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International Seed Industry and Food Production Potential of NZ Small- and Medium-Scale Direct Drilling Technologies

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Summary

Improved New Zealand direct drilling / seeding technologies practised as no-tillage and reduced tillage using small and medium-scale light-weight equipment offer a new dimension for sustainable agriculture globally covering seed industries and general food production in developing and developed economies. New Zealand scientists and engineers have researched and developed unique technologies that (1) create definable inverted-T-shaped seed slot micro-environments to improve seed performance and seedling emergence, and (2) improve low-cost foam-plastic seed and fertiliser metering devices that provide minimal damage and maximum accuracy. These developments are now available, with varying degrees of sophistication, from a range of NZ manufacturers, as matching technologies for 7-11kw[1], 37-56kw, and 56kw and above tractors. These technologies apply at all levels of the seed and food chain / industry throughout the world including research, research-outreach, extension and production on non-cultivated as well as cultivated land.

Key words: Sustainable agriculture, seed and food chain / industry, improved seed and fertiliser metering, direct drilling, no-tillage, reduced cultivation, inverted-T seed slot, improved micro environment for seedling establishment.

[1] Equally suited to animals, all terrain vehicles and small tractors.

Introduction

NZ inverted T-shaped soil slot openers (Baker, 1976a; Baker, Saxton & Ritchie, 1996) and soft foam plastic seed and fertiliser metering devices (M.W.Cross, unpublished data, 1960), have been major factors in the successful global development of large-scale direct drilling technologies over the past 40 years [2]. This includes improved seed and fertiliser metering, seed germination and establishment, and early seedling vigour covering a very wide range of seed sizes and crops (Choudhary and Baker, 1981; Baker, Chaudhry and Springett, 1988; Ritchie, Baker and Hamilton-Manns, 2000). Out of these technologies has emerged a new era of smaller (1 – 2.4m) lightweight New Zealand drills now coming into the international market (Stevens et al. 2000). Drills, which are suited to 7 – 56kw tractors and all terrain vehicles (ATVs) used in flat, rolling and mountainous ecologies in developed and developing countries.

By using these drills, high quality seed can now be planted simply and reliably in affordable ways at substantially reduced seeding rates using no-tillage, reduced tillage and normal cultivation under sustainable as well as traditional agriculture using the same equipment. This means that direct drilling is no longer an "all or nothing option". By using the same equipment for all systems, it provides farmers with the option of managing risks, on a field-by-field basis. Farmers can now maximise the benefit of one system, while at the same time guarding against the relative disadvantages of the other. These technological advances have emphasised the urgent need to pay greater attention to seed lot quality going beyond traditional norms of germination and purity, to routinely include seed lot vigour testing and reporting (Hampton et al. 2000; Hill, 1999).

This paper introduces and describes key NZ direct drill components and associated technologies. An interactive global help group has been established by the New Zealand - Australia Branch of the International Association on Mechanisation of Field Experiments (IAMFE) and the NZ Seed Technology Institute (SEMEC, www.semec.ws) to help extend these technologies through on-line global networking and co-operation. Particular emphasis is being given to strengthening seed industry and research-farmer linkages and resources for improved seed maintenance, production and usage including the establishment, organisation, and development of integrated seed chains / systems (Fig. 1). Targeting improved seed and food production and security for humanitarian relief, reconstruction / restructuring assistance, poverty alleviation, development, and regular production.

Discussion

Cultural Practices and Considerations

Advantages and disadvantages of direct drilling compared with traditional cultivation are well documented in the literature (Lal & Pierce, 1991; Edwards, Lal, Madden, Miller & House, 1993; Pottinger, Lane & Wilkins, 1993; Carter, 1994). No other technique has been as effective as direct drilling for reducing soil erosion and making food production more sustainable. Achieving this, however, requires specialised equipment and learned management practices.

[2] Also known as "conservation tillage" or "eco-tillage" given its ecologically friendly implications spanning organic farming, sustainable agriculture, environmental rehabilitation and conservation, and recreation support.

