Minimal soil disturbance sowing in New South Wales and its relevance to reducing water erosion in Western Australia

K J. Bligh
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Minimal Soil Disturbance Sowing
In New South Wales,
And Its Relevance To Reducing Water
Erosion In Western Australia

K.J. Bligh

Disclaimer

The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

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Summary

A study tour was undertaken investigating minimal-soil-disturbance sowing in New South Wales, from September 12-28, 1988. Both inexpensive modifications to existing seeders and “state of the art” new mechanisms were investigated. Narrow—winged points can readily be fitted to existing tined seeders to immediately reduce water erosion in Western Australia. Press wheels may improve crop establishment, particularly with early sowing in this predominantly winter-rainfall region. Front disc coulters may reduce blockages of tined seeders where low stubble and straw spreading at harvest are insufficient. Strategies for achieving adoption of minimal-soil-disturbance sowing on erodible, loamy soils in Western Australia are canvassed.
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1. Introduction

Water erosion is a virtually irredeemable form of land degradation. Soil must remain in place in order to be in a stable condition to sustain production levels. Rates of soil formation are considered to be less than one millimetre per thousand years in Australia (Little and Ward, 1980; Walker, 1980; McFarlane and Ryder, 1987). Therefore comparable erosion rates are required for indefinite maintenance of the soil mass for sustained productivity.

Soil movement of the order of millimetres has been observed on Western Australian cropland in single seasons (e.g. Bligh 1987a; 1989; McFarlane and Ryder, 1987). On the other hand, erosion rates of approximately one millimetre of soil loss per thousand years have been recorded on pastured land with slope lengths typical of contour bank spacings in New South Wales (Edwards, 1987). Measurements of suspended sediment from 4 m² infiltrometers in Western Australia also suggest similarly low rates of soil loss in the absence of rill and gully erosion with minimal-soil-disturbance sowing using a triple-disc drill (Bligh, 1984).

Stubble cover is generally not available on most Western Australian cropland, because crop-pasture rotations are commonly practiced (Bligh, 1987b; 1988a). Sowing with minimal soil disturbance minimises soil erodibility during crop years. The principle aim of minimal-soil-disturbance sowing for reducing water erosion is to eliminate disturbance of the entire topsoil structure in tillage, by cultivating only a minimal width in the sown rows.

Satisfactory crop yields have been achieved with minimal-soil-disturbance sowing, and water erosion reduced, in wheat-soybean double cropping rotations in North—Coastal New South Wales (Desborough, 1983). The Connor-Shea “inverted—T” Coulter Coil Tine Drill® (after Baker 1976), is used on approximately 50% of cropped land (Desborough, P.J. pers. comm. 1988) in a newly—developed cropping system, which was extended to landholders as a package.

In Western Australia, comparable crop yields have been achieved under continuous cereal cropping whether minimal-soil-disturbance, one, or the traditional three tillage operations were used in areas receiving greater than 350 mm average annual rainfall (Jarvis ~ et al 1986). The cropping system in these areas is traditional having been developed over several generations. Therefore minimal-soil-disturbance sowing cannot be extended as a new cropping package, as in North-Coastal New South Wales.

The adoption of minimal-soil—disturbance sowing in Australia has been hindered by the lack of suitable seeding mechanisms (e.g. Quick and Brown, 1984; Sweeting, 1985). The triple-disc-drill has been generally abandoned for sowing cereals in Western Australia, largely because of unreliable crop establishment in some seasons (R. Jarvis, W.A. Dept. of Agric., pers. comm. 1987). Relatively high point wear rates reported using the seeders such as the Connor-Shea Coulter Coil Tine Drill® and John Shearer Coulter Drill®, together with their availability in maximum widths of only 2.7 m, have generally precluded their use in broad-scale cropping. Inexpensive replacement of wearing points,
and practical seeders must be developed in order to systemically mitigate water erosion on cropland by minimal-soil-disturbance sowing in Western Australia.

The design of reduced and minimal-soil-disturbance seeders have so far been basically empirical (Baker et al., 1979a). Baker et al. (1979b) tested more than 50 combinations of mechanisms in developing a notched, plain disc with a split, narrow tine and press wheel mounted on either side, known as the Bioblade® (Baker, C.J., pers. comm. 1988). Ward and Norris (1982) evaluated 34 mechanisms in the field prior to recommending a disc coulter—spear point—press wheel combination (Freebairn et al. 1986). Frye and Lindwall (1986) report a consensus at an international conference on zero—tillage research priorities, that the physical requirements of the seed zone must be better defined, to enable objective design. Meanwhile judicious trial-and-error remains the only available technique for developing minimal-soil-disturbance openers.

After reviewing machinery for cropping with reduced water erosion (Bligh 1987b; 1988a) and minimal soil disturbance (Bligh 1988b; c), a brief study tour was undertaken (Appendix 1) to inspect relevant seeder research and its adoption at Cowra, Condobolin, Gunnedah, Tamworth and Grafton in New South Wales, and to visit relevant machinery manufacturers in Southern Queensland. The aim of the study tour was to determine desirable seeder mechanisms for evaluation and demonstration in Western Australia. A paper reviewing minimal-soil-disturbance seeders was presented at the “Soil Management 88” Symposium in Toowoomba, Queensland, and at the 1988 Conference on Agricultural Engineering at Hawkesbury Agricultural College, New South Wales (Bligh, 1988b; 1988c).

This report documents relevant technical developments, and the adoption of minimal soil-disturbance sowing in New South Wales and elsewhere. Mechanisms considered more economically acceptable for adoption in the short term are discussed in greater detail than newer, more complex mechanisms, in order to facilitate their immediate evaluation and demonstration in Western Australia.
2. Minimal-Soil-Disturbance Sowing Mechanisms Used In New South Wales

Seeders currently used in New South Wales for sowing with minimal-soil-disturbance include the narrow-winged point after Baker (1976), spear-point openers (e.g. Kneipp, 1987), the triple disc drill (after Karonka, 1973) and the Bioblade® (Baker et al. 197gb). Each are reported to provide adequate crop establishment in specific soil and environmental conditions.

