One Drill For All Establishment Systems – Is It Possible?

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Abstract

Current farmer practices for pasture and crop establishment range from conventional cultivation for preparation of a seedbed, to reduced (minimum) tillage to no-till (direct drilling). The success of these operations depends on a number of factors including soil type, land contour, soil structure, vegetation cover, seed quality, and the machinery used; the outcome can range from excellent establishment to complete failure. Through a series of farmer case-studies, this paper describes the capabilities of a seed drill which has been used successfully for non-till, reduced tillage and conventional establishment systems in a wide range of soil types and vegetation cover throughout New Zealand on flat, rolling and high country sites. Key features include the spring tine configuration and excellent tip penetration in all soil types, including compacted soils and stoney ground. The importance of seed quality for the success of establishment is also discussed, and the need for improved information transfer among farmers, the seed drilling industry and the seed industry highlighted.

***Additional key words*:** Sustainable agriculture; no-till; reduced tillage; conventional establishment; spring tines; tip penetration; seedling establishment; seed quality.

Introduction

Each year more than 1 million hectares of agricultural seeds are sown in New Zealand between latitudes 34° S and 47° S from sea level to more than 450 m above sea level, covering a wide range of agro-ecologies. Farmers generally use no-tillage, also known as direct drilling, conservation tillage or eco-tillage, and reduced tillage methods in conjunction with periods of traditional cultivation. For this, they require a seed drill suitable for all three types of operation. Such drills must perform well for a variety of crops often grown under contrasting soils and climatic conditions using very different management systems. Locally designed and manufactured as well as imported drills are used.

Historically, cultivation has been used to remove inter-plant competition, level ground, aerate soil and release nutrients within the drilling zone, the object being 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. New Zealand scientists and engineers have developed unique opener technologies that are now used in more than 25 countries throughout the developed and developing world for creating definable micro-environments using an inverted-T-shaped seed slot (Fig 1) to improve seed performance and seedling emergence (Stevens *et al.*, 2000). The need for cultivation can be removed by using these soil openers to create suitable micro environments through reduced tillage and no-till that facilitate high emergence (near to 100%), regardless of soil and residue conditions (Baker, 1976a; Baker *et al.*, 1996;

Ritchie *et al.*, 2000). As a result, New Zealand no-till (direct drilling) and reduced tillage technologies have helped to introduce unprecedented flexibility into arable crop, livestock and other agricultural and horticultural systems, as well as environmental conservation and management plans, compared with traditional cultivation and drilling.

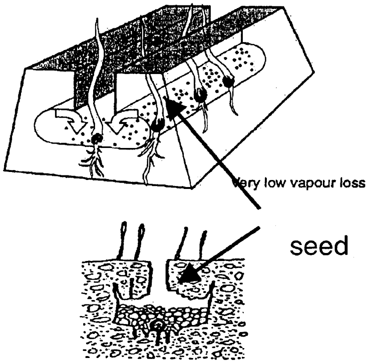

Fig. 1. "Inverted-T" slot shape (after Carter, 1994; Baker *et al.*, 1996).

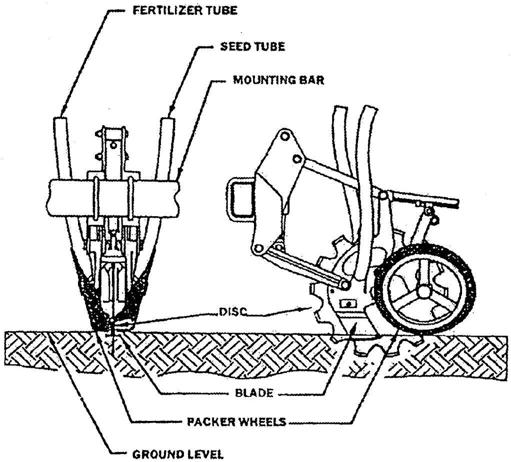

Fig. 2. Cross Slot assembly mounted on parallelogram drag arms (Baker *et al.*, 1996).