Historically, cultivation has been used to remove inter-plant competition, aerate soil and release nutrients within the drilling zone. Also, to prepare a good firm seedbed with a well fertilised desirable tilth, where relatively unsophisticated seed drill openers can travel freely and planted seeds can germinate and grow to the best of their genetic potential. The need for cultivation can be removed by using state of the art soil openers to create microenvironments through direct drilling so favourable that exceptionally high germination rates (near to 100%) can be achieved routinely, regardless of soil and residue conditions (Baker, 1976b, Baker *et al.*, 1996). When combined with improved seed and fertiliser metering systems, lower than normal seeding rates can be used, saving seed costs and improving ratios of seed planted to seed / food and other crops produced.

Failures in field establishment using direct drilling commonly reflect the sowing of low quality / low vigour seed. Loss of seed vigour can often occur before there is obvious sign of deterioration as shown by germination loss. Thus it is possible to have similarly high germinating seedlots, which can vary greatly in their "vigour", and hence their subsequent field establishment. This highlights the need for close co-ordination and liaison between the direct drilling community and the seed industry. Seedlots stored for any length of time should be re-tested before using, including standards tests for seed vigour (Hampton et al. 2000; Hill, 1999).

By 1996, USA had 19.4 million hectares (16% of crop land) under no-tillage, Brazil (8 million hectares or 25%), Canada (6.7million hectares or 18%), Argentina (4.4 million hectares or 28%) and Australia (1 million hectares or 10%). Global estimates of remaining areas suited for no-tillage and reduced tillage include, USA 50-60 million ha; Latin America 20 m ha; and Australia 10-15 m ha (variously reported by Derpsch, 1998; Erenstein, 1998; Hebblethwaite and Towery, 1998; and Hebblethwaite, 1997). The extent of areas in CIS countries presently under no tillage is unknown, but during the Soviet period more than 20 million ha were under some kind of minimum-tillage in the Eurasian steppes (verbal communications from FAO, 2000).

Direct drilling and reduced tillage can provide unprecedented flexibility in arable crop, livestock and other management combinations and / or environmental conservation compared with traditional cultivation and drilling. There are many millions of hectares of land in the CIS and China where environmental managemnt as well as the production efficiency and sustainability of seed and food production can be strengthened substantially by up-grading traditional seeding practices in affordable ways using technologies comparable to those described in this paper. This includes relay seeding of traditional and alternate crops, and cereals spring planting directly into winter fallowed land. Oil seeds, vegetables, oats, wheat and barley can be sown as a single crop or used as a cover crops for establishing high-value under-storey crops. Improved grasses and clovers can be introduced directly into existing swards / bare ground to reduce erosion and / or improve fodder production with a minimum of soil and other management disturbance. These technologies are particularly invaluable for the rehabilitation of eroded catchments where run off and /or wind blown material is silting up dams and waterways or, otherwise encroaching on farm, horticultural or urban land. Strategic areas can be sown as wildlife habitat.

By using direct drilling and reduced tillage, cropping decisions can be made much later than normal in the season, with less notice and implemented sooner than otherwise possible. Less tractor hours are required per hectare meaning larger areas can be planted using the same equipment. Time available for planning is increased, since planting can begin immediately rather than after cultivation, once land comes into condition (dries out enough for tractors) and continue up until the season ends. Depending on equipment and soil type, land can be safely direct drilled at higher soil moisture content than it can be cultivated, further widening the window of opportunity for seeding and / or making optimal use of available soil moisture.

The turn-around time between harvesting and sowing a new crop can be reduced to practically zero. Time isolation can be achieved more reliably than normal in seed maintenance and production systems where it would not otherwise be possible. This is particularly important where there are narrow windows of opportunity for land preparation when sowing at higher latitudes and altitudes, and/or within intensively managed systems. Direct seeding rice, or wheat after rice in sub-tropical and tropical areas for example, require only one or two passes in a field, compared with up to 10 using conventional tillage. Lighter than normal machinery and smaller tractors than usual can help reduce ground compaction.

Increased residue and other living ground cover retained through direct drilling protects soil from erosion, helps prevent nutrient runoff and limits sediment build up in streams and lakes. At the same time, however it can encourage the build up and carry over of soil and plant borne pests and diseases from one crop to the next, more so than with cultivation. Nutrients locked up in this residue need to be replaced with starter fertiliser sown to boost seedling vigour while direct drilling seed. Shallower than normal planting is required when direct drilling into cold soils covered with residue, because they tend to warm up more slowly in the spring than their cultivated counterparts. Using cold tolerant cultivars and hybrids, and high vigour seed can help to get the best out of direct drilling.

