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Pasture Improvement Research in Eastern and Southern Africa

Proceedings of a workshop held in Harare, Zimbabwe, 17–21 September 1984

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Pasture Improvement Research in Eastern and Southern Africa

Proceedings of a workshop held in Harare, Zimbabwe, 17–21 September 1984

Editor: Jackson A. Kategile

Cosponsored by the
Southern African Development Coordination Committee, Gaborone, Botswana,
and the
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Abstract: The proceedings contains reviews by national scientists on pasture research done primarily in Eastern and Southern Africa (Ethiopia, Kenya, Tanzania, Burundi, Zambia, Zimbabwe, Swaziland, 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.

Résumé: Dans les actes ci-joints, des scientifiques de divers pays analysent la recherche entreprise sur les pâturages en Afrique orientale et australe (Éthiopie, Kenya, Tanzanie, Burundi, Zambie, Zimbabwe, Lesotho, Botswana, Mozambique et Madagascar). L'utilisation des résultats obtenus et les connaissances acquises sont mises en lumière, puis utilisées pour établir les priorités nationales en matière de recherche. Les actes comportent une analyse critique des méthodes de recherche actuelles sur les pâturages : rassemblement, entreposage et diffusion du matériel génétique; mise à l'essai et évaluation de ce matériel; expériences de pâturage; évaluation nutritive des pâturages et exploitation rationnelle de ceux-ci. On présente des lignes directrices précises sur les méthodes à suivre, qui seront utilies aux agronomes en charge des pâturages, aux spécialistes de la nutrition animale et aux scientifiques responsables de la gestion des pâturages.

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 for Eastern and Southern Africa (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 Africa oriental y meridional (Etiopía, Kenia, Tanzania, Burundi, Zambia, Zimbabwe, Suazilandia, 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 Africa Oriental y Meridional (RIPAOM).

CONTENTS

COMMERCIAL SEED INCREASE OF NEW PASTURE CULTIVARS: ORGANIZATION AND PRACTICE

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Abstract *Pasture seed production technology is reviewed in the context of commercial increase following the release of a new cultivar. Particular emphasis is placed on the organization and location of production, crop establishment and management, harvesting, and the role of research with brief notes on drying, processing, packaging, storage, seed testing, and seed certification.*

Seed production is a crucial step in the commercialization of newly released pasture plants. Most improved pastures are established from seed. Unless this necessary seed is produced, the final step of widespread commercial sowings with the new cultivar cannot take place and all the preceding work of plant introduction and evaluation before release will have been wasted.

The strategic importance of seed production is far greater than its immediate economic value. This was recognized in Queensland during the late 60s when lack of seed prevented the commercial use of a number of new grasses and legumes developed during the so-called tropical pasture revolution. This problem has since been largely overcome in Queensland, but the scenario could be repeated in the future as new cultivars are developed and released in other countries such as those of eastern and southern Africa represented at this meeting. The application of pasture seed production technology to the multiplication of commercial seed supplies after release is therefore the subject of this paper.

MECHANIZATION

It is neither necessary nor desirable for pasture seed production to be highly mechanized where labour is both abundant and cheap. However, the degree of mechanization required is an internal decision for each country and must be made in the light of prevailing social and economic factors.

Pasture seed production in the countries represented at this workshop is likely to rely on a substantial labour component in the foreseeable future unless suitable machinery for use with arable field crops is already available in some situations. In time, this emphasis may change in response to social and economic trends such as occurred in Queensland 30-50 years ago when farmers were forced into mechanization by the increasing cost and scarcity of suitable labour. Machinery, however, is expensive and the cost is usually spread over other crops in mixed enterprises, or over even larger crop areas by contractors.

At the same time, mechanization may be inevitable in some situations: for example, mechanical harvesting of crops such as Greenleaf and Silverleaf desmodium (Desmodium intortum, D. unicinatum) and the tropical stylo cultivars (Stylosanthes guianensis var. guianensis) may be the only means by which large quantities of seed can be produced. Again, however, this is an internal decision to be made by each country in the light of local conditions.

LEVEL OF TECHNOLOGY

Intensive seed production with high levels of technological input is not necessarily the most cost-effective approach, particularly with grasses that flower strongly throughout the growing season enabling seed to be produced under less elaborate systems. For example, large quantities of seed are produced from buffel grass (Cenchrus ciliaris), Pioneer Rhodes grass (Chloris gayana), and green and Gatton panics (Panicum maximum) by opportunist harvesting of pastures in central Queensland; paddocks are shut up for seed production after good rains in late spring or early summer and crops generally receive little deliberate management beyond shutting the paddock gate (Loch 1983a). However, a much higher level of input is required in other cases, particularly shy-seeding cultivars such as Narok setaria (Setaria sphacelata var. sericea) or grasses with restricted flowering periods (e.g., Callide and Samford Rhodes grass).

The wide range of available grasses and legumes together with social differences have resulted in a multiplicity of seed production systems such as those described for Latin America by Ferguson (1979). Intensive systems, however, generally give higher yields and more consistent production than opportunist ones and should therefore be adopted with new cultivars, at least until adequate supplies of seed are available commercially. In Queensland, the trend in recent years has been to restrict first-stage seed increase where possible to the best and most conscientious growers with a proven record, and access to supplementary irrigation is almost mandatory. These precautions reduce the risk of losing the small and valuable nucleus of seed that is available at the time of release. They also maximize the multiplication factor so that full-scale commercial seed production, possibly based on a less elaborate system, can be undertaken as soon as possible after release.

Intensive systems do not necessarily imply mechanization. Instead, a careful rather than a casual approach is intended with plants being established and managed primarily as seed crops. With this approach in mind, appropriate systems with a substantial labour input will no doubt evolve in response to different social structures and pressures in various countries.

