C.J. Goebel, B. Motsamai, and V. Ramakhula 153

Pasture Research and Development in Zambia  
J. Kulich and E.M. Kaluba 163

Past and Current Trends of Pasture Research in Kenya  
Abdullah N. Said 180

Pasture Research in Tanzania  
A.B. Lwoga, M.M.S. Lugenja, and A.R. Kajuni 210

Forage Legumes in Agropastoral Production Systems within the Subhumid Zone of Nigeria  
M.A. Mohamed Saleem 222

Session II  
**Pasture Research Methodologies and Regional Networks** 245

Collection and Preliminary Forage Evaluation of Some Ethiopian Trifolium Species  
J. Kahurananga, L. Akundabweni, and S. Jutzi 247

Theory and Practice in Forage Germ-Plasm Collection  
J.R. Lazier 260

Germ-Plasm Storage and Dissemination  
Adolf Krauss 296

Tropical Pasture Germ-Plasm Evaluation: Strategy and Experimental Designs  
A.B. Lwoga 312

Introduction and Evaluation of Large Germ-Plasm Collections  
D.G. Cameron 334

Methods of Pasture Establishment  
P.J. Grant and J.N. Clatworthy 349
Animal Experiments as a Measurement of Pasture Productivity  
   P.T. Spear 368

Commercial Seed Increase of New Pasture Cultivars: Organization and Practice  
   D.S. Loch 392

Evaluation of the Nutritive Value of Forages  
   Kassu Yilala and Abdullah N. Said 425

Range Monitoring Methodologies  
   Moses O. Olang 452

Australian-Southeast Asian and Pacific Forage Research Network  
   T.R. Evans 465

Network Approach in Pasture Research: Tropical American Experience  
   J.M. Toledo, H.H. Li Pun, and E.A. Pizarro 475

Discussion Summary and Recommendations 499

Research Priorities and Future Strategies on Germ-Plasm Collection (Multiplication, Storage, and Dissemination) 499

Selection and Evaluation Methodologies 502

Establishment and Management 504

Research for Small-Scale/Small Producers Pasture Improvements 506

Organizational Aspects 507
METHODS OF PASTURE ESTABLISHMENT

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Abstract Establishment of pasture plants is probably best studied by sowing seeds under the conditions they are likely to encounter in agricultural practice and counting the survivors. On a more theoretical level, establishment can, however, be regarded as three separate phases - germination, emergence, and survival - and factors likely to affect each of these phases are reviewed. Practical considerations involved in the establishment of pastures are then discussed.

In this paper, the subject of pasture establishment has been considered from the aspect of the Third World countries with limited resources of staff, finance, and facilities where the need is to apply these resources to greatest immediate advantage. Probably the most appropriate research methodology for examining pasture establishment is to sow the seeds of pasture plants likely to prove ecologically adaptable in situations where they are likely to be agriculturally valuable using methods that are likely to be practical agriculturally and then to determine the proportion of the seeds that give rise to established plants. The number of times that "likely" occurs in that sentence indicates the extent to which local expertise is invaluable in deciding which pasture strains to sow, how they would be used in farming practice and what sorts of technology are available to the farmer.

In Zimbabwe, for instance, different answers would probably apply on a large-scale commercial farm and on a small-scale subsistence one; on a farm on a clay soil and on a farm on sandy soil, and for reinforcement of native grassland as opposed to sowing legumes on
arable land. Because of this, it is difficult to outline a single, step-by-step procedure to be followed in all cases. What we have done is to outline the stages between the seed and the established plant and the factors that we consider important in ensuring that the developing plant passes from one stage to the next until it is established. There are always arguments about what can be considered as an "established" plant: under our conditions, where we work essentially with perennial species in an area characterized by distinct wet and dry seasons, we could consider a plant established if it survived into the growing season after that in which it was sown.