Soil incorporation of fertiliser, insecticides and weedicides can be more difficult with direct drilling compared to traditional methods. Also, there is increased plant competition for light and nutrients from previous as well as existing vegetation, made worse by a seed bank of un germinated seeds remaining in the soil, compared with traditional cultivation.

Equipment Design Criteria for Small- and Medium-Size Direct Drills

Direct drills must have seed and fertiliser boxes. The fertiliser box must be fitted nearest to the tractor for safety reasons, especially on small tractors. The drill chassis and attachments must have a low centre of gravity and follow close behind the tractor, since they are often required to operate on undulating and steep terrain. A range in sowing widths is needed from 1.0 to 2.4m (in 25cm increments) supporting multiple tines and soil openers at 7 to 15cm row spacing, upwards.

Drills must be light, robust and durable, in keeping with the weight and draft capacity of animals / equipment used to pull them (i.e. animals, 7-11kw, 37-56kw and 56kw tractors and above). Three-point linkage and trailing options are needed. Seed and fertiliser metering devices must reliably and uniformly handle a wide range of seeds and fertiliser under various conditions, with specified accuracy / precision. Soil openers must penetrate and plant reliably with minimum downwards pressure, into root-bound sod; sandy, stony or clay soils, compacted and/or capped soils with and without a heavy covering of residue.

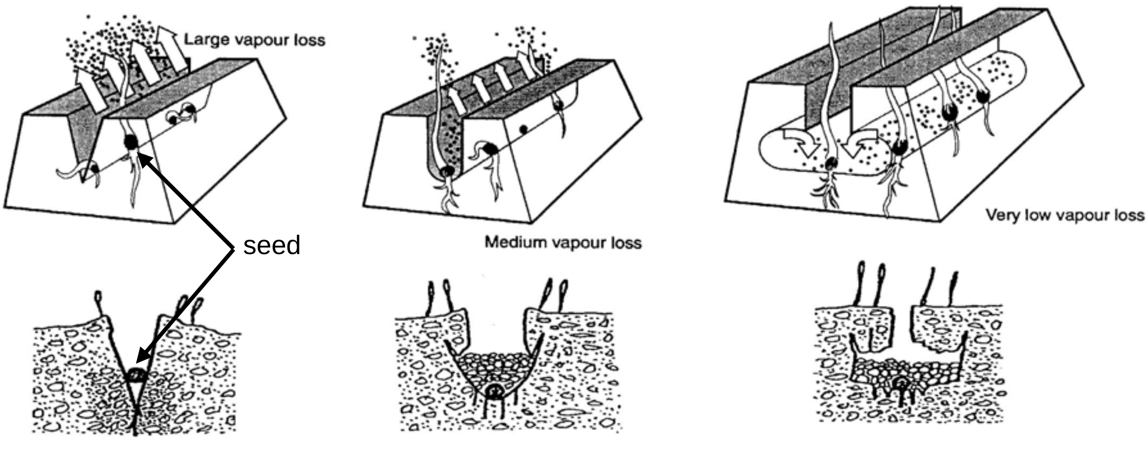
Within prescribed design limits, soil opener assemblies must be able to faithfully follow land contour / undulations including rough un-tilled / range conditions, drainage ditches, old plough finishing lines, ridged maize stubble and the like.

These criteria we have found, can be easily achieved at affordable prices by working with NZ manufacturers. Users must select and use appropriate combinations of NZ soil openers, chassis, seed / fertiliser boxes and foam plastic seed and fertiliser[3] metering devices, matched with other technology aids discussed in this paper as an integrated system. This includes custom fitting, by arrangement, an international range of precision seed metering equipment variously described by Betzwar (1996, 1987); Muller (1996); Hege Hans-Ulrich (1987). NZ soil openers and foam plastic seed and fertiliser metering devices can also be adapted to fit this type of international research equipment to broaden its application at affordable prices where reliable seeding is required with less cultivation.