Advanced New Zealand no-tillage technologies using the Cross Slot™ opener (Fig. 2) to create slots are built around a central disc used to give improved performance in residue, plus leg wings for the separate placement of seed and fertiliser along either side of the soil slot. Such units can track over 50 cm undulations at speeds of up to 16 kmph, and slice through up to five tonnes of plant material on hard or soft soils while placing seed and fertiliser at uniform depths. Cross Slot assemblies have become an industry standard against which other technologies may be compared (Lessiter, 1995). They are well suited to large-scale farming and contracting (Baker, 2003a,b), having been shown to be economically justifiable over lesser technologies on the basis of increased yields. However, such advanced levels of technologies still lie beyond the reach of many medium and smaller-scale farmers and contractors who own smaller tractors and seek more affordable options, and are concerned about soil compaction resulting from the use of heavy equipment. In these instances, intermediate technologies are required, which is the main focus of this paper.

Intermediate-level New Zealand technologies primarily use a simple winged opener known generically as a "Baker Boot" (Fig.3.). These boots are usually fitted to vertically mounted heavy-duty cultivator tynes operated either with or without leading discs (Fig. 3; Baker, 1976a,b). Compared with the Cross Slot™, the main disadvantages of this opener configuration are: (a) poor residue handling qualities, (b) incapacity to separate seed and fertilizer in the slot, (c) difficulties in getting the tyne to follow reliably behind the disc opener (d) poor contour following abilities and sowing depth control on undulating and/or soft ground, and (e) difficulties with penetrating hard ground, while maintaining the inverted T slot shape under these conditions. This is especially so with boots that use heels located above the inverted T, to trap soil needed to create a wear surface to prolong the life of the tip. A Tungsten tile cast using Nihard steel protects the leading edge of tips.

During work, the contour following ability of vertically mounted coiled tynes seldom exceeds 50 mm vertical / lateral displacement. The effect of this is accentuated as the distance between rows of tool bars to which tynes are attached is increased to improve residue passage. This also occurs when land wheels are mounted on the extreme outside and/or toward the rear of the drill to improve the stability. Generally, the narrowest practical row-to-row spacing achievable using these tynes without compromising the passage of residue is 150 cm.

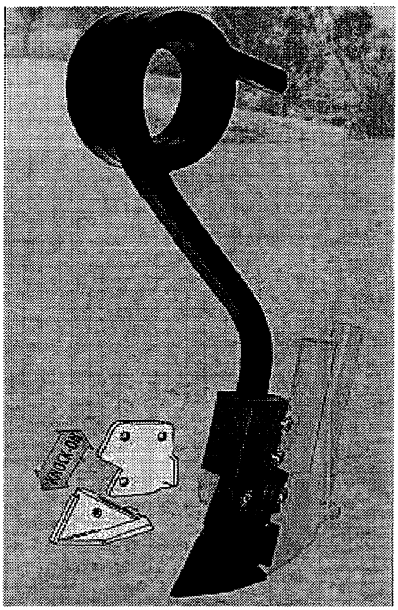

Fig. 3. Commercial variant of the original Baker Boot (P. Aitchison)

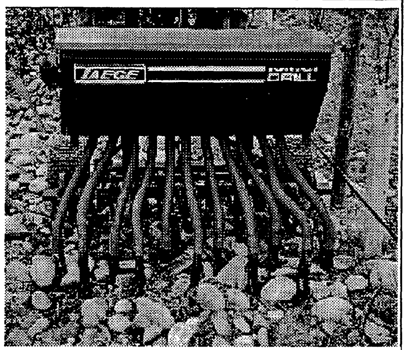

Fig. 4. Mini drill direct seeding into stoney ground between grape vines.

If the tynes block, residue does not fall cleanly away from them once they are lifted out of the ground. These tynes do not easily ride over and/or pass around fixed obstacles; rocks, roots and other partially buried or buried obstacles. If tynes break, mostly as they rebound after excessive deflection, they are relatively expensive to replace (NZD 100 to 120 each, retail). On undulating / stony ground, tip wear can be accentuated unduly on the base of the inverted T, caused by the inflexibility of tynes which place undue downward pressure on the base of tips, including rounding the leading edge, which limits penetration.