2.1 Narrow-winged Openers

Narrow—winged openers till the soil in the sown row only, leaving the inter-row strip largely undisturbed.

Some minimum tillage seeder developments in New South Wales were reported by Mead and Wedd (1982) and Mead (1985). Mead and Chan (1988b) report increased penetration, and soil fracturing favourable to root development, using 40 mm wide narrow—winged points, compared with either lucerne points (12 mm wide), or standard combine seed drill points (100 mm wide) on hard—setting sandy loam soil at Cowra in Central-Western New South Wales. Planar voids were formed by the passage of the narrow-winged points, which were not detected by either bulk density or shear strength measurements in the seedbed (Chan and Mead 1988). Impregnation of the seedbed mass with epoxy casting resin (after Dexter ~ et al. 1983) revealed their presence.

Wedd (1988) reports that draft forces increased in the order of winged, lucerne and standard combine points on this undisturbed sandy loam soil. The addition of a deep front blade protruding 25 mm below the wings (see Plate 1) resulted in the maximum draft force measured in both undisturbed soil, and soil which had been compacted using a rubber-tyred roller.

A prototype 80 mm wide winged point, a lucerne point and McKay “Slimline”® combine point achieved comparable establishment on loamy sand, though not on a red—brown-earth in Western New South Wales (Palmer ~ et al. 1988). A Connor-Shea “inverted-T” opener consistently achieved the highest seedling establishment counts, though still only 65% of viable seeds sown. The lucerne point required the lowest penetration and draft forces of the four points tested on the loamy sand at speeds of both 4.0 km h~ and 8.5 km h~ (Palmer, A.L., pers. comm. 1988).
Plate 1. The author, holding a 50 mm-wide narrow-winged combine seed drill point (left), and a similar point equipped with a front blade to cultivate 50 mm below the seed zone at the wings.

Soil disturbance was increased, with more soil displaced downslope when drilling on the contour using an “inverted-T” point, than using either a triple-disc or Bioblade® opener on loamy soils in North-Coastal New South Wales (Baker and Desborough, 1984). Some smearing of the seed slot occurred using the “inverted-T” and triple-disc openers. Heavy stubble was satisfactorily handled at row spacings of 250 mm to 350 mm, using staggered openers on two ranks (Quick and Brown, 1984). Narrow points have been reported to improve trash clearance because of reduced blockages by clumps of mixed soil and stubble (Lackie, 1975; Packer and Hamilton, 1984).
2.2 Spear-Point Openers

Spear-point openers are typically used on black, clayey soils in Northern New South Wales (e.g. Kneipp, 1987; Thompson and Elliott, 1988a, b), spear points are usually mounted on a parallelogram linkage sometimes coupled with a disc coulter, with or without attached rubberized drums for depth control (Plate 2).

Plate 2. A spear point opener close-coupled on a parallelogram linkage, with a disc coulter with attached rubberized drums for enhanced stubble handling and reduced soil disturbance with precise depth control

A 20 mm-wide Janke® spear point with a wingspan of 30 mm, or a 30 mm-wide Mason® spear point with a wingspan of 50 mm, are commonly used in New South Wales and Queensland. The Connellan® spear point is also commercially available with adaptors for mounting on either chisel plough or scarifier tines (Ward et al. 1988).

Generally comparable seedling emergence was achieved in Western New South Wales using Connellan® spear points, lucerne points, standard combine seed drill points and Connor- Shea “inverted-T” points in untilled loamy sand (Palmer et al. 1988). A draft force of approximately 0.4 kN was required to pull each tine equipped with spear, lucerne or standard combine points at a speed of 4 km h⁻¹ in the red-brown earth, compared with approximately 0.9 kN for the “inverted—T” point (Palmer, A.L., pers. comm. 1988). Draft forces generally increased by 10—20% at 8.5 km h⁻¹. The vertical
forces required were least for the lucerne point, and greatest for the "inverted-T" point, though all required less than 0.3 kN per tine.

Spear points have generally been used to place the seed with minimal soil disturbance, in order to reduce the evaporative loss of soil moisture in New South Wales (e.g. Kneipp, 1987). Ward ~ et al. (1988) report beneficial effects on seedling establishment and vigour using either 50 mm-wide spear points or 100—mm wide “ducksfoot” points, similar to a low-profile combine seed drill point. They attribute this improved establishment to better soil tilth in the clayey soils. Seed cover was sometimes inferior using the spear point, whereas the “ducksfoot” point formed a micro-seedbed of loose soil.

Water erosion on clayey soils in northern New South Wales occurs mainly during the summer months (Edwards, 1984, 1987). Therefore, the reduced soil disturbance achieved using spear point openers may result in less water erosion, because vegetative cover is increased and soil erodibility reduced in the period before full canopy development of summer crops. Thompson and Elliott (1988a) advocate paired rows, sown using spear-point openers 0.12 m apart, with a further spear point for fertilizer placement located midway in the 0.38 mm space between pairs, in order to reduce soil disturbance, erosion and soil structural degradation.

2.3 The Triple—Disc Drill

The triple disc drill, has been used extensively as replacement combine seed drill undercarriages (Plate 3) in the Murrumbidgee Irrigation Area of New South Wales for sowing rice, usually pre—irrigated, moist soil. It is not generally used for broad-scale sowing of other crops. Compaction and smearing of the bottom and sides of the slot under wet conditions may restrict downward root development in dry soils (e.g. Baker, 1976). Depth of sowing was inadequate using the triple disc drill in tight soil conditions in North-Coastal New South Wales (Baker and Desborough, 1984), where front coulters 0.5 m in diameter were required in order to clear heavy stubble residues encountered in a double-cropping rotation.