Openers

"Opener" is used rather than "coulter" in this paper to avoid confusion. In Australia coulter is a disc, in the UK it is an opener, being that part of a drill that forms the soil slot into which seed is placed, of which there are three main shapes "V", "U" and "inverted-T". Disc, hoe and inverted-T openers variously form these, respectively. Each slot shape forms it's own particular microclimate in which planted seeds germinate and grow during their early stages (Fig. 2). From these diagrams, it is easy to see the relative merits of the inverted-T slot, in creating a highly favourable microclimate for both seed and seedlings.

Design concepts behind disc and hoe openers used to generate "V" and "U" shaped slots are easily understood. The inverted T principle requires more precise explanation along with the associated soil openers. This slot shape was discovered and developed in NZ for pasture renovation and later extended to other crops as a geometrical alternative to common "V" and "U" shaped slots. It is specifically aimed at improving seed germination, seedling emergence, survival and early seedling growth. By slicing open the soil, planting seed and fertiliser in the wings of the slot, then folding soil back into position in controlled and predictable ways it is possible to improve moisture availability / conservation and provided shade from direct sunlight. Achieved without smearing or crusting the walls of the slot, which limits the exploration, proliferation and development of seedling root systems.



"V"-Shaped (disc) "U"-Shaped (hoe) "Inverted-T" (Baker Boot / Cross Slot)

[3] Besides foam plastic rollers for granulated fertiliser, dual transverse rubber roller systems developed in NZ are used to overcome problems of metering sticky fertiliser, enabling it to be applied between 10 and 600 Kg/ha.

Fig. 2. Slot shapes formed by different kinds of soil openers, position of seeds planted, and associated microclimates / vapour losses (after Carter, 1994; Baker *et al*., 1996).

Inverted-T Openers

The simple winged opener now known generically as a "Baker Boot" came first (Baker, 1976a,b; Fig. 3). Followed by the Cross Slot opener (Fig. 4) built around a central disc to give improved performance in residue and separate placement of seed and fertiliser along either side of the soil slot. Baker Boots remain a mid-range industry standard. In comparison, the Cross Slot is at the upper end of the range, for price and technologies. This may change, once Cross Slot openers are mass-produced, bringing them into the mid range for price, while still holding their position at the top end for technology. Factory kits can be ordered to fit Baker Boots or Cross Slot assemblies to a range of seed drills and planters, including research and commercial equipment.

Compared with the Cross Slot, Baker Boots require slightly less draft power per unit to operate which is a consideration while targeting machinery for small and medium-size tractors. The main disadvantages of Baker Boot openers are; (a) poor residue handling qualities, (b) incapacity to separate seed and fertiliser in the slot and, (c) their surface-following abilities and inherently good depth control characteristics are compromised when mounted on simple drills. The Cross Slot™ assembly will track vertically over 50cm high undulations, while most trailing leg assemblies fitted with a Baker Boot will only handle 12 to 15 cm, and the coil spring tine 5 cm variations.

NZ inverted-T soil openers have been successfully fitted to a range of hand seeders and bullock ploughs manufactured in Asia over the past 20 years, including the single row direct drill described by Muhtar (1984). This has allowed traditional seeding rates to be more than halved by farmers while going from broadcast to row sowing without compromising traditional integrated forage, fodder and grain production.

Baker Boot

The "original Baker Boot" was literally like an inverted T, with the top bar of the T being an arrow forming the base of the boot, sharpened at the point, and angled down slightly to ensure penetration while slicing through the soil in conjunction with a leading disc. This boot, complete with leading disc, was first used internationally in the highlands of Peru in 1977, fitted to a NZ drill (Stevens, 1981; Stevens and Villata, 1981). Since then, more than seven commercial variations of this boot have come on to the market, locally and abroad.

Not all manufacturers provide a leading disc as originally envisaged and / or some manufacturers use heels on the inverted T to reduce wear. This can result in edges of the slot being torn and inconsistent, resembling more the slot shape of a hoe than an inverted-T opener making controlled closure of the slot difficult with a corresponding loss in microclimate effect. Leading discs work reasonably when the disc and the boot are mounted in close proximity on the same trailing leg assembly. Spring tines mounted behind leading disc assemblies do not track as well. A variety of press wheels, rollers, and/or trailing weights, or harrows are often used behind Baker Boots to help close the slot.