ORGANIZATION OF SEED INCREASE

Since the early 70s, the initial multiplication of commercial seed supplies for each new cultivar in Queensland has been organized by a separate and autonomous Seed Increase Committee (SIC), the operations of which are described by Hopkinson (1980). Each SIC consists of a chairman from the Queensland Department of Primary Industries (QDPI), one representative each from the Seed Industry Association of Australia (the merchants) and the Queensland Seed Producers' Association, and a member appointed by the Queensland

Herbage Plant Liaison Committee that makes the decision to release each new cultivar. In recent years, SICs have tended to operate on a statewide level in contrast to the more parochial district basis of earlier Committees. All necessary arrangements, including selection of growers and pricing and distribution of seed, are made through the SIC until it decides to disband when adequate commercial supplies of seed are available.

Before the 70s, each new cultivar tended to be released and almost immediately forgotten by official bodies whose task had been completed. The main impact of the SIC system has been to maintain official interest beyond the point of release until the new cultivar has in fact been launched commercially. This particular system, however, need not necessarily be adopted in other countries provided the new cultivar receives the required impetus after release from other sources. In Queensland, for example, the successful commercial increase of Callide and Samford Rhodes grass (two of the forgotten cultivars from the 60s) and of Hatch creeping bluegrass (Bothriochloa insculpta) was recently coordinated without formal SICs.

Commercial seed increase is extremely vulnerable in the early stages because of the restricted scope of production and limited experience with the new crop. The overall risk of failure can be reduced by carefully selecting a minimum of three to four experienced seed growers each with a reasonable-sized area; if possible, production should also be spread geographically into different districts to minimize the impact of natural disasters (e.g., prolonged drought, unusually heavy frosts, and rain and wind at harvest). With a small nucleus of seed (50-100 kg or less), the SIC is restricted to a "bulk-up" year involving a few selected growers; when larger quantities of seed have been produced, they can then advertise for wider applications for new seed areas. With larger quantities of seed at release (100-200 kg or more), the SIC is able to call immediately for wider applications from a larger number of growers (usually more than 10).

Despite the best laid plans, individual areas may fail and it is not uncommon to produce little or no seed until at least the 2nd year after release, particularly with the slower-establishing, longer-lived perennials.

Hopefully, however, there will be one or more notable successes on which future multiplication can be based. Over a period of years, it has also been possible to identify the most consistent growers for first-stage seed increase, thereby increasing the chances of success with future releases.

Seed prices during the initial stages of multiplication are set by the SIC bearing in mind the effects of supply and demand. These are generally lower than could be expected in an unrestrained market, but higher than likely long-term values. Although relatively high seed prices for a new cultivar are often decried, this attitude is unrealistic and ignores the accompanying benefits. First, these prices provide entrepreneurial returns to successful first-stage growers who contribute greatly to our overall experience with the new crop. Second, they are a necessary catalyst to attract new growers, leading to full-scale commercial production and lower prices as soon as possible after release. Third, they enhance market development by spreading limited supplies of seed over a larger number of consumers, not just a few big orders.

Publicity for the new cultivar should coincide with the availability of adequate supplies of seed, not with the earlier date of release. Otherwise, farmers will simply lose interest in hearing about what they cannot buy. Publicity at this stage is also incumbent on the institutions that developed the new cultivar if they hope to keep faith with the growers who have taken the necessary risks in producing the required seed. Very recently, there have been moves to include the coordination of publicity among the duties of the SIC.

LOCATION OF SEED CROPS

The choice of a suitable locality or localities for seed production has been strongly emphasized in the past (e.g., Hopkinson and Reid 1979; Loch 1980) and should be the first consideration with seed production in a new country. Biologically, the location of seed crops depends primarily on climatic factors and to a lesser extent on soils. In practice, it also depends on other factors such as the availability of machinery and associated services, farmer expertise, and historical reasons; however, these are perhaps of less relevance to African conditions.

Climate

The legumes and grasses sown for pasture use in the tropics and subtopics comprise a diverse group adapted to a wide range of different environmental conditions. As a result, no single environment can be regarded as the best for growing seed crops of all of these. Seed production of individual cultivars tend to gravitate toward different districts according to their general adaptation. In addition, a larger number of cultivars can be grown in districts with a greater amount of climatic diversity, simply because suitable niches can be found for each one. On the Atherton Tablelands of north Queensland, for example, there is a steady gradation from a hot monsoonal climate on the lower northern end (Walkamin-Mareeba) through to a cooler, moister, higher-altitude environment in the Atherton-Kairi-Tolga area; this is accompanied by a change from crops such as siratro (Macroptilium atropurpureum), stylo, Caribbean stylo (Stylosanthes hamata), shrubby stylo (Stylosanthes scabra, and sabi grass (Urochloa mosambicensis) at the northern end to others such as Greenleaf desmodium, glycine (Neonotonia wightii), Kenya white clover (Trifolium semipilosum), green and Gatton panics, Rhodes grass, and setaria on the higher parts.

Tropical Legumes

The climatic requirements of the more uncompromisingly tropical legumes have been discussed in detail by Hopkinson and Reid (1979). Most show some kind of short-day response and require sufficient seasonal variation in daylength to give clearly defined phases of vegetative and reproductive development for a heavy seed crop; however, this must be balanced by frost-free conditions because of their winter-flowering behaviour. With siratro and centro (Centrosema pubescens), in particular, an element of stress (most conveniently from soil moisture) is necessary to promote vigorous reproductive growth, hence the need for a climate with reliable and well-defined wet and dry seasons. This is also an advantage with Malawi glycine because it will flower strongly and set little seed unless further vegetative growth is curtailed by drought during flowering. A 4-month wet season appears adequate for the vegetative growth of most tropical legumes, with a lower limit of about 800 mm average annual rainfall (AAR) to provide sufficient soil moisture, and an arbitrary upper limit of 2,000 mm to avoid excessively wet conditions for crop management operations and to reduce the risks of disease.