A vertical force of approximately 1 kN per single-row triple-disc assembly was required to penetrate a red-brown earth soil at Condobolin (Palmer, A.L. pers. comm. 1988). Draft forces were generally comparable to those required for spear, lucerne or standard combine points, though the vertical force required was several times less for the points. Emergence of wheat seedlings using the triple—disc drill was inferior to that achieved using these points in untilled loamy sand, though comparable in untilled red-brown earth soil, and in black clayey soil with surface stubble (Palmer et al. 1988). Seedling establishment using the triple disc was superior to tined assemblies in a sandy loam soil in Southern Queensland, but was inferior in several clayey soils (Ward ~1988).
Plate 3. Rear view of double-disc openers mounted behind the front disc coulters of a triple disc drill (after Karonka, 1973)

2.4 The Bioblade®

The notched-disc, split-winged point and press-wheel combination, known as the Bioblade® (Plate 4) was developed for improved stubble handling and reduced wear at Massey University in New Zealand (Baker et al. 197gb). The Bioblade® was the most successful of a wide range of direct—drilling mechanisms tested for sowing wheat and soybeans on non-sticky, sandy loam soils at Grafton Research Station (Baker and Desborough, 1984; Desborough, 1981a, 1985). Reduced erosion was the principal reason for selecting the minimal-soil-disturbance Bioblade® opener (Desborough, 1981b). Additional reasons included timeliness of sowing, trafficability, agronomic and economic factors. Dwyer and Page (1988) also refer to a requirement that fertilizer not be placed in contact with the soy bean seed.

Draft forces using the Bioblade® averaged 3 kN per opener (Plate 5) on untilled red-brown earth soil at Condobolin - more than double that of any of the other nine openers tested (Palmer, A.L. pers. comm. 1988). Vertical forces averaged approximately 2kN per opener. These were approximately double those for the triple—disc drill, which itself required vertical forces several times higher than those of any other opener tested.
Plate 4: The Bioblade® minimal-soil-disturbance seeder with 450 mm-diameter notched discs, and 50 mm-wide press wheels, used at Grafton Agricultural Research and Advisory Station since 1982. (Photo, courtesy P.J. Desborough)

Plate 5. Bioblade® openers with 560 mm diameter notched discs and 100 mm wide press wheels, mounted under a force-measuring tillage dynamometer at Condobolin Agricultural Research and Advisory Station.
A front-wheel-assist 80 kW tractor was required to pull a 14-row, 3.5 m wide “Aitchison Seedmatic 2000” Bioblade® unit (Plate 6) at typical sowing speeds in sandy loam soil at Cowra (Mead, J.A. pers. comm 1988). The seeder remained unused at Condobolin Agricultural Research and Advisory Station from 1985 until viewed in September 1988.

Plate 6. The Aitchison “Seedmatic 2000” Bioblade® seeder

Plant emergence after sowing with the Bioblade® averaged approximately 10 per cent of viable seeds sown on the red-brown earth soil at Condobolin (Palmer et al. 1988). Many seeds stuck to the notched disc, became dislodged above ground level and fell onto the soil surface (Palmer, A.L. pers. comm. 1988). A pin has since been developed for insertion in the sowing boot, in order to reduce dislodgement of seed from the seed groove by the disc (Choudhary ~ et al. 1985).

Manufacturing rights for the Bioblade® have recently been acquired by El Al Agribusiness of Washington State, U.S.A. (Peter Aitchinson, Managing Director, Aitchison Industries Limited, Wanganui, New Zealand, pers. comm. 1988). Stubble-handling ability (e.g. see Plate 7) appeared to be superior to that of any other opener tested in early trials at Washington State University (Hyde, G.M., Associate Professor of Agricultural Engineering, pers. comm. 1988).
2.5 Associated Mechanisms

Devices such as front disc coulters for improved stubble handling, and press wheels to enhance seedling emergence and establishment are an integral part of some seeders used in New South Wales.

2.5.1 Disc coulters

Disc coulters are sometimes used in front of tines to cut through stubble and vine weeds in New South Wales and Queensland. Some straw may merely be pushed into the soil by the disc, like a hair pin, leaving the ends sticking out. Seeds germinating on decomposing stubble may then suffer toxicity effects from break-down products, inhibiting the growth and establishment of seedlings (Baker, 1983).

Articulated, rippled—disc coulters (see plates 8 and 9) can be fitted to stump-jump mechanisms, replacing cultivating tines on some combine seed drills (e.g. the John Shearer “Trash-Culti Drill®”). Satisfactory stubble handling using rippled-disc coulters has been reported at Cowra, New South Wales (Mead, J.A., pers. comm. 1988; Packer, I.J., pers. comm. 1988). Disc coulters are also mounted directly in front of the narrow points on tined seeders in order to slice through the relatively heavy stubble remaining from the preceeding crop in the wheat-soybean double-cropping rotation commonly used in North-Coastal New South Wales (Desborough, 1983), and in annual cropping in Northern Victoria (Steed and Robertson, 1988).
Disc coulters 450 mm in diameter were found to be superior in stubble-cutting ability to those 300 mm in diameter in North-Coastal New South Wales (Baker and Desborough, 1984) and Southern Queensland (Freebairn et al. 1986), though requiring greater downward force for penetration (L.D. Ward, pers. comm. 1988). Fluted disc coulters were generally considered marginally beneficial, in clayey soils in Southern Queensland (Ward ~ et al. 1988). Improved wheat seedling establishment was observed using a disc coulter and spear point combination than a spear point alone (Norris, 1987).
Plate 9. Mountings for articulated disc coulters distributed throughout the tine pattern at 250 mm row spacing on this John Shearer “Trash Culti Drill”. The weight of the entire seeder, and downward forces of the action of the points, is then available to assist penetration of the discs.