Viable intermediate-level alternatives are needed to help overcome these problems, which is the focus of work reported in this paper incorporating a novel approach to using offset 12mm cultivator tynes, fitted with a "knife-like" boot (see insert below).

During the early 1980s, vertically mounted 12 mm S-shaped cultivator tynes (fitted with hoe openers) were used on some intermediate-technology multi-purpose New Zealand seed drills, with variable results. During the 1990s this approach was modified with outstanding success using a standard 12mm cultivator tyne; by opening up the gap between individual tool bars, while at the same time, rotating the angle of presentation to offset ("lay back") tynes. At the same time, an additional tool bar was added to some drills, taking the norm from two or three, up to four.

Approximately 300 of these drills are now working in New Zealand between Te Anau in the south and Kaitaia in the north. Drills vary in size between 900 mm and 3.6 m wide (Fig. 4, 5, 6, 7 and 8). They are routinely used for no-till, reduced tillage and traditional cultivation within horticulture, viticulture, pasture and crop management systems. Single and double box drills have been sold, suitable for seed and fertilizer. All 3.0 and 3.6 m drills have attachment points for end tow.

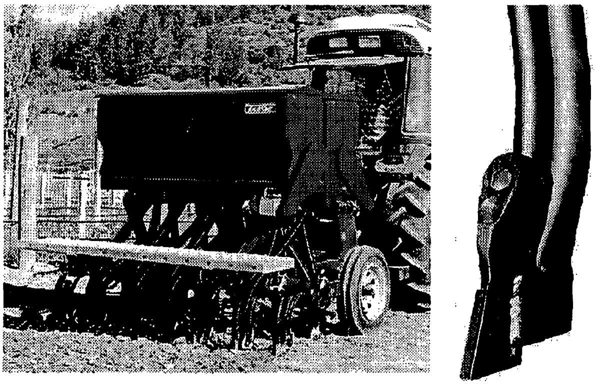

Fig. 5. Vineyard / Plot drill (Model 1.4 ED) direct seeding. "Knife–like" boot shown as insert (B. Taege).

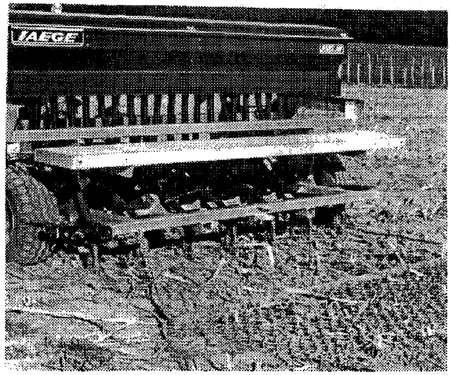

Fig 6. Single box drill (Model 300 MS) working after arable forage maize.

Fig. 7. Single box drill (Model 300 MS) working in tussock country.

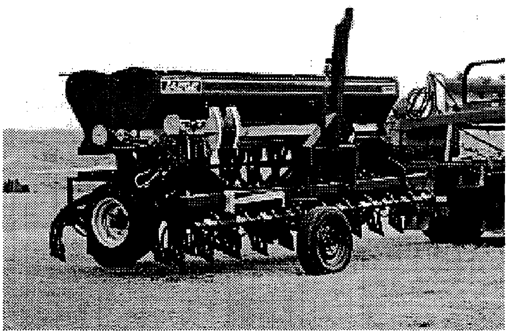

Fig. 8. Double box drill (Model 360 MD) fitted with end-tow (farmer version).

Materials and Methods

Early in 2004, a two page questionnaire plus covering letter was mailed to 250 owners / operators of drills fitted with offset 12mm cultivator tynes, inviting them to comment on their experiences, and to offer their suggestions for improvement. Forty-six questionnaires were completed and returned; at least one from all major agro-ecologies / management systems in New Zealand where the drills were known to be operating. Follow-up phone calls and several farm visits were made. The data obtained have been combined with field experience gained over the past four years by the manufacturer, dealers and the authors. Between 2001 and early 2004 dealers, farmers and other users were informally consulted.