Within those general requirements, there are specific preferences for particular crops. Centro, puero (Pueraria phaseoloides), and calopo (Calopogonium muconoides) require warmer winters than most other species. Siratro performs best under a fairly short wet season and with a winter climate modified by irrigations (Hopkinson 1977). Glycine, axillaris (Macrotyloma axillare), and the desmodiums prefer a more prolonged wet season and rather cooler conditions than other winter-flowering species, hence the location of seed crops in the warmer lowland subtropics or in elevated tropical districts with some frost risk.

Diseases may also influence the final choice of site for seed production, although the use of fungicide is sometimes justifiable. With siratro, Rhizoctonia largely prevents seed production in wetter areas, and bean rust has increased difficulties in marginally cool districts. In the case of Stylosanthes species, botrytis head blight and, more recently, anthracnose have imposed serious restrictions on seed production in some areas.

Subtropical Legumes

There is a further heterogeneous group of legumes that are grown for seed under subtropical conditions in Queensland. Essentially, these legumes are adapted to subtropical temperature regimes; most escape frost because of their flowering behaviour; and stress has little or no apparent effect of stimulating flowering. Kenya white clover (which is also grown at higher elevations in the tropics) flowers during winter and early spring, but is generally unaffected by anything other than the heaviest frosts in the moist subtropics. Lotononis (Lotononis bainesii) flowers mainly during spring. Fine-stem stylo (S. guianensis var. intermedia) flowers strongly during summer and early autumn due to an apparent quantitative long-day requirement (Cameron and Mannetje 1977). Bargoo jointvetch (Aeschynomene falcata) and Wynn roundleaf cassia (Cassia rotundifolia) appear insensitive to daylength and can flower throughout the growing season provided there is adequate soil moisture. The newly released American jointvetch (Aeschynomene americana) cultivar Glenn also has some prospect of seed production in subtropical coastal districts because its late autumn flowering behaviour allows sufficient time for a seed crop before frosts are likely; however, it may be restricted to relatively warm sites to minimize the risk of botrytis head blight through longer periods of dew on heavy crops as nights become cooler. A similar cultivar of American jointvetch is already grown for seed under subtropical conditions in Florida.

The various subtropical legumes need a period of favourable growing conditions to establish the framework on which the harvested crop is produced, although this is generally shorter than the 4 months suggested earlier for tropical species. The wider distribution of rainfall in the subtropics allows this to be done earlier in the growing season (e.g., fine-stem stylo) or during late winter (e.g., lotononis). Where crops mature during summer, this also tends to reduce the incidence of disease during flowering and the risk of wet weather interfering with harvest.

Because of the more erratic rainfall in the subtropics, supplementary irrigation improves the reliability of cropping and increases seed yields. This is of particular importance in lower rainfall districts (e.g., fine-stem stylo) and with lotononis and Kenya white clover because adequate soil moisture is required during winter and early spring when rainfall tends to be at its lowest and most erratic.

Grasses

In Queensland, rainfall is the basic determinant of the distribution of grass seed crops depending on their general adaptation and daylength response (Loch 1980). Three broad groups are recognized:

(a) Buffel grass, Pioneer Rhodes grass, makarikari grass (Panicum coloratum var. makarikariense), and green and Gatton panics grow well under drier inland conditions, flower throughout the growing season, and will seed freely without special management. The bulk of seed is therefore produced by opportunist harvesting of pastures under about 700 mm AAR in the drier parts of their range in southern and (particularly) central Queensland where advantage can be taken of locally available machinery and naturally fertile soils in recently cleared areas. Inverell purple pigeon grass (*Setaria porphyrantha*) has similar attributes and is likely to come into this category in the future.

(b) Grasses in the second group also grow well in pastures in drier areas, but are short-day plants that, as seed crops, require moisture during the restricted periods when inflorescences emerge strongly. Seed production is therefore best in the wetter parts of their adaptive range where rain-grown crops have a greater chance of receiving adequate moisture late in the growing season during flowering and seeding, and where there is less risk of low-temperature damage to crops maturing in late autumn. For these reasons, supplementary irrigation is also an advantage. In Queensland, Callide and Samford Rhodes are major examples of this group: seed crops are now grown successfully in higher rainfall areas (generally 1,000-1,200 mm AAR) after earlier failing in drier districts where most Pioneer Rhodes seed is produced. Other examples include creeping bluegrass, late flowering strains of Indian bluegrass (*Bothriochloa pertusa*), and gamba grass (*Andropogon gayanus*).

(c) The third, rather heterogeneous group includes grasses such as signal (*Brachiaria decumbens*), para (*Brachiaria mutica*), guinea (*P. maximum*), paspalum (*Paspalum dilatatum*), plicatulum (*Paspalum plicatulum*), and setaria. Unlike the first two groups, these grasses do not grow strongly under drier inland conditions and, regardless of daylength response, seed is produced in the higher rainfall districts (c. 1,000 mm AAR or more) to which they are adapted. Within the group, however, moisture requirements vary appreciably. For example, setaria does not recover well from dry periods during crop growth and continuous moisture availability is essential for good seed yields. Under rain-grown conditions in the subtropics, the highest commercial yields have come from the highest rainfall districts used (c. 1,600-1,800 mm AAR) and supplementary irrigation is also an advantage, especially toward the lower rainfall limits.

Temperature influences the location of grass seed crops, first by the potential effects of low temperatures on the seed set of late-flowering grasses, and second through differences in general adaptation. Within group (c), for example, grasses such as para grow and seed well only in warmer tropical areas where other species best suited to cooler subtropical and tropical highland conditions (e.g., setaria, paspalum) would not succeed.