Establishment is unusual among the various aspects of grassland research in that laboratory and greenhouse trials can form an important part of the program. Initially, the value of these trials is almost entirely exploratory, although once models have been derived they can be used for prediction purposes. Because of the relevance of laboratory work and because establishment trials are in most cases short-term, establishment studies form a very suitable topic for graduate projects at universities and this is a source of research expertise that should be borne in mind. One danger, although, is that too many trials end at the laboratory stage. As an example, tests of methods of breaking hardseededness in legumes should include field sowings and not merely present petri-dish results.

PRINCIPLES

Ensuring Maximum Germination

Dormancy may be a problem and very low germination is obtained with freshly harvested seed of some grasses. Tropical pasture species, both grasses and legumes, are very recent selections from wild plants and retain a number of survival mechanisms, such as seed dormancy, that have been largely eliminated by selection for rapid germination from the temperature cultivated species. Although it may be possible to overcome dormancy by such treatments as the concentrated sulphuric acid used by Smith (1966a) on Sabi pancium (P. maximum), these are not usually feasible with large lots of seed. It is usually a wise precaution, as
recommended by Liebenberg (1955), to sow seed of grass species known to exhibit dormancy only in the second season after harvesting.

Hardseededness is a very common cause of reduced germination in subtropical legumes and among methods used to overcome it are: dry heat (Holm 1973; Anonymous 1977; Mott 1979), hot water (Gray 1962; Phipps 1973; Savory and Thomas 1977), fluctuating temperatures (Quinlivan 1961, 1968; Cameron 1967; Taylor 1981), cold treatments (Phipps 1973), microwave radiation (Nguyen Tran 1979), mechanical abrasion (Grant 1979a, 1980), concentrated sulphuric acid (Phipps 1973; Pentney et al. 1984), and seed coat nicking (Pentney et al. 1984). "Large increases in germination can be achieved that would enhance successful establishment and economise in seed" (Phipps 1973).

The actual method used would depend on the cultivar and the feasibility of the treatment, e.g., dry heat is a very suitable method to use on tobacco farms where barns at the correct temperature are available during the curing season; with peasant farmers, methods using boiling water are more feasible than those that require a lower specified temperature.

Rapid and complete germination of sown species is probably an advantage in sowings on arable land where a suitable seedbed can be precisely prepared, and the relatively small areas can be sown rapidly when conditions are near ideal and when it is essential that sown species establish before weed competition becomes too severe. It may be desirable to retain a proportion of hard seed as an insurance against complete failure in grassland reinforcement projects where there is less control over the conditions and where "false flushes" of germination are more likely to occur. It is likely that, because of the effect of fluctuating temperatures in reducing hardseededness (Cameron 1967), differences in germination between treated and untreated seed will not be as great in field sowing as in the petri-dish.

Trials in which seeds are sown at frequent intervals, preferably over more than one growing season, and the emergence compared with relevant meteorological data, give an indication of the conditions that favour germination and emergence (Smith 1966a). Then,
from an analysis of long-term meteorological records, such as those of Lineham (1967), it is possible to predict the time of the season at which these conditions are most likely to occur. The risks inherent in this probabilistic approach can be reduced if accurate medium-term weather forecasts are available to the farmer.

Compaction of the soil around the seed increases water flow into the germinating seed. Compaction can be done with a roller, ideally both before and after sowing the seed (Grant 1976, 1978). The germination of fluffy seeds, such as Buffel grass (Cenchrus ciliaris), may be increased by hammer milling the seed to remove bristles and glumes (Humphreys 1978). Finally, pelleting the seed may increase water uptake by surface sown seeds and so aid germination (McWilliam and Dowling 1970).

Differences occur in the ability of pasture species to germinate under moisture stress. Ryegrass (Lolium perenne), for instance, germinated at suction potentials that inhibited germination of Phalaris (P. tuberosa), Lucerne (Medicago sativa), and Subterranean clover (Trifolium subterraneum), and McWilliam and Dowling (1970) suggested that this might be one of the reasons contributing to the successful establishment of ryegrass from aerial seedings.