Cross Slot

The Cross Slot opener comprises a central disc (often scalloped to increase its effectiveness in actively cutting through residue), against which two fixed legs, angling out at the base, are run parallel to, and in close proximity with, the side faces of the disc. The disc slices a vertical path through the soil and residue. The leg wings open up the side flaps of the inverted T slot for seed and fertiliser to be placed in them separately, then folded back into place and pressed down again and closed by the two trailing wheels shown in Fig. 4.

Mounted between parallel drag arms fitted with a hydraulic damper, Cross Slot assemblies can faithfully track over 50cm undulations at speeds of up to 16 kmph, helping to even out the effects of machine bounce using a parallel drag arm. They reliably slice through plant material accumulated at concentrations of up to five tonnes per hectare on hard or soft soils. Openers have low maintenance for more than 10,000 hrs, requiring minimal adjustment between crops. They are a reliable base-line against which other openers can be realistically compared for all types of drills (Lessiter, 1995). A new model of this opener (Mark IV) has recently entered the market, very well suited to retro-fitting / up-grading conventional maize seeders for no-till, reduced tillage and conventional planting.

Seed and Fertiliser Metering Devices

Available seed and fertiliser metering technology can be categorised as either forced feed or assisted gravity. Metering and delivery of seed and fertiliser is an important element of commercial as well as research direct drilling equipment. Three main types of commercial seed and fertiliser metering systems are marketed in combination with advanced NZ direct drilling openers: (a) star cogs and dual transverse rubber rollers (fertiliser), hard fluted rollers and tooth peg rollers (seed); (b) soft foam plastic (vertical, axial and tangential) rollers and pads (seed and fertiliser, variously); and (c) vacuum systems (seed). The normal range of cone and belt seeder attachments can be variously fitted for specialised research applications. Added to this are two main types of delivery systems, one purely gravitational, the other including additional forced / compressed air assistance.

Forced feed systems entrap seeds / fertiliser (either individually or collectively) in discrete cells, and forcibly eject them in a controllable manner during metering and delivery. This creates periodicity of supply. Seed / granule damage often results. However, seeding / fertiliser rates are accurately controlled and ground metering is easily achieved, whereby seeding rate per metre travelled remains constant regardless of forward speed. This is something very difficult to obtain using assisted gravity systems that allow seed / fertiliser to flow out of variably sized holes assisted only by mechanical agitation. They are, however, low cost and usually free from periodicity problems and product damage.

NZ designers have found ways of combining the best attributes of forced feed with low product damage and have eliminated periodicity by using foam plastic as the primary metering device in which seeds / fertiliser granules embed themselves according to their variable shapes and sizes. A range of options exist including: (a) rubbing a foam disc against a stationary backing plate (Fig. 5, radial seed flow); (b) rubbing a foam cylinder against the inside of a stationary backing cylinder (axial seed flow); (c) two counter-rotating foam rollers, equally suited to seed and fertiliser (tangential seed and fertiliser flow). The latter approach also allows a high degree of individual seeds to be metered (singulation) using specially-shaped rollers at a much-reduced cost compared with vacuum-based singulation systems commonly used with precision planters to achieve the same effect.

The metering systems are either driven mechanically from a ground wheel or, electrically from a 12 volt DC supply, able to operate with ground speed radar and microprocessor controlled metering rates changed with the turn of a knob. Sowing rates for seed can be varied from 0.5 to 350 kg/ha, including seed of species considered difficult to meter, for example, chicory (*Cichorium intybus*), sulla (*Hedysarum coronarium*) and prairie grass (*Bromus willdenowii*).

Conclusions

Small- and medium-scale multi-purpose NZ direct drilling equipment plus associated technologies has the international potential to make increased seed and food production a reality at affordable prices for a wide range of farmers / farming systems, without depleting the underlying resource base on which they depend. With increased levels of global participation and co-operation via the internet and otherwise, we predict that international usage of NZ inverted-T opener technologies and, soft foam seed and fertiliser metering devices will rapidly expand in the future using small and medium scale arable, reduced tillage and no-tillage drills built locally and internationally.