Seed Production in Marginal Environments

In some cases, it may be necessary to undertake seed production in an unsuitable climate, although this should only be considered as a last resort. For example, the range of available climates may not be sufficient in a small country where it is also not economically possible to import seed. In such circumstances, it may be possible to increase the chances of success by modifying the best available climate to some extent. In particular, careful site selection based on local experience can reduce or eliminate the risk of frost in marginal environments. With many legumes, irrigation is a satisfactory biological substitute for rainfall, though some legumes (e.g., creeping vigna - Vigna parkeri) and most grasses from higher rainfall environments (e.g., setaria) also seem to need accompanying humidity. With twining legumes (e.g. siratro), the use of trellises or even a growing upright framework such as rows of maize may improve seed production in marginally wet and marginally frosty environments: the exposure to either better light or a drier microclimate seems to stimulate flowering and reduces disease, and the greater elevation helps avoid light ground frosts.

Soils

Seed crops of both grasses and legumes can be grown on a wide range of well-drained soils. However, soil requirements for different cultivars vary and a good agricultural soil is not always the best option: it is the adaptation of the particular plant that determines the suitability of different soil types, not personal prejudices based on what is appropriate for annual field crops. For example, setaria will grow on relatively poorly drained soils that are not suitable for Inverell purple pigeon grass, a member of the same genus. In general, however, a soil with good moisture-holding capacity is an advantage with grasses in providing a buffer against vagaries in the amount and the distribution of rainfall and against inefficient irrigation. By comparison, soil fertility is usually less important provided fertilizer can be applied to correct any nutrient deficiencies.

Greater weed competition can be expected on fertile soils, especially in old cultivations. With the shorter, less competitive legumes in particular (e.g., lotononis, Bargoo jointvetch, fine-stem stylo), lower fertility soils are therefore preferred for seed production. Similarly, for seed crops in general, newly cleared land is often used to reduce competition.

ESTABLISHMENT

The same general principles apply to the establishment of pastures and the establishment of pasture seed crops. The major difference lies in the "thickening up" phase that normally follows the initial phases of seedling emergency and establishment in pastures. In contrast, the aim with seed crops is to eliminate, or at least drastically reduce, the need for any thickening up of the initial plant population (Fig. 1).

Where a pasture sward is being established specifically for seed production, it should be regarded primarily as a "crop." As such, it warrants more care and expense during establishment than pastures sown for grazing. Land preparation is generally more thorough to give a clean, firm, fine seedbed. High-quality, readily germinable seed is preferred and, as a rough rule of thumb, seeding rates should be about twice those recommended for normal pasture sowings. The temptation to reduce seeding rates when multiplying scarce or expensive seed must be resisted: it is always better to establish a smaller area properly than to risk stretching the seed too far. Inoculation of legume seed before sowing is a cheap insurance against failure, especially where legumes have not previously been sown.

Fig. 1. A dense weed-free seed crop of roundleaf cassia (Cassia rotundifolia cv. Wynn) 4 months after sowing in southern Queensland.

Because the seeds of most pasture plants are relatively small, they are generally sown on the surface or lightly incorporated to no more than about 1 cm depth. The seedbed should then be rolled to improve seed-soil contact.

In Queensland, seed is often mixed with fertilizers (usually superphosphate) to facilitate distribution and two precautions are necessary. First, legume seed should be pelleted to protect the inoculum. Second, mixtures of superphosphate and unprotected grass seeds must be sown immediately as the acid conditions can reduce germination even after storage overnight.

In theory, row planting has long been recommended for pasture seed crops to assist in the rogueing of off-types and to allow for interrow cultivation, similar to the situation with a number of annual field crops. In practice, the adoption of row planting with pasture seed crops has been limited, and the use of interrow cultivation is even less widespread despite the sometimes good intentions of growers. Row-planting is of greatest value with the tree legume leucaena (Leucaena leucocephala), with vigorous sprawling legumes (e.g., stylo), and with tussock grasses (e.g., Panicum and Setaria spp.) where the highest seed yields have been obtained from particular row spacings (Boonman 1972a; cf. Hacker and Jones 1971). With maximum productivity depends on the early formation of a closed canopy where soil moisture and nitrogen are adequate, although wider rows are advisable if either factor is likely to be in short supply (Loch 1982; Boonman 1973). Broadcast sowings may be equally useful or even preferable with other plant types, including stoloniferous plants such as Rhodes (Boonman 1972b), creeping bluegrass, lotononis, and Kenya white clover, and shorter, less-competitive legumes (e.g., fine-stem stylo, Bargoo jointvetch).

Because of its annual habit, Townsville stylo (Stylosanthes humilis) must be reestablished each year and control over plant density is necessary to maintain seed production (Shelton and Humphreys 1971). Similar considerations apply to Verano Caribbean stylo, which must be renovated annually because perennating plants lack vigour. Plant density can be controlled by the number of cultivations before reestablishment, or by thinning the seedlings with spike harrows or paraquat sprays (although the rate and the droplet size are critical).

Weed control cannot be overemphasized and should begin during establishment. The various options include pre-plant-incorporated or pre-emergence herbicides applied to the seedbed (Hawton 1976, 1980; Hawton and Johnson 1980), selection of planting time (Johnson and Hawton 1980), and hand weeding where cheap labour is available. The "stale seedbed" technique is not often used because of the time required, but it can be very effective in controlling populations of weeds that are resistant to selective herbicides; it follows normal seedbed preparation and involves the destruction of up to three successive germinations of small weed seedlings with desiccant herbicides before the crop is sown into the stale seedbed with a minimum of soil disturbance.

MANAGEMENT

Recent articles by Hopkinson and Eagles (1980) and Loch (1982) indicate the major aspects that must be considered with new seed crops. However, it is best to treat legumes and grasses separately because of differences in emphasis between the two groups.

Legumes

Effective weed control is a prerequisite to successful long-term seed production of legumes. After establishment, the first objective with the bulkier tropical species is to produce a dense closed vegetative canopy as early as possible. This helps to smother weeds and provides a framework for later crop development. Where cheap labour is available, hand weeding and hoeing are probably the best means of maintaining a clean, weed-free crop. Alternatively, post-emergence herbicides can be recommended for broadleafed weed control in several crops (Hawton and Johnson 1980), although there is less information on the "subtropical" plants that generally compete less strongly with weeds. These methods can be supplemented by rope-wick weeders that are both a cheap and an effective means of removing taller growing weeds from shorter non-twining legume crops; in particular, inexpensive hand-operated versions (called chemi-hoes) could usefully extend the range of options available with hand labour. Recent results with the new herbicide fluazifop have also been encouraging: all but a few grass weeds appear to be controlled, particularly in the seedling stage, without harming legumes.