Ensuring Maximum Emergence

Numerous greenhouse studies have shown that with small-seeded pasture species, depth of sowing is critical to emergence, and recommendations for optimum depth of sowing range from 5 to 15 mm (Bogdan 1964; Smith 1966a; Stonard 1969; Grant 1975). The reduction in emergence resulting from deeper sowing may differ with soil type (Grant 1975). In a field trial with Tall fescue (Festuca elatior) varieties, Brock (1973) showed that emergence was greater for sowings 15 mm deep than from 5 or 25 mm sowings.

For large-scale field sowings, accurate control of depth of sowing depends on using a precision drill or on the creation of furrows of a suitable depth in which the seed can be placed. This is one of the effects of prerolling with a Cambridge roller (Grant 1979b).
Marked surface crusts can develop on certain soil types - usually those with a high silt content. On these soils, emergence of seedlings can be greatly reduced (Leslie 1965; Brock 1973; Grant 1975), although there is evidence that the reduction may be due to mechanical impedance by the soil and not to the direct effect of the crust (Leslie 1965). On these soils, attempts to compact the soil around the seed may have a harmful effect, especially if a spell of dry weather follows.

The formation of a crust and the mechanical impedance of the soil are greatly reduced if the soil is moist (Grant 1975), and this is one of the reasons for the beneficial effects of a mulch, such as that recorded by Smith (1966b) on a soil very prone to crusting. Rickert (1970) also recorded beneficial effects of mulching on grass establishment, but there was a reduction of grass yield at very high levels of mulch.

There are two ways in which the soil around the seed can be kept moist: by good (or lucky) timing of sowing before a rainy spell and by reducing the loss of moisture from the soil surface. The latter can be done by shading the soil with a mulch (which accounts for the beneficial effects of a mulch on noncrusting soils) or with a cover of vegetation. Thus, McWilliam and Dowling (1970) found that establishment of surface-sown seed was greater under grass that had been killed with herbicide than on bare soil and Miller and Perry (1978) recorded greater germination of Townsville stylo (Stylosanthes humilis) seed under standing grass than on a burnt area.

Leslie (1965) recorded greater emergence of seedlings from soil which that had been sterilized by autoclaving than from control soil and tentatively ascribed the effect to fungal organisms. Treatment of grass seed with seed dressings may be warranted. As most of the pasture legumes exhibit epigeal germination, the effect of seed treatment is less marked and it may interfere with inoculation.

In Leslie's trial (1965), the emergence of Rhodes grass (Chloris gayana) was reduced by surface crusting more than was that of green panic. This does not appear to accord with the results of Smith (1966a) who recorded a much greater response to mulch, in terms
of number of seedlings emerged, of Sabi panicum than Katambora or Giant Rhodes grass. There are obviously differences in the ability of different species to emerge under adverse conditions, although, on this limited evidence, the effects do not always appear to be consistent.

Ensuring Maximum Survival

The first stage is the reduction of weed competition by preseeding treatments to eliminate, or reduce the effect of, the existing vegetation. In grassland reinforcement projects, the complete elimination of the vegetation is obviously undesirable and the aim is to reduce the vigour of the existing grasses by heavy grazing and trampling (Edwards and Mappledoram 1973), by burning (Stocker and Sturtz 1966; Chadhokar 1977), by cultivating strips (Clatworthy and Thomas 1972; Mills 1978; Cook and Dolby 1981), or by herbicides (Campbell 1976; Cook and Dolby 1981). Almost invariably the greater the reduction of the native vegetation, the greater the establishment of the sown species (Pearen and Keoghan 1982).

On arable land the aim is the complete elimination of the existing vegetation by several cultivations, and possibly by herbicide application, before the pasture seed is sown. Postsowing treatments that reduce the effects of the weeds include:

(a) Use of herbicides. Most of the herbicides are preemergent and applied either before or immediately after sowing the seed. Examples are Trifuralin (Cameron 1971), Eptam (Grant 1978), Alachlor and Metalochlor (Irvine 1984) for legumes, and Atrazine for grasses. Postemergent herbicides are less commonly used, although 2,4-D is effective against dicotyledonous weeds in grasses and may also be used to control certain weeds in Stylosanthes species (Scanlan 1981).

(b) Weeding or cultivation is greatly eased if the pasture seeds have been sown in drills. Mechanical cultivation is possible on a large-scale but hand-weeding can only be used on small-scale plantings and where labour is very cheap.