2.5.2 Press Wheels

Improved wheat seedling establishment and vigour was frequently observed using smooth or single—ribbed rubber press wheels (Plate 10) to firm soil over and around the seed on clayey soils in Southern Queensland (Ward et al. 1988). The use of press wheels is generally recommended for sowing summer crops in well-structured, clayey soils in northern New South Wales (e.g. Kneipp, 1987; Thompson and Elliott, 1988b; Esdaile et al. 1989). Wheat seedling emergence was increased using press wheels on a range of soils in Western New South Wales (Palmer et al. 1988).

Steel V—shaped press wheels have been recommended for sowing wheat in Southern New South Wales (Hill, 1986). These may be more conveniently mounted with the capability of varying pressures from the tractor seat through remote hydraulics, rather than having to stop and adjust spring loadings in order to vary pressures on different soil types (J. Hill, then Agricultural Mechanization Officer, Department of Agriculture and Fisheries, Yanco, pers. comm., 1988).

The use of vertical forces equivalent to 15 kg per centimetre width of press wheel has satisfactorily increased seedling establishment on clayey soils in Southern Queensland (Ward et al. 1988). However, similar forces on press wheels inhibited plant establishment and vigour in some soils in some years. Wheat seedling establishment was increased on coarser-textured soils when forces were reduced. Ward and Norris
(1982) considered the use of press wheels superfluous in situations where adequate plant establishment could be achieved without press wheels.

Plate 10. The various shapes of press wheels used in New South Wales include single—ribbed (left), loose (so—called “zero pressure”) rubber to minimize clay adhesion (centre), and steel "V" (right)

2.6 Wear of Ground Tools

Relatively rapid wear rates of narrow-winged “inverted-T” points led to the development of both the inexpensive “knock-on, knock-off” replaceable narrow winted point (Peter Aitchison, pers. comm. 1989), and the Bioblade® (Baker et al. 1979). Wear of the Bioblade® is largely confined to the easily-replaced split-wings (Plate 11).

Spear points are generally of cast steel construction. Depending on the shape of the spear and its angle of mounting, they may be designed to wear in such a manner that they remain sharp for consistent penetration. Janke Bros Ltd of Mt Tyson (approximately 40 km west of Toowoomba, Queensland) provide two qualities of cast spear points, one less brittle for use in stony soils.

Tungsten carbide has been successfully braised onto both pressed and cast steel points in New South Wales (Packer, I.J., Cowra Soil Conservation Research Centre, pers. comm. 1988). Cleanliness and care are required in order to achieve good adhesion in the braising operation. Tungsten carbide has also recently been successfully mounted on cultivator points using epoxy resin and heat—treated at 200°C (R. Ainge, Hard Metals Aust. Ltd. pers. comm. 1988).
Rolling disc coulters characteristically wear more slowly than fixed openers, particularly in moist clayey soils. High disc wear rates have been reported on triple—disc drills in stony soils, (Bligh, 1987). Penetration and scuffing by stones may also cause deterioration of rubber depth drums, attached to disc coulters for depth control.

Plate 11. The replaceable split wings being demonstrated on a Bioblade® opener removed from the Aitchison “Seedmatic 2000” seeder by Alan Palmer, Agricultural Engineer, N.S.W. Dept. of Agriculture and Fisheries, Trangie
3. Review Of Relevant Developments Elsewhere

3.1 Minimal-Soil-Disturbances Sowing

Crop establishment using the triple disc drill assembly was inferior to either the “inverted—T” or more traditional hoe point openers under dryland conditions in New Zealand (Baker, 1976; Choudhary and Baker, 1981, 1982; Choudhary et al. 1985; Choudhary, 1988). Establishment was also unsatisfactory in parts of drill plots in some seasons in wheat-pasture rotations on loamy soils in Western Australia (R.J. Jarvis, W.A. Dept. of Agric., pers. comm. 1987).

Baker and Mai (1982) reported indications of greater compaction at the base of triple-disc grooves than at the sides. Lupin root growth was inhibited after sowing a silt-loam soil of bulk density 1.32 g cm\(^{-3}\) using a triple-disc drill, compared with that sown using an “inverted-T” opener, though not when the bulk density of the same soil was reduced to 1.04 g cm\(^{-3}\).

Baker (1976) reported greatly increased seedling establishment using an “inverted T” narrow-winged opener with 14 mm wide shanks and a maximum width at wing extremities of 38 mm at very low speeds, than using either “U” and “V” shaped slots formed by traditional hoe points and triple-disc openers, respectively. A shallow U-shaped zone of crumpled soil is formed above the seed placed at the bottom of the slot in unstable soil conditions, using narrow-winged openers at speeds in excess of 5 kmh\(^{-1}\) (Choudhary and Baker, 1982). “Inverted T” openers have been manufactured in New Zealand by Aitchison Industries Ltd of Wanganui since 1970 (P. Aitchison, Managing Director, pers. comm. 1989).

Wheat seedling emergence was superior using the Bioblade® at a ground speed of 5 km h\(^{-1}\) in a silt-loam soil, than using a hoe opener in one out of nine, and a triple-disc opener in two out of nine sequential sowings at two—week intervals in New Zealand (Choudhary and Baker, 1982). Sub-surface seedlings survived under dry conditions when sown with the Bioblade® in a further two sowings, when no seedling emergence occurred after three weeks in any of the three treatments. Emergence following use of an early-model Bioblade® without a seed-locating pin was inferior to that using triple-disc and “inverted-T” or hoe openers on silt loam and sandy soils (Choudhary ~ 1985). The insertion of the pin behind each opener blade beside the central disc controlled the depth of sowing, resulting in emergence comparable with the other two treatments.