Adequate nutrients, insect control, and disease avoidance are required for healthy, productive crops. Insects in particular must be considered. These include the various lepidopterous larvae that feed on pods and flowers, sucking bugs that also affect pods and flowers, and root-eating coleopterous larvae that are the most difficult to control.

Cutting management varies. In Queensland, axilleris crops are allowed to build up gradually throughout the growing season. However, crops of rampant short-day legumes such as stylo, may be trimmed c. 4-6 weeks before floral initiation, thereby reducing the bulk and allowing plants to recover by the start of the reproductive phase; cutting too late simply delays flowering, prolongs the reproductive phase, and reduces seed yields (Loch et al. 1976). In contrast, terminal and axillary shoots of lotononis and Kenya white clover need exposure to light for proper floral development. Swards should therefore be maintained in a short, open condition by regular cutting or close grazing until flower buds are produced.

Irrigation strategy also varies. Siratro and centro are instances where changes in soil moisture override the effects of daylength in the field. In districts with a reliable dry season, flushes of seeding can be induced by alternating periods of irrigation and moisture stress as described by Hopkinson (1977). In contrast, lotononis and Kenya white clover require adequate winter moisture to maintain a strong vegetative framework for the eventual seed crop; however, watering should cease with the onset of warmer spring weather to avoid excessive vegetative growth that encourages head rots and makes harvesting difficult.

Grasses

With grasses, the overall aim of management is to produce synchronized, high-yielding crops by promoting the uniform development of dense inflorescence populations. This depends largely on the combination of cutting management and fertilizer N to encourage the rapid early production of new tillers that form the basis of a synchronized crop.

Where possible, grasses should be grazed between cropping cycles so that a lenient cleaning cut is carried out at the start of the new crop. A severe cleaning cut can delay regrowth, prolong inflorescence emergence, and may ultimately result in fewer inflorescences (Loch 1983b).

In equatorial regions and with daylength-insensitive grasses at higher latitudes, flowering can occur throughout the year, allowing cleaning cuts to be timed according to anticipated growing conditions. Away from equatorial regions, however, the timing of cleaning cuts on short-day grasses such as Callide and Samford Rhodes, creeping blue, and gamba is related to their restricted periods of flowering (Loch 1980; Andrade et al. 1983). During autumn, these grasses do not seed earlier if a cleaning cut is carried out before the latest safe dates; rather, they simply produce taller, bulkier plants that are more difficult to harvest.

Nitrogen is regarded as the main nutritional determinant of grass seed yield. The necessary fertilizer should be applied as a single dressing as soon as possible after the cleaning cut. Established stands require more N fertilizer than 1st year crops and the optimum level also depends on species, cultivar, soil, and rainfall. In practice, the need for fertilizer N can be reduced by regular renovation through cultivation or by effectively "mining" naturally fertile soils after clearing as has been done for a number of years in arable districts of central Queensland.

The best grass crops are produced when there is no moisture stress to affect synchronization and reduce individual components of seed yield. Although satisfactory results have been obtained with many grasses under rain-grown conditions in suitable localities, supplementary irrigation improves the reliability of cropping and increases yields. It is of particular importance during the early stages of seed increase, and with moisture-sensitive species (e.g., setaria) or late-flowering cultivars (e.g., Callide and Samford Rhodes).

Weed control measures are less critical than with legumes because well-fertilized, established grass seed crops compete strongly with contaminant species. In general, insects and diseases also pose fewer problems than with legumes, although some potentially damaging diseases have so far been excluded from Queensland by quarantine measures. Plagues of rats and mice, however, occasionally wreak havoc with ripening grass seed crops in the field.

TIME OF HARVEST

Proper choice of harvest time is important, particularly where a single destructive harvest is to be taken from the standing crop. The period over which high yields of good-quality seed can be harvested varies considerably and depends both on the cultivar and on weather conditions, especially wind and rain. Peak presentation seed yields are maintained for only short periods in many crops such as stylo, desmodiums, lotononis, purple pigeon grass, and green and Gatton panics; in other cases, however, the timing of harvest is less critical because of the longer periods of peak yields (e.g., shrubby stylo, Kenya white clover, setaria).

Various indicators can be used to determine when to harvest, although all are easier to apply with a well-synchronized crop. In legumes, these include the degree of pod shattering and the proportions of mature and immature pods and flowers, as well as the quantity of ripe seeds that can be shaken from plants (e.g., stylo). With grasses, the main visual indicators are the ease of seed removal (coupled with biting or rubbing of the seed to check for the presence of caryopses), the amount of seed shed, and changes in overall field colour that reflect changes in seed pigmentation during maturation in many grasses. All of the available indicators of ripeness, however, are subjective; and for an accurate assessment of the overall stage of crop maturity, there is no substitute for experience aided by a keen sense of observation.

METHOD OF HARVEST

A variety of harvesting methods can be used. Regardless of which method is adopted, care should always be taken to ensure that the harvested sample can be cleaned to the required purity standards with minimum wastage of seed and time.