(c) Grazing, mowing, or slashing the pasture if
weeds threaten to shade the pasture seedlings is often recommended. The treatment must be carefully controlled if the pasture seedlings are not to be damaged.

(d) Underseeding the pasture in a crop, usually of maize, is a practice that offers a number of advantages especially for establishment of legume seedlings (Thomas 1975). Among these advantages is the partial suppression of grass weeds by the maize canopy, allowing the legume seedlings to compete on more favourable terms.

Early nodulation of the legume seedlings helps to make them independent of soil nitrogen and so better able to compete with the grasses. Most of the pasture legume cultivars nodulate satisfactorily with local soil Rhizobium strains and inoculation may prove unnecessary in practice, except for very small-seeded legumes (such as Lotononis bainesii) and those with very specific Rhizobium requirements. However, until it is known which legumes do not need inoculation it is always advisable to inoculate, especially in experimental sowings. Dry cultures of inoculum are readily available commercially and travel well by air freight. Inoculation of legume seeds is a simple process. Instructions are usually included with the inoculant and can be found in books such as Humphreys (1978).

Postemergent attacks by fungus diseases or by insect pests may seriously reduce the stand of the young pasture. Treatment against these problems may be relatively simple - Jones (1965) recommended seed treatment of Siratro (Macroptilium atropurpureum) with Dieldrin to prevent attack by bean stem maggot (Melanagromyza phaseoli) and seed dressings may help to prevent fungal "damping off."

It is desirable to apply fertilizer to correct known deficiencies in the soil, and soil analysis and local experience are very useful guides to fertilizer treatment. In extreme conditions, complete failures of pasture seedings may result unless soil nutrient deficiencies are corrected; the coastal sandy "Wallum" soils of Queensland are a well-known example (Andrew and Bryan 1955).

Phosphatic fertilization is particularly important, especially for legume establishment, and plants with a
balanced supply of nutrients may be better able to withstand stress. Souto and Dobereiner (1970) showed that seedlings of *Neonotonia wightii* with adequate phosphate were more heat tolerant.

Recent work at the Grasslands Research Station, Marondera, Zimbabwe, (Grant and Tanner, unpublished) indicates that several subtropical pasture legumes possess an ability to extract phosphate that would normally be considered unavailable. Therefore, in assessing soil analyses some attention should be paid to the total phosphate because legumes responded equally to a large amount applied initially as to a series of smaller dressings over several years. These remarks also applied to other species, mainly grass, which tended to show greater responses than legumes in some cases.

One of the legume species, fine-stem stylo cv. Oxley (*Stylosanthes guianensis*), after large initial responses to single superphosphate eventually almost disappeared in some plots, whereas Siratro (*M. atropurpureum*) gave continuing responses on granite sands. Stylo decline correlated significantly with decreased concentration of zinc in the herbage, and this correlated with higher phosphate level.

In the second season, stylo numbers were greatest where the soil had contained 150-160 ppm total soil phosphate, with a marked fall off either side. Zinc sulphate applied to another pasture significantly increased legume numbers.

Millikan (1962) with Subterranean clover found that critical herbage zinc levels varied according to soil phosphate. Deficiency symptoms did not relate to soil zinc, but to a high phosphate to zinc ratio. He, therefore, suggests that zinc is essential to phosphate utilization by the plant.

Other recent work at Grasslands has consistently shown responses of many subtropical pasture legumes during establishment to dolomitic lime, interacting with the level of single superphosphate application. This can be related mainly to calcium and also magnesium.
Edye et al. (1964) (quoted by Humphreys 1978) showed the marked effect of NPK fertilizers on establishment and yield of Buffel grass. Nitrogen applications to young pastures need to be carefully monitored. There is usually a release of nitrogen during soil preparation and extra nitrogen may merely cause the annual grass weeds to grow faster and smother the slow-growing perennials. Nitrogen must be used particularly carefully on pastures containing legumes.