Wheat seedling emergence increased when pressures of 35 kPa and 70 kPa were applied directly over the seed using hoe or triple-disc openers, before covering with a bar harrow (after Baker, 1970), in a fine sandy loam with soil moisture close to wilting point, but not after covering (Choudhary and Baker, 1981). All openers were operated in undisturbed turf blocks in tillage bins at very low speed. Seedling emergence was 58.4% using a narrow-winged opener, 31.3% using a hoe opener, and 10.5% using a triple-disc. The low emergence using the hoe opener was attributed to reduced germination, whereas seeds mainly germinated after sowing with the triple disc, but subsequently...
died. The narrow-winged and hoe openers gave similar emergence counts when sowing into initially moist soil (mean, 68.8%) and the triple—disc, 42.0%.

Krall and Dubbs (1979) report higher yields using a triple-disc drill than a disc coulter—hoe opener combination. Minimal soil-disturbance sowing resulted in less germination of weeds between the rows in continuous cropping than using furrow openers.

A narrow-winged point with a deep front blade is available from Ralph McKay Ltd. in either “Nok—on” or bolt—on fittings for combine seed drills, in order to cultivate up to 50 mm below the seed zone located at the 55mm wide wings. Draft forces at 4 km h⁻¹ in a sandy loam soil at 21—26% moisture content were comparable to those required for a narrow-winged point, a lucerne point and Baker “inverted—T” point. Soil disturbance was significantly less than that using a similar point with a blade at the same depth enclosed at the back, (particularly at 8 km h⁻¹) (Riley, T.W., South Australian Institute of Technology, pers. comm. 1988). Both types of narrow winged-and-deep-bladed points required higher draft forces at 8 km h⁻¹ than at 4 km h⁻¹, increasing from 388 N to 480 N for the front-bladed point, and from 587 N to 640 N for the enclosed-bladed version. Lower rhizoctonia-disease levels have been reported in wheat by Dr A. Rovira (CSIRO Soils Division, Adelaide), using deep, enclosed-bladed points (Sweetingham, M., W.A. Dept. of Agric. pers. comm. 1987). Draft forces required for the other openers did not increase significantly at 8 km h⁻¹ compared with 4 km h⁻¹, remaining in the range of 350 N to 395 N. Draft and vertical forces also remained relatively constant at field speeds for a range of tined and disked furrow openers in Canada, (Sheaf et al. 1979).

Vertical forces in the range 101-120 N per opener were required for both deep-bladed points, which were approximately double those of the Baker point. The Lucerne point required vertical forces of 353 and 370 N per opener at 4 and 8 km h⁻¹, and the narrow-winged point, 453 and 401 N per opener, which was significant at the 5% level.

3.2 Stubble Clearance

Cereal stubbles were reported to be readily passed through tines more widely—spaced that four times the mean stubble length in New South Wales (Quick, 1985). An “arrowhead” configuration of tines proved superior to a “reverse arrowhead” pattern, though disc coulters were required in the heaviest stubble conditions. Allen (1988) reported that wheat stubble of 3.5 t ha⁻¹ appeared to be close to the limit of clearance for a hoe—press drill.

Disc coulters mounted directly in front of each tine have been reported to assist in slicing through stubble (e.g. Anon, 1986; Freeborn et al. 1986). Kushvaha et al. (1986) found that discs with a diameter of 460 mm, cut stubble better than 300 mm or 600 mm, with little difference between plain and fluted discs. Morrison and Allen (1988) detailed several combinations of disc coulter-tine combinations used in Texas.

Mead (1985) and Krall and Dubbs (1979) observe that disc coulters should be mounted in such a manner as to allow separate break-out action in stony soils, for reasonably
trouble-free operation. Net vertical forces were downward when disc coulters were set at depths less than those of following conventional points at the Agricultural Machinery Research and Design Centre of the South Australian Institute of Technology (Anon. 1986). Draft forces increased rapidly when the disc coulters were set deeper than the points, with little increase when set shallower. Soil disturbance was reduced using the disc coulters though the self-cleaning action of the tine was reduced.

Baker et al. (1983) commented that a front disc coulter seldom improves stubble clearance. Baker (1983) observed that uncut but "hair-pinned" stubble poses a danger to germinating seedlings from fatty-acid decay products in wet soils.

The practicality of punch—planting, in which the seed is placed in a hole punched in the soil, was investigated by Srivastava and Anibal (1981). They reported that the concept has merits if the wheel on which the punches are mounted is powered with positive slip, and the seed is propelled aerodynamically rather than under gravity alone. They also reported that seeds should be accurately graded for size.

An experimental punch seeder reported by Rogers and Baron (1987) operated with pneumatic seed and fertilizer delivery. Punches mounted on a rotating wheel required about 0.25 kN load to penetrate 30 mm into a stubble field in Canada. The wheel hub was being re-designed to minimise bounce of the seeds onto the surface after the punch leaves the soil. Low draft and accurate sowing—depth control are reported using this innovative seeder.

Stubble handling begins at the harvest of a preceding crop. Harvesting height and straw choppers mounted on harvesters affect the amount of loose stubble (Porritt, 1987) and its distribution behind the harvester. Several harvester fittings for chopping and spreading straw and chaff residues are described by Butt and Quick (1986). An experimental, second knife to reduce the height of standing stubble without increasing through-put through the harvester and therefore, reducing speed, is described by Robotharn and Ward (1984).
4. Relevance To Reducing Water Erosion On Cropland In Western Australia

4.1 Technical Relevance

Severe water erosion typically occurs on tilled cropland in Western Australia (Bligh, 1989). It was estimated in 1975, that contour banking was required to reduce erosion of tilled cropland on up to 45% of the 16 million ha of agricultural land in Western Australia (Anon., 1978). Contour banks have been constructed on only a small proportion of erodible land to date.