Hand Harvesting

Hand-harvesting methods are the simplest and also the most logical to use where labour is plentiful and cheap. These include hand-picking of legume pods (e.g., siratro, leucaena), which can be repeated on the same area at regular intervals over a prolonged period, and hand-sweeping from the ground during the dry season where crops (e.g., Townsville stylo, Caribbean stylo, signal grass) have been allowed to ripen and shed. Grass inflorescences may be cut above the leaf canopy with sickles (Fig. 2), taking care to remove any weeds; these are then bound and stooked to cure in the field for about 2 weeks before threshing, normally by beating the seed out with sticks on a sheet. For chaffy-seeded grasses (e.g., buffel), a hand-stripper can be easily constructed by attaching nails to a bar at appropriate intervals; when this is drawn through the

Fig. 2. Hand harvesting of Rhodes grass (Chloris gayana) seed in Ethiopia.

crop, ripe seeds are stripped into a bag trailed behind the collecting bar. A similar device with a tray rather than a bag has also been used to collect ripe seeds from fine-stem stylo.

In countries with high wage structures, there has been a trend toward mechanization. Larger areas can be harvested quickly with less labour, although yields and quality of seed tend to be lower than from hand-harvesting.

In Queensland, for example, combine harvesting with conventional self-propelled machines fitted with open fronts is now the main method of harvest for most grass and legume seeds. The standing crop is usually harvested direct, but prior windrowing is practiced with the desmodiums, some crops of glycine and lotononis, and occasional grass crops when rainfall is unlikely. Specialist seed growers tend to produce heavier seed crops and generally choose machines with relatively narrow fronts so that their threshing and cleaning capacities are not overtaxed by the amount of bulk taken in at the front.

In north Queensland, larger and more expensive machines can be justified because pasture seed crops are combined with large areas of annual field crops. The recent trend toward these has greatly improved the recovery of seed from the bulkier tropical legumes (largely through brute force) and also signal grass where substantial quantities of fallen seed are recovered from the mat of horizontal leaves by harvesting very low. In contrast, annual field cropping is more restricted in coastal southern Queensland and less power is required to handle the grasses and the less bulky subtropical legumes grown there; smaller machines (usually purchased secondhand) are therefore used because of the risks associated with pasture seed production. In the case of opportunist harvesting (e.g., in central Queensland), wider fronts can be used to increase the rate of harvest because lighter crops are produced.

The progression toward combine harvesting includes the reaper and binder that mechanizes the collection and binding of inflorescences into sheaves. Tractor-mounted mowers are still used by some north

Queensland farmers to collect guinea grass inflorescences that are "seated" in moist heaps for a few days before shaking out the detached seeds and drying them. A leucaena stripper has also been designed in central Queensland using an overhead boom arm from the three-point linkage to strip ripe pods onto a trailer/sledge drawn behind the tractor.

Over the years, a variety of special machines have been built -- often in farm workshops -- for the selective recovery of mature grass seed. They allow multiple harvests to be taken from the same crop and are of particular value with chaffy-seeded grasses (e.g., buffel, creeping blue), although Pioneer Rhodes and smooth-seeded species such as the panics have been harvested in the past. Most of these machines are comparatively inexpensive, particularly the earlier ones described by Cull (1963) and Purcell (1969). The simplest type is an open box covered with gauze at the top and the back and possibly with tensioned wires across the front; it is mounted on a vehicle and driven through the crop at c. 20-30 kilometres per hour (kph). This basic design has been improved, largely by mounting independent beaters or wire brushes in front, to give a second group of machines that operate at much safer speeds of c. 5-8 kph. More recently, modified combine harvesters and cotton pickers (typically with large beater-type fronts, high cleaning capacities, and collecting bins that can be emptied quickly) have been used in the Callide-Dawson area of central Queensland.

In the USA, difficulties with chaffy-seeded grasses (mainly Bothriochloa and Dichanthium species) have also generated special harvesting machinery, culminating in the OSU (Oklahoma State University) grass seed stripper (Whitney et al. 1979) and the Woodward flail-vac seed stripper (Beisel 1983; Dewald and Beisel 1983). In particular, the latter design represents a radical departure from beater-type machines because it is based on the use of brush rotating away from the machine and upward at the leading edge.

The recovery of fallen legume seed has been mechanized by pneumatic harvesting (commonly called suction or vacuum harvesting because of the most widely used type of machine). This was developed for subterranean clover and medic seeds in southern Australia. For efficient recovery, the soil must be hard and dry with an extremely level surface free of vegetation; preparations therefore begin at the time of sowing. On the debit side, suction harvesting is an extremely slow and dirty operation involving specialized, expensive machinery, and the removal of weed seeds and large volumes of soil during cleaning becomes progressively more difficult and expensive with smaller-seeded legumes. In practice, suction harvesting is mainly used either with light seed units where the true seed is enclosed in a pod segment (Townsville, Caribbean, shrubby, and fine-stem stylos) or with relatively large dense seeds (siratro). Other methods of harvest are preferred where a high proportion of total seed yield is carried on the standing crop at some stage.

DRYING

Seed harvested from the standing crop may be dried in shallow layers on sheets in the sun or an airy shed, or in artifical batch dryers. With moisture levels of up to 50-60% or more, drying should commence as soon as possible after harvest, at the most within a few hours, and continue without interruption until completed. The required capacity for artificial dryers depends on the maximum amounts of seed harvested per day. High levels of relative humidity (e.g., at night) need to be lowered by heating the air if drying is to continue. A maximum temperature of c. 35 °C is commonly regarded as safe. General principles of seed drying have been reviewed in a number of papers (e.g., Nellist and Hughes 1973) and the advantages of slow-drying for certain smooth-seeded grasses (Hopkinson 1976) should also be noted.

SEED PROCESSING AND PACKAGING

Seed processing aims at producing good-quality seeds that meet the recommended standards for germination, weed freedom, and seed size. Because processing is less urgent than harvesting or drying, it generally takes place sometime later and at slower daily rates. Allowance must be made for temporary storage of dried, uncleaned seed that can also be transported to more distant processing facilities if necessary.