Leslie (1965) remarked that in his experiments very little mortality of seedlings occurred more than 5 weeks after emergence. This may be so on ploughed land but in grassland reinforcement, mortality is common at much greater ages and marked differences between species may occur. These differences appear to increase as the degree of competition to which the seedlings are subjected increases. Thus, Cook and Dolby (1981) found that Buffel grass established as well as Siratro on cultivated strips but less well when sown into grassland. Differences were also observed in the time of mortality - most of the grass seedling deaths occurred during the 12 weeks after emergence whereas Siratro was more persistent over the period but suffered greater losses over the winter-spring period.

Similarly, Clatworthy (1980), comparing 12 legume strains at two sites, recorded marked differences in the survival of seedlings from the first count (6 weeks after seeding) to the last (in the following rainy season) when sown into disced grassland. On the sandy soil, only the *Stylosanthes* species and Siratro had survival rates greater than 25% and three strains of *Desmodium* species each had less than 1% survival. In contrast, on the heavier soil, where weather conditions were also more favourable, more than 25% of the seedlings of all the legume strains survived, but *Stylosanthes* species and Siratro again had the highest values. The selection of species or strains of high survival ability is particularly important when pasture plants are sown in adverse conditions.

**PRACTICAL APPLICATIONS**

(a) **Scarification of seed** Maximum germination is obtained with some seed damage with some hard seeds.
In the Third World countries, where control over sowing conditions is less certain, this option may be useful even for arable land. The harmless inexpensive method of natural fluctuating temperature would suit many Third World countries like Zimbabwe where germination of fine-stem stylo seed spread in the sun during the dry season increased from 10 to 40%. Acid treatment and even hot water may present practical difficulties, but some seeds can be scarified by rubbing between flat pieces of wood, and other types can be churned in an abrasively lined barrel. Criteria for commercial mechanical scarification of nearly all types of seed do exist, and where machinery is available this method is very useful for bulk quantities.

(b) **Species** Legume seedlings are particularly vulnerable during the 4-6 week period when developing their tap root. Particularly with species that germinate under stress, the presence of some trash or mulch will ensure that at least some of the seedlings survive subsequent dry spells.

(c) **Soils** that form a hard crust The seedbed should be left rough without cracks and should not be rolled. Legumes are better sown at 5 mm only, and cluster sowing helps crust penetration. It is usually better to allow the action of raindrops to cover the seed. Experimental watering every 5-6 days in combination with a thin mulch fractured the crust and increased emergence, but otherwise emergence was reduced. The variable mulching usually practiced gives fair results under most conditions, and drilling by hand or machine possesses the advantage of loose soil above the seed.

(d) **Weed control** If herbicide is not justified (e.g., for seed crops or valuable nurse crops) then mechanical control must be done. The weeds must germinate first and in unsuitable seasons the optimum period may pass. Expertise is needed to assess the correct moment to eliminate the weeds when they are most vulnerable.

(e) **Fertilization** Fertilizer recommendations for pasture establishment should include up to 500 kg/ha (preferably dolomitic) of lime and about 3 kg/ha of zinc oxide or equivalent when applying phosphate, and
farmers should obtain local information on other trace element deficiencies.

Grassland Reinforcement

A major effect of burning off existing vegetation is to reduce its vigour. This should be done after soaking rains have started and the new growth has flushed. Another method is to reduce the vigour by deliberate overgrazing. The use of a plough can produce uneven seedbeds. For many peasants, the only available tool is the plough and, if so, considerable pressure should follow, perhaps with the wheel of a heavily loaded scotchcart.

Strips in the grassland are best made using units of three to four discs in pairs about 1 m apart, but can also be done with an ox cultivator. In either case, a second pass with the implement is better, and about one third of the area should be cultivated. Strips should not be less than 30-cm wide because the roots of other species below the strip may cause seedling mortality during dry spells. Seed and fertilizer can be applied mechanically by attachments to the disc unit and relate to the disturbed area. Seed may be covered either by drawing a roller or by some means of brushing behind. Remarks made under 'fertilization' apply particularly to virgin grassland. Successful reinforcement has been done on old Star grass pasture using legume mixtures but the Star grass must not have been given any nitrogen the previous season.