Erosion of tilled cropland typically occurs within weeks of the initial tillage operation in this predominantly winter-rainfall region, frequently before appreciable settlement of tilled soils has occurred. Increased infiltration and reduced suspended sediment mobilisation have been observed under reduced tillage and, particularly, triple-disc-drilling on sandy loam and loamy sand soils (Bligh 1g84). Contour farm planning with contour working and strategic diversion banks would still be required to discharge concentrated flows with a minimum of erosion, however.

Long-term cereal yields have been maintained using triple-disc drills on loamy soils in medium (~ 325 mm average annual) rainfall areas, compared with a tillage operation approximately 50 mm deep at sowing, or three tillage operations per season (Jarvis et/al. 1986). Therefore minimal-soil—disturbance sowing is a potentially viable method of reducing water erosion on cropped loamy soils in Western Australia.

Though typically 70% to 80% of soil losses occur in the first three months of the year at Cowra (Edwards, 1987), signs of water erosion were evident on sloping cropland in September 1988 (Plates 12 and 13) following relatively high winter rainfall. Severe rilling occurred even on direct-frilled-sandy-loam soils at the Soil Conservation Research Centre at Cowra, for example (Plates 12 and 13). Conservation Research Centre photographed in September 1988

Packer (1988) reported significantly reduced runoff under simulated rainfall on 0.8 m—square plots after five years continuous cropping to cereals in Central Western New South Wales. Traditional tillage (four tillage operations each year) resulted in the highest runoff, followed by reduced tillage (two) and direct drilling (one tillage operation; at sowing). The presence of 3 t ha~ of stubble significantly decreased runoff under reduced tillage and ~ treatments, though not under traditional tillage and ungrazed direct-drilling. Sediment loss was significantly reduced in the same order as runoff. Significant reductions in soil movement were observed when stubble of 3 t ha~ was applied under traditional and reduced tillage, but not under either the grazed or ungrazed direct-drilling treatment. Packer cautions against stubble retention alone on degraded soil, advocating stubble retention with minimal-soil-disturbance sowing to optimally reduce runoff and water erosion.
Plate 12. An erosion nil looking down a contour-worked slope at Cowra Soil Conservation Research Centre photographed in September 1988
Packer and Hamilton (1988) comment on the overriding effects of good soil management over tillage level for reducing water erosion. Machinery selection, herbicides, weeds, stock management, stubble, alternative crops and deep ripping are included in good soil management. Trends in runoff and sediment loss for all conservation tillage treatments were significantly different from those for traditional tillage at two intensively sampled sites in the Cowra area. Multiple regression analyses indicated that decreased runoff resulted mainly from the development of stable biopores, particularly those larger than 0.75 mm in diameter in a sandy-loam soil. On a loamy soil, decreased runoff resulted from increased total porosity (i.e. reduced bulk density) rather than specific pore sizes. Plant establishment was significantly reduced on the sandy loam soil when surface crusting developed. Organic matter increased with reduced tillage, depending on organic litter or stubble more than on degree of soil disturbance. They advocate maximum retention of stubble for soil conservation in long—term cropping in arid cereal-growing areas.

Grain yields generally increased when soil physical conditions stabilised after three or more years of conservation tillage (Packer and Hamilton, 1988). Mead and Chan (1988b) observed reduced wheat seedling vigour with tillage level following five years of pasture. They advocated reduced rather than minimum tillage in the initial years of continuously cropping hard—setting sandy loam soils, with timely cultivation to minimise soil erosion and recompaction. Mead believes that direct—drill yields in Southern New South Wales, are limited chiefly by biological factors, which are evidently ameliorated by tillage (pers. comm. 1988).

Row spacings used for cereals in New South Wales are typically 200 mm — 300 mm compared with 150 mm to 180 mm in Western Australia, where yield reductions have
been demonstrated at wider spacings (Burch and Perry, 1986). The greater space and reduced expense per unit width of seeder, allows the use of more complex mechanisms in New South Wales, such as parallelogram linkages and depth and press wheels for improved depth control and seed-soil contact on minimal—soil—disturbance seeders’.

Water erosion typically occurs during summer months in the winter cropping areas of Southern New South Wales (Edwards, 1987). Minimal-soil-disturbance sowing is even more relevant in Western Australia, where erosion typically occurs shortly after the sowing when soil erodibility is high. A perspective on its prospective adoption may be obtained from experience in other parts of the world, particularly in the United States of America where documentation is more complete.

4.2 A Perspective on Prospects for the Adoption of Minimal-Soil-Disturbance Sowing for Reducing Water Erosion of Cropland in Western Australia

Soil movement of the order of millimetres depth has been measured in several recent seasons in Western Australia (McFarlane and Ryder, 1987; Bligh, 1987; 1989), compared with soil formation rates estimated at less than one millimetre per thousand years. Shallow soils are more vulnerable to productivity losses than deeper soils, because water storage and fertility become more limiting with erosion.

Average annual soil erosion on cropland in United States was 20 t ha~ in 1982 (Lee, 1984), equivalent to approximately 1.6 mm depth on cropland, and approximately 1.5 mm on all agricultural land. However, soil loss tolerances are considered to be 1 mm per year for many soils in the United States. Depending on the depth of fertile soil available to be “mined” in this way, the relative erosion risk to sustained productivity may be more severe in Western Australia, where soil formation rates are extremely low, than in the United States.