Various authors have discussed seed processing (e.g., Vaughan et al. 1968; Linnett 1977), which is based essentially on screening and winnowing. In more traditional situations, hand methods may be supplemented very cheaply by a simply constructed winnower (Verhoeven 1964) provided a suitable fan is available (Fig. 3). In large cleaning plants, the main cleaning machine will operate faster and more efficiently with a precleaner to remove the larger trash; it may also be followed by length and gravity separators, or replaced by special machines (e.g., buffel grass cleaners) to cope with particular difficulties. It cannot be overemphasized that clean seed comes from clean fields; no amount of seed cleaning after harvest can compensate for inadequate weed control in the growing crop.

After processing, seed should be packed into new bags, either polypropylene or jute, to avoid contamination. Dry sealing of seed with thick polyethylene liners for longer-term storage can also be carried out at this stage. Bags should be packed to standard weights to facilitate subsequent handling.

SEED TESTING

Seed testing (e.g., Harty 1980) provides the basis for regulatory controls over seed quality, for price and consumer discrimination among available seed lots, and for the adjustment of sowing rates. Appropriate procedures are gradually developed for new cultivars and eventually become accepted into the rules of the International Seed Testing Association.

Separate specialized laboratories for the routine testing of pasture seeds and other seeds are generally not warranted. A mixed laboratory has advantages of spreading the workload more evenly throughout the year and of providing wider experience for testing staff.

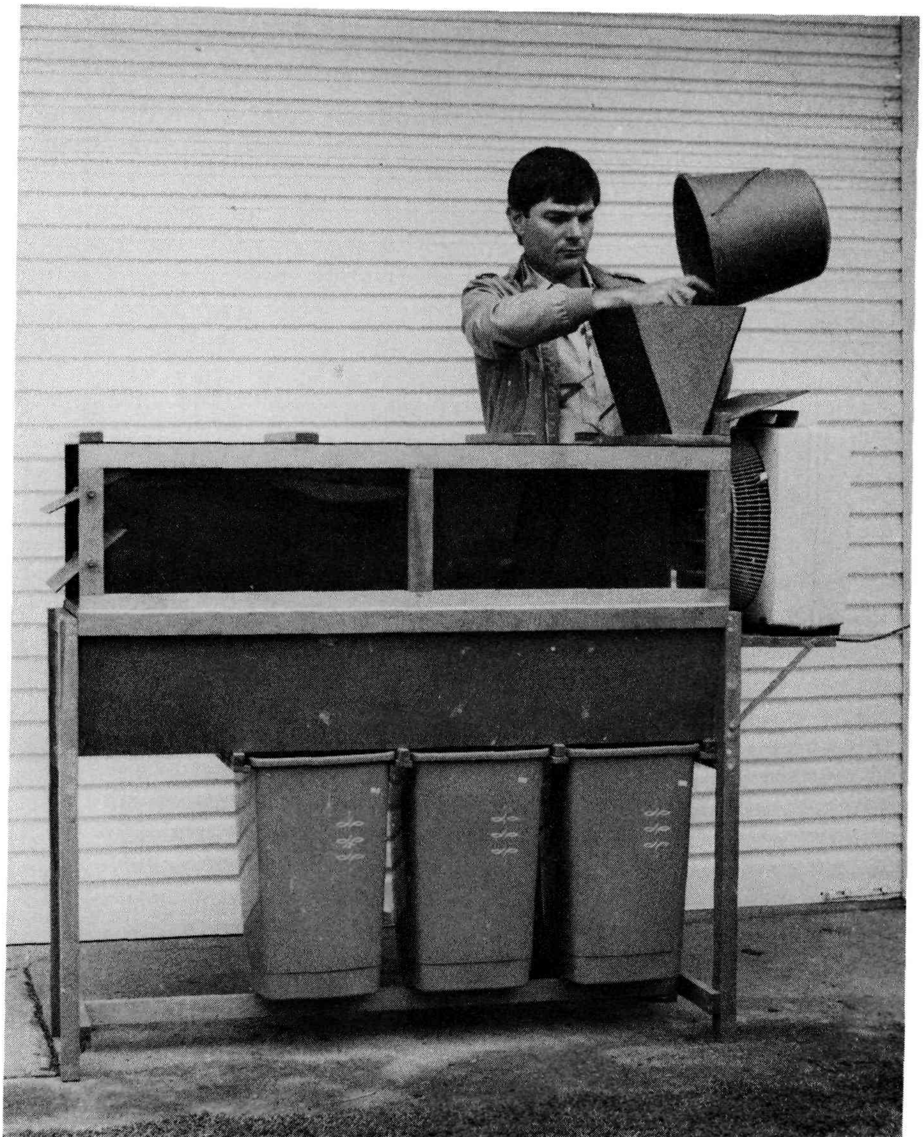

Fig. 3. A simple, inexpensive winnower described by Verhoeven (1964).

SEED CERTIFICATION

The high level of pasture seed certification in temperate countries is not necessarily appropriate to tropical and subtropical situations at the current stage of development. Local needs and objectives need to be critically examined before certifying a new cultivar. In

Queensland, certification (usually on a pedigree basis) is offered where there is a risk that cheap seed of an inferior cultivar will contaminate, or be substituted for, expensive seed of a desirable cultivar (Loch and Friend 1980). In general, the pasture seed industries do not place high priority on varietal uniformity and stability, and are reluctant to pay the extra cost of maintaining it. To date, there has been no critical study of genetic drift in tropical or subtropical plants, and there is a suspicion in scientific circles that variability and the capacity for varietal change may be useful adaptive attributes, particularly in pioneering situations.

SEED STORAGE

Seed storage is particularly important in tropical countries where high temperatures and humidity combine to accelerate the loss of viability and are unsuited to anything other than short-term storage. Seed at 10% moisture content (MC) will store well at most ambient temperatures, but can regain moisture from the air and quickly rise to the danger level of 14% in humid weather and begin to deteriorate rapidly.