Results and Discussion

Survey data, when analysed as a series of case studies, confirmed that, in four years, the drill has developed a well proven record of field success as an intermediate level of technology suitable for no-tillage, reduced tillage and conventional cultivation, as practiced within the area surveyed. This included a number of agro-ecologies with major international analogues in the developed and developing world

Farmers who responded were mainly drilling between 50 and 300 ha per year; with some up to 500 ha. Contractors were drilling between 500 and 1200 ha per year. Many farmers in Otago and some in Canterbury mentioned that they would have done more drilling during 2003/4, but for a drought, and that once the drought broke, significant areas of their farm would need to be re-grassed.

Drills were owned either individually or as part of a group comprising between two and four members. A wide range of seeds were routinely being been established successfully with the drill, with seed ranging in size from small (brassicas, clovers, herbs and grasses) up to medium (cereals) to large (peas, beans and forage maize). These sowings were achieved with minimal adjustment of the drill, other than adjusting sowing depth and using small seed inserts as required (to sow seeding rates below 4-5 kg ha) and varying the type and weight of harrows and /or roller towed behind the drill, according to the crop.

The use of 12 mm offset tynes and the knife-like boot were reported as the key features of the drill. Compared with other established intermediate level approaches already described using the "Baker Boot", this combination enabled improved tip penetration and contour following, while also providing even sowing depth and improved tilth within the seed slot, especially on undulating compacted and/or stoney soils. It also allowed row spacing to be reduced from 150 mm down to 121 mm, which appealed to farmers wanting early ground cover to control weeds, conserve moisture and reduce erosion. It was also noted that land wheels had been kept near to the central tool bar of the drill, which combined with the offset flexible tyne, improved fore and aft contour following.

Offset tynes enabled the tips to easily ride over and/or around large buried obstacles, rocks, timber and other debris, particularly where the soil was compacted. In the absence of leading discs, aided only by the offset vibrating tyne and wider than average tool bar spacing, a broader range of residue tended to pass through the drill compared with vertically mounted tynes in spite of narrower row spacing, where it was dry and crisp. When the drill blocked, residue fell cleanly away from the tynes in their "laid back position" once they were lifted out of the ground, more so than with vertically mounted tynes.

Tyne vibration helped "walk" residue through the drill. The tynes vibrated more at higher than lower ground speeds, hence farmers reported that it was important to speed up rather than slow down if the drill was blocking. Drilling speeds of between 3-5 km/h were reported on stoney, hard or rough ground and up to 10 – 12 km/h under favourable conditions. Speeds of between 6 and 8 km/hr were the norm. Reduced drilling speeds were necessary in cultivated ground, (to 6-7 km/h, even less at times) to limit the bow wave effect of tynes, especially while sowing lucerne, and more so if the harrows being used were too light or not deep enough to effectively even out ridges left through the bow wave effect.

This drill system worked well, seeding into various forms and levels of ground and vegetation cover, wherever it was actively growing (i.e. fresh, green)or well attached to the ground. This included 100 % hieracium mat; fescue tussock and matagouri; short gorse and broom; rushes, rape and choumollier stubble; and snow tussock in addition after fodder maize, hay or silage crops; and after some cereal grain crops, where there was only limited straw.

Standard three tool bar models of the drill did not perform as well as four tool bar models in heavy residue, particularly where residue was not firmly attached to the ground, or consisted of partly decayed and/or on long lengths such as maize stalks, cereal grain residue after combining, cut thistles, cut rushes, heavy willow weed, or rank kikuyu or other rank grasses. There were more problems when the residue was wet than when it was dry and crisp. The problem was worse, for example, where stubble had been left to decay; rank paddocks had been sprayed and left to die off and begin to rot; or stock had been put on rank growth and had only partly eaten the residue while trampling the remainder. Mulching, cutting, raking, baling and burning residue was used by many farmers to overcome these problems, usually just before seeding to preserve soil moisture. On rough terrain, the standard three tool bar drill followed the contour better than the four tool bar drill.