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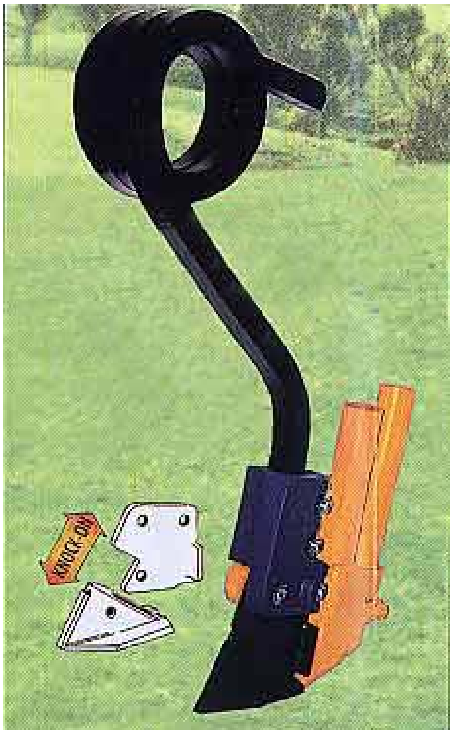


Fig. 3. Commercial variant of the original Baker Boot (P Aitchison).

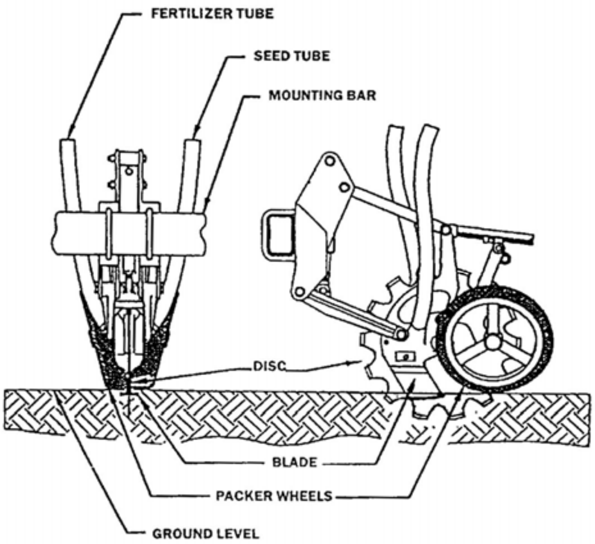


Fig. 4. Cross Slot assembly mounted on parallelogram drag arms (Baker *et al.*, 1996).

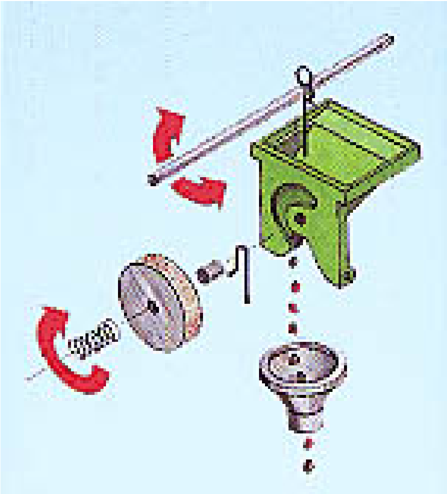


Fig. 5. Radial foam plastic seed metering system (P. Aitchison).

Figure 1. Establishment and Organisation of Seed Systems[4]

Seed Science & Technology

Quality Assurance and Control:

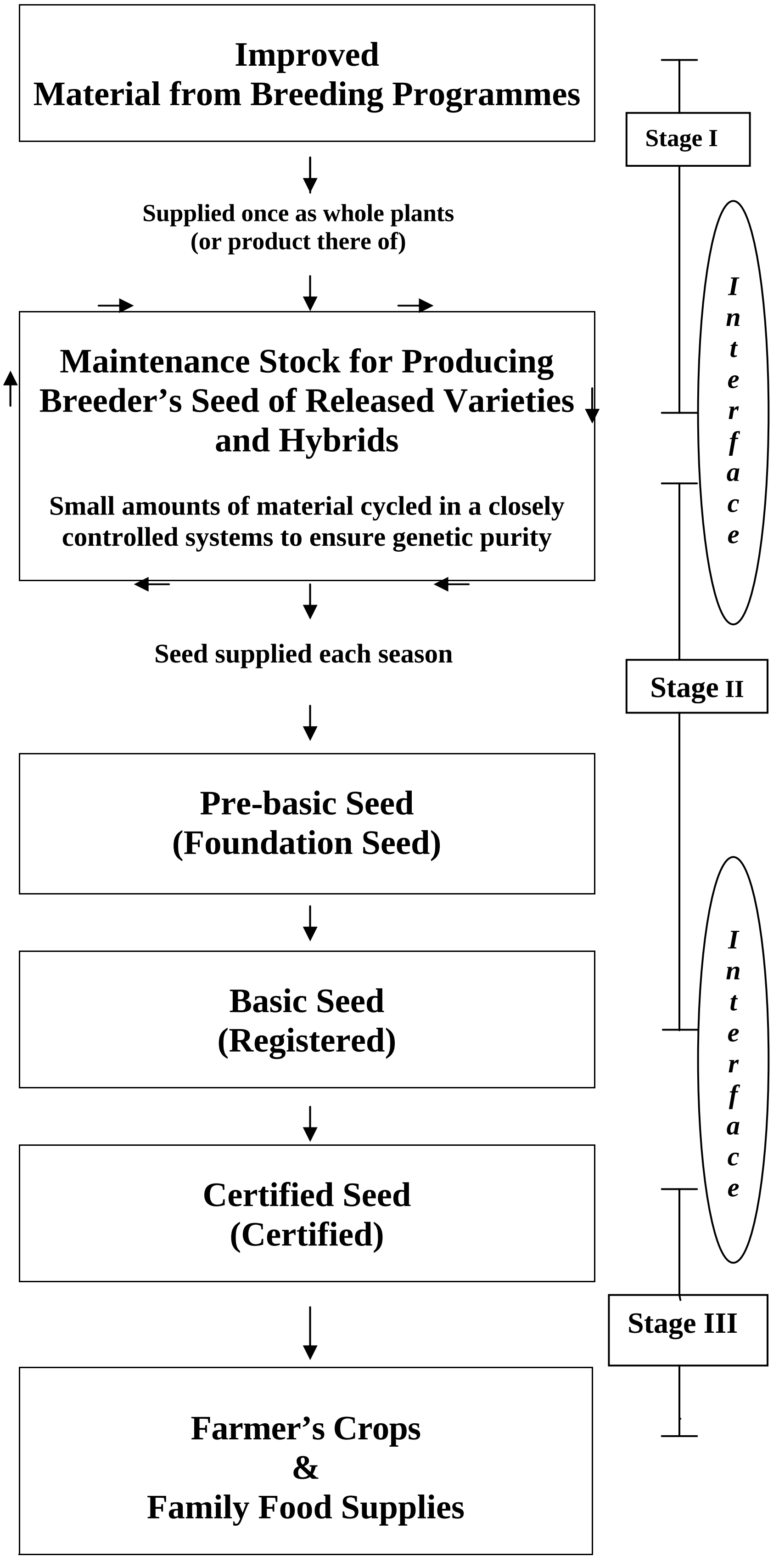
- ✓ Seed Policy
- ✓ Rules / laws / acts
- ✓ Regulations
- ✓ Standards
- ✓ Quarantine
- ✓ Variety* examination
- ✓ Variety registration
- ✓ Variety protection
- ✓ Variety release
- ✓ Certification
- ✓ Superintendence
- ✓ Post harvest / storage loss

Project & Programme Support:

- ✓ Networking organisations / institutions / agencies / individuals
- ✓ Bio-diversity / gene banks
- ✓ Agro-ecology survey / analysis
- ✓ Environment Mgmt
- ✓ Winter nurseries
- ✓ Under graduate and graduate studies
- ✓ Farmer and technician training,
- ✓ Starting & managing projects - (identification, formulation, monitoring & evaluation, reporting)
- ✓ Donor & other financing
- ✓ Machinery / equipment / instruments / field & laboratory layout
- ✓ National & international workshops / conferences / conventions
- ✓ Restructuring into market economies
- ✓ Synthesis & exchange of data, methodologies, technologies, know-how.
- ✓ Marketing

Note: * Hybrids, also

Plant Breeding & Production Agronomy



[4] Conforming to OECD (Organisation for Economic Development) and AOSCA (Association of Official Seed Certifying Agencies) nomenclature (in parenthesis).