Several recent reviews of seed storage are available, (e.g., Delouche et al. 1973; Justice and Bass 1978; Arvier 1983; O'Dowd and Dobie 1983) and seem generally applicable to pasture seeds. In particular, seed longevity depends both on the state of the seed entering storage and on the conditions of storage. Facilities required depend on the anticipated quantities of seed and the expected length of storage in each case. These range from a well-ventilated rodent-proof shed without any localized "hot spots" for short-term storage (less than 1 year) to dry sealing of carryover seed at 10% MC for longer term storage.

ROLE OF RESEARCH

With any new cultivar, the greatest barrier to successful seed production is ignorance of its requirements. This is the situation with many of our new pasture plants that have only recently been plucked from relative obscurity, hence the need for research.

The specialist nature of seed production research was recognized in Queensland in 1970 with the appointment of two scientists by QDPI. This has enabled concentrated work on many aspects of seed production technology in contrast to earlier piecemeal work by part-time researchers. Emphasis has also been placed on applied research involving a research phase to generate results followed by a development phase to apply these results in larger-scale commercial practice. Research personnel should be closely involved in the development phase because it is their knowledge that is being applied; moreover, the feedback during application helps to formulate future research more realistically. At the time of release, the current state of the art should be summarized as a guide to seed producers; this recipe can then be updated progressively in the light of subsequent experience (see the example in the Appendix).

Where little is known about the seed production of a new cultivar, a two-stage approach (Loch 1982) is preferred. It initially involves making a detailed record of crop growth and development, including seed production and loss. This is done under standard management conditions at a single site in a single-treatment sequential harvesting experiment or in combination with a single management variable (e.g., N in grasses). In this way, some understanding of the new crop is gained before seeking solutions to its problems in subsequent work. Ideally, such research should start just before release to provide information for commercial growers, although in practice this is not always possible. In lieu of more complete information, experience gained during the previous multiplication of seed on experiment stations can provide a useful guide, particularly if supplemented by more detailed experience with other crops of similar morphology and flowering behaviour. For legumes, herbicide tolerances can be checked by rapid screening in the field (e.g., broadleaf cassia -- Appendix), although formal experiments are necessary before chemical registration can be sought and definite recommendations made.

ADDITIONAL SOURCES OF INFORMATION

The technology of pasture seed production is a large topic that cannot be reviewed in detail in a single short paper. Additional information on particular aspects can be obtained from a number of useful publications in addition to those references already given. The more general of these include the book by Humphreys (1979) and articles dealing with specific countries (e.g., Boonman 1979, 1980; Rayman 1979; Hare and Waranyuwat 1980) or specific crops (e.g., Hopkinson and Loch 1977; Hopkinson and English 1982; English and Hopkinson 1983). Special mention must also be made of the booklet by Harding (1980); it contains much valuable information on practical aspects of seed production in general and that of a number of little known grasses and legumes.

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APPENDIX -- CROP SUMMARY EXAMPLE

Wynn Roundleaf Cassia

Roundleaf cassia (Cassia rotundifolia) is a new legume for subtopical areas. The first cultivar, Wynn, was released in Queensland in 1983. It is perhaps best described as a self-regenerating, short-lived perennial.

Establishment

It is important to establish seed crops of Wynn only on well-drained soils. Poor drainage restricts plant growth, thereby allowing weeds to dominate the sward. Freedom from nut grass (Cyperus rotundus) is also important because this plant cannot be controlled adequately in the seedbed and competes strongly with establishing seedlings of Wynn.

Seed should be scarified mechanically to reduce hardseededness if necessary and inoculated with Group I inoculant before being broadcast at 4-5 kg/ha onto a well-prepared seedbed with pre-plant-incorporated trifluralin; very shallow incorporation of seed may give better results in the drier subtropics and tropics. The seedbed should be rolled after sowing. Rates of 250 kg molybdenum superphosphate and 100 kg muriate of potash at establishment have been suggested for infertile soils. Because machinery must subsequently be operated as close as possible to the ground to harvest the standing crop, the paddock surface should be stick-free and as even as possible.

Flowering Behaviour

Wynn appears insensitive to daylength and will flower throughout the growing season provided adequate moisture is available. Crops can be harvested when a sufficient bulk of material has accumulated and is carrying large numbers of ripe pods.

Management

Post-emergence weed control is important because Wynn can be severely retarded by weed competition. Preliminary screening of herbicides indicates that bentazone (at 3 L/ha of 48% products) and dinoseb (at 4 L/ha of 20% product) can be safely used for broad-leafed weed control. Grass weeds can be sprayed with fluazifop (at 1-2 L/ha of 21.2% product), either to kill these in the seedling stage or to set back established plants while the crop develops. Wick-wiping with concentrated glyphosate is also a useful method of weed control.

Annual maintenance dressings of up to 125 kg superphosphate and possibly 50 kg muriate of potash/ha may be warranted. Molybdenum at c. 100 g/ha should also be applied every 3 years to ensure continued productive growth.

Heavy infestations of green vegetable bug (Hezara viridula) during flowering and seeding can severely reduce the yield and the quality of seed if not controlled by spraying with a suitable insecticide (e.g., endosulfan at 2.1 L/ha of 35% product, methomyl at 1.5 L/ha of 22.5% product). These sucking insects feed on the developing pods, resulting in a high proportion of shrivelled seeds even though the pods externally appear normal (i.e., not misshapen or twisted).

Harvesting

Unless flowering ceases due to moisture stress, the timing of harvest does not seem critical. Where crops are flowering continuously, standing seed yields apparently remain near the peak for prolonged periods because the loss of seed from the shattering of ripe pods is offset by new pods entering the system.

High yields of more than 200 kg cleaned seed/ha/crop can be produced by direct-heading with a conventional combine harvester. A drum speed of c. 1,000 rpm with the concave nearly closed and a light flow of air over adjustable sieves has given satisfactory results. Because of the continuous flowering nature of Wynn, more than one seed crop may be harvested during the growing season from the same area, particularly under irrigation.

Large quantities of seed accumulate on the ground as a result of continuous flowering coupled with the ready shattering of ripe pods. This also provides scope for suction-harvesting and hand sweeping.