Open Seeding Arable Land

The degree of soil disturbance should suit the type of seed. A plough is not an ideal seedbed tool and to avoid seedbeds that are not firm, either a disc harrow or cultivator followed by drag harrow and roll is better. Where most tools are available, the best combination for small legume seeds is the Cambridge roller before seeding and a flat roller afterward.

For seeding legumes, the largest lumps of soil should have a width about twice the required depth avoiding cracks where seed can be lost. But for a seeds mixture where grass seed is usually pressed into the soil surface, the best average is to sow onto a 3-cm
tilth and then cover with any type of roller. Peasant farmers are unlikely to possess a roller, but seed can be covered with a thorn brush.

The foregoing remarks apply to sands, sandy-loams, and loamy-sands if the season is not too wet. On silts and clays, special expertise is needed. The use of a roller is inadvisable and in any case seed will be covered by raindrops.

Precision drills are useful, but in the long run broadcasting the seed has proved to be as good as drilling. It has been found that spreading a seed mixture in front of tractor wheels gives results similar to drilling without the drilling problem of overcrowding seedlings. For this purpose a seedbox can be mounted on the tractor mudguard conveying the seed by wide flexible steam-hose pipes to the front of the big tractor wheels. The drive is taken from the axle using a bicycle wheel frame as a reduction gear. This method places most seed firmly at the correct depth on sandy soils if the tractor wheels have fairly new tread. On heavy soil, suitable conditions would be most unlikely and seed should be broadcast.

The peasant farmer may not be able to employ a tractor, but he could use the two wheels of a scotch-cart with perhaps two children at each side dropping a measured quantity of seed from a bottle. It would be an advantage for the scotchcart wheels to have a heavy tread, and it should also be as heavily loaded as possible.

Underseeding of Arable Crops

The provision of a nurse crop for shade has the extra advantages of better land use, saving of extra cultivation, weed control, and various moisture benefits. During the early stages of a nurse crop, there is a gradual increase in shade but demands for moisture are fairly small. The leaves of the crop also attract moisture on clear nights, which benefits seedlings establishing on the surface. This advantage continues well after the nurse crop begins to extract moisture at the deeper levels. When the nurse crop has developed a canopy it also helps to suppress weeds to the advantage
of undersown shade-tolerant species such as Silverleaf and P. maximum.

If weed control by herbicide is available it is possible to establish less shade-tolerant species under a thinner crop. With herbicide (Alachlor or Eptam), undersowing is best done at the time of nurse-crop emergence. For this, tractor wheel seeding is particularly useful. However, seed can be broadcast between the rows using a seed measure equivalent to two or three paces and someone to cover it up by gently brushing the soil. Application of nitrogen top dressing to a nurse crop that is to be undersowed should be timed after the legumes have produced trifoliate leaves, and never top dress just before undersowing.

Peasant farmers are unlikely to possess either the expertise or the funds for herbicide use and so cultivation by hand or with oxen will be necessary. Underseeding should still be done as early as possible while there is moisture between the rows of the crop. Peasant farmers can perhaps make up for lost time by being able to utilize unpaid family help for handweeding. It is also possible to consider seeding pasture legumes within the actual row of the crop and then to plant or seed grass between the rows after cultivation. If the undersown pasture has to compete with weeds as well as the nurse crop, poor establishment will result.

Grazing of crop residues can be done with care after the legumes have been either frosted or become dormant during the dry season, but sheep should be avoided, because they nibble close to the crown of the legumes. Grazing of crop residues should stop when the legumes send out fresh green shoots in spring and should not be resumed until there are sufficient other species grazing to satisfy the animals.

Underseeding may lead to another weed problem in the following season. The presence of a desirable grass will help to reduce this problem, but there is always a period before the grass is fully established when broadleaf weeds will flourish. If these weeds are mown in time, pasture survival will be improved, but, because it is also a period of much farm activity, weeds may either be allowed to seed or be cut too soon. The cost of mowing is questionable unless the cut herbage can be
preserved as fodder and silage making is a good gambit.

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