Napier (1988) observes that erosion-control programmes carried out to date in the United States are difficult to justify in terms of on—site costs, and that off—site costs are not borne by landholders at present. A similar situation also pertains in Western Australia, where water erosion reduction has historically depended on the goodwill of offending landholders. The availability of satisfactory techniques for reducing water erosion may therefore be a necessary if not sufficient condition for their adoption by landholders.

The profit—maximising desire of landholders may be expected to result in earlier sowing in order to achieve higher yields in Western Australia. Weed control under minimal—soil-disturbance sowing will necessarily depend more on adequate weed seed-set control in the previous season, through the use of cereal—legume rotations or pasture-topping. Weed control by tillage in the cropping season is then likely to be less critical. The prospective use of press wheels may increase the reliability of early establishment through increased seed—soil contact in generally drier, early—season conditions.
Landholders may still choose to reduce their weed risk through tillage, because water erosion is not an appreciable current cost in Western Australia. Risks may be less using a systems approach to weed seed-set with appropriate rotations and pasture topping, though improved management may be required. Hurley et al. (1985) found that Victorian farmers were aware of benefits, but worried both about new investment costs in machinery, and risks of yield reductions.

The 50% adoption of a minimal-soil-disturbance cropping system in North-Coastal New South Wales for reducing water erosion, suggests that farmers are amenable to a demonstrated, credible systems approach. Emphasis should therefore be placed on a minimal-soil-disturbance systems approach which minimises weed control and crop establishment fears, in extension of minimal—soil—disturbance sowing for reducing water erosion in Western Australia. McGowan and Associates (1988), for example, have recommended increased tax write-offs for approved conservation seeders together with contour farm practices for reducing water erosion in the Avon Valley of Western Australia.

Indices of rainfall erosivity are several times higher in North-Coastal New South Wales, than in South-Western Australia (Mcrarlane and Clinnick~. 1984). Suitable minimal—soil-disturbance seeders were also at first unavailable for use in this cropping system. The Connor-Shea “Coulter Coil Tine Drill”® (sometimes known as “The Bean Machine”), and other seeders utilizing the “inverted—T” concept (after Baker, 1976), and subsequently the Bioblade® (Baker and Desborough, 1984) were then developed in acceptable sowing widths, in order to enable the ready adoption of minimal-soil-disturbance sowing. Cropping, then a new land treatment in the area (Desborough, 198lb), was effectively extended as a “package” which included direct-drilling as an integral part of the system.

A similar situation pertained in extension of direct-drilling in the lupin phase of wheat-lupin continuous cropping rotations in Western Australia. Wheat stubble is required on the soil surface in order to reduce “brown spot” infection of the succeeding lupin crop. Either traditional prior tillage is typically carried out in the wheat phase, or the soil receives full tillage at sowing using a combine seed drill or air seeder equipped with overlapping, conventional points.

The fact that tillage is still typically carried out in the wheat phase of wheat—lupin rotations in Western Australia, supports evidence that farmers favour least—risk techniques (e.g. Napier and Camboni, 1988; Napier, 1988). No-till farming has been developed and extended by scientists primarily to reduce water erosion (Van Es and Notier, 1988). Water erosion has usually been given a minor consideration in landholders’ reasons for it’s adopting on 1.5 million ha of cropland in the United States (Christiansen and Norris, 1983). Napier (1987) suggests that the “carrot” is likely to soon be replaced by the “stick” in the United States Government’s dealings with farmers regarding water erosion. He suggests that it is therefore in farmers best interests to adopt conservation techniques on erodible land before they are forced to, by possibly unpalatable methods.
Plate 14. Minimal—soil-disturbance seed grooves formed by narrow-winged-and-deep bladed points on a combine seed drill at Chapman Valley Research Station near Geraldton, Western Australia in 1988
5. Discussion And Recommendations

5.1 Narrow-winged, and Narrow-winged-and-deep-bladed Points

Most detailed seed-groove investigations have involved towing openers in undisturbed turf or annual pastures, either at very low speeds in tillage bins (e.g. Choudhary and Baker, 1981), or at more representative speeds of 4.0—8.5 km h⁻¹ in field situations (e.g. Choudhary and Baker, 1982; Palmer et al. 1988). Groove formation may be different at higher speed in soils with negligible or dead vegetation. For example, grooves formed using the McKay narrow—winged-and-deep—enclosed-bladed point appear to resemble more a generalised “U” or “V” shape depending on soil texture and moisture content (Plate 14) than the “dagger” shape of the point (Plate 1 right) in Western Australia. Further establishment trials are suggested following superior wheat yields at four out of five sites than those achieved with full tillage on loamy soils using similar points in the 1988 growing season (C. Henderson, Department of Agriculture, Western Australia, pers. comm. 1989; Bligh, unpublished, 1989). Narrow—winged points without a deep blade should also be tested, particularly on sandy loam and clayey soils, where deeper cultivation may not be required for adequate establishment (R. Belford, Department of Agriculture, Western Australia, pers. comm. 1988).

5.2 Press Wheels for Seed Firming with Minimal Soil Cover

Considerable loose soil cover appears to be thrown into grooves formed by front tines by adjacent following tines (Plate 14). It is therefore difficult to arrange a machine configuration so that pressure can be applied by press wheels to seeds before covering (after Choudhary and Baker, 1980). Press wheels would have to be mounted immediately behind each time, and in front of adjacent tines, in order to minimise soil cover before pressing. Space limitations usually prevent the use of such a configuration (Bligh, 1987b). Rear-mounted press wheels could be tested with a finger harrow immediately in front to remove excess soil, with a further finger-harrow following the press wheel to provide loose soil cover. Alternatively bar harrows (after Baker, 1970) could be considered for trailing behind the seeder if press wheels are not required, and their operation is not hindered by obstacles such as stones or stubble collecting in front of the bars.