Additional strategies were developed and tested to improve the passage of residue through these drills by; (a) fitting a gang of independently sprung leading discs spaced 121 mm apart, mounted in pairs directly in front of the first row of tynes, and (b) by manufacturing and mounting comparable disc assemblies directly behind the tractor, to which the drill was then attached. In both instance, it was difficult to get the tynes to consistently line up with, and track within, grooves cut by the disc assemblies, more so than with vertically mounted, rigid tynes. This was caused mainly by the flexibility of the tynes combined with the wider than average spacing of the tool bars on which they were mounted, both on the three and four-tool-bar models.

Discs were not needed to assist penetration under any conditions and on hard ground, when they were mounted on the drill, they tended to limit penetration. Tips did not, however, penetrate wet and frozen clay soils during early spring On rough ground, tynes would routinely operate with 100 to150 mm vertical and horizontal deflection without permanent damage. If the tynes broke or bent, farmers felt they were cheap to replace (NZD 18 to 20 recommended retail). Because offset tynes vibrated more vigorously than vertically mounted tynes, (a key factor in tilth formation) they required heavier than normal seed delivery hose. A number of respondents noted that light (industry standard) seed hose used on their drills failed on compacted or stony soils, and needed up-grading.

Under wet and / or poorly compacted soil conditions, sowing depth was less uniform than on hard ground, and the tyne left an open groove with minimal tilth. Under these conditions it was especially important to use trailing harrows and/or a roller to improve seed coverage and soil-seed contact, as with other established approaches. Many farmers, irrespective of soil conditions, routinely used trailing harrows plus either steel or water ballasted rubber tyre rollers (manufactured using used truck or car tyre casings).

Different types, weight and design of harrows were used depending on conditions. Mostly they were of the chain type, ranging in weight from light covering harrows used on cultivated ground, to very heavy types used in thick turf. On cultivated ground they were used to even out the soil bow wave left by the last row of tynes to ensure uniform seed coverage with soil and promote even plant emergence. In heavy turf, heavy harrows were needed to break up turf and release additional soil to cover seed. This was particularly important in the Central North Island or where cereal seeds were sown 60 to 70 mm deep directly into un-cultivated ground.

For planting cereals where the ground was compacted farmers would sometimes first cultivate the ground lightly to a depth of 50mm with a single pass of a spring tyne cultivator before drilling, then over drill on the diagonal. In this way, the drill would easily penetrate a further 20mm into undisturbed ground, placing the seed well away from birds and within the moisture zone. On hills, this approach helped prevent more than one tyne running in the same slot, a common problem encountered while sidling on steep slopes where the ground was compacted.

On rough ground, it was not uncommon for farmers to cross drill fields on the diagonal to improve contour coverage, using half the rate of seed. This was particularly successful for no-till seeding of brassica , since these crops responded well to the increased tilth generated by the second pass. While doing this, farmers noted that cross drilling at 90 as compared with 45 degrees brought up more turf in larger pieces, which was undesirable. Using this approach, most farmers drilled the seed during no till; however for reduced tillage, some broadcast the seed after taking the seed hoses off the tips and letting the seed fall freely on the ground. With cross drilling, on the second pass it was important to lift the drill out (by adjusting the depth blocks on the land wheel rams), since tips would penetrate 20 to 30mm deeper than on the first pass. Using this approach and single box drills, some farmers would first shallow sow a short rotation rygrass, then undersow a forage cereal at a deeper level.

A useful degree of separation was reported between the placement of seed and fertilizer when it was sown using standard double tips fitted to double box drills and tilth backfilled the seed slot to more than 50 % of the seeding depth. Mainly this applied to dry, hard and compacted soil conditions. It did not apply on damp and wet soil conditions, particularly in the top 30 mm of soil when the tip tended to make an open groove leaving seed and fertilizer to fall together. Under these conditions, the standard seed delivery attachment to the boot tended to block. A differently designed more open boot was fitted for consistently wet soil, and for, at times, pumice soil