Pressures of approximately 35-70 kPa appear desirable (after Choudhary and Baker, 1981). Difficulties of measuring pressures in field soils suggest that its expression as its static equivalent, in kilograms per centimetre width of press wheel, is preferable for extension purposes (after Ward and Norris, 1982; Ward et al. 1988). Pressures as low as that provided by a mass of 3 kg per centimetre width of press wheel are suggested by Riethmuller (Agricultural Engineer, W.A. Dept. of Agric., pers. comm. 1988).

5.3 Point Wear

Excessive wear rates of narrow—winged McKay points reported by a Western Australian farmer Peter Copestake in 1988, may be reduced by the attachment of tungsten carbide tips. Aitchison Industries’ “knock-on, knock-off” winged points appear
to warrant trial use in this regard, with the possible added advantage of depth separation of seed and fertiliser delivered through separate tubes. Deep front blades currently manufactured for separate replacement where wear rates exceed those of the narrow-wings, (W.M. Johnson, Concept Engineer, Ralph McKay Limited, pers. comm. 1989), also warrant investigation for possible economic use on existing combine seed drill tines.

5.4 Disc Coulter

The mean length of stubble should be reduced to less than one quarter of minimum distance between tines on a rank (after Quick, 1985), either at harvest or prior to sowing, in order to facilitate the passage of seeders without disc coulters. Evaluation of disc coulters in front of tines appears warranted where heavy stubble or vine weeds still collect between widely—spaced tines (after Baker and Desborough 1984; and Morrison and Allen, 1988). A disc diameter of 400—460 mm appears to adequately trade off stubble-clearing ability with downward force requirements for penetration. From evidence reported in the literature, there appears to be little to choose between plain, rippled and fluted discs in their ability to cut a path for tines through stubble, though rippled discs are reported to be more self—sharpening than plain discs (Morrison and Allen, 1988). The reduced soil disturbance of front disc coulter-tine combinations, and reported, though unexplained improved establishment compared with tines alone (Norris, 1983), may also be useful in contributing towards their adoption for reducing the erodibility of cropland by minimal-soil-disturbance sowing and stubble retention.

5.5 Bioblade

The Bioblade® has reportedly achieved excellent plant establishment in heavy stubble in North-Coastal New South Wales, the North-Western United States, and in some soils in New Zealand. Disappointing results in moist, relatively sticky soils in Western New South Wales, and in some soils in New Zealand, suggest that the Bioblade® may be a relatively soil-specific minimal-soil-disturbance seeder mechanism. A watching brief appears warranted on the commercial development of this complex seeder mechanism in the United States.

5.6 An Integrated Minimal—soil-disturbance System

A satisfactory systems approach with emphasis on weed control and adequate crop establishment should be developed and extended with contour farm planning as a conservation package, in order to achieve a reduction in water erosion through minimal-soil-disturbance sowing in Western Australia. Narrow—winged and narrow-winged-and-deep-bladed points appear to have the potential to maintain crop yields, particularly if used in combination with press wheels for reliable early sowing, and front disc coulters, if found to be satisfactory for clearing stubble and surviving summer vine-weeds.
6. Acknowledgements

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7. References


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Appendix 1 Study Tour Itinerary

Monday. September 12  
Fly to Sydney, and drive to Cowra.

Tuesday. September 13  
a.m. Discussions with Ian Packer, Brian Murphy  
and Evan Thomas (Research Officers) at Cowra Soil Conservation Research Centre. 
Inspect machinery, tillage practices trials and the former runoff and soil loss plot sites.

Tuesday September 13  
p.m. Discussion with Ashley Mead (Research Officer) at Cowra Agricultural Research Station. Inspect trial sites and seeders.

Wednesday September 14  
Discussions with Alan Palmer (Agricultural Engineer) and Neil Fettell (Research Officer) at Condobolin Agricultural Research and Advisory Station. Inspect tillage and sowing machinery, and cropping and chemical fallow trials.

Thursday September 15  
a.m. Travel to Gunnedah 
p.m. Tour of the Gunnedah-Breeza area of the Liverpool Plains with John Kneipp (District Agronomist, Dept. of Agriculture and Fisheries), then visit Gunnedah Soil Conservation Research Centre for discussion with Col Rosewell (Research Officer).

Friday September 16  
a.m. Discussion with Lindsay Ward (Conservation Farming Officer, Soil Conservation Service), at Tamworth  
p.m.Discussions with Col Rosewell. Greg Elliott and Bob Crouch (Research Officers) Gunnedah Soil Conservation Research Centre. Inspect an experimental twin—row seeder and the former contour bay trial and runoff and soil loss plot sites.

Saturday September 17  
Drive to Brisbane via Inverell

Sunday September 18  
Travel to Toowoomba

Monday September 19  
Attend Soil Management 88 Symposium at the Darling Downs

Wednesday September 21  
Institute of Advanced Education, presenting a paper entitled “A review of machinery for seeding with minimal soil disturbance.

Wednesday September 21  
late p.m. Inspect spear-point seeders at Mason Conserva—til Ltd.

Thursday September 22  
am. Travel to Janke Bros. Ltd., Mt. Tyson to inspect and discuss seeders and associated components with Noel Klease (Sales and Development Manager).

Friday September 23  
Travel to Grafton Agricultural Research and Advisory Station, New South Wales for discussion with Peter Desborough (Research Agronomist). Inspect minimal—soil—disturbance seeders and trial sites.
Saturday September 24  Travel to Karuah, en route to Sydney

Sunday September 25  a.m. Travel to Sydney

Wednesday September 28  p.m. Attend pre-conference tour, and the Agricultural Engineering Conference of the Institution of Engineers, Australia at Hawkesbury Agricultural College.

Wednesday September 28  late p.m. Fly to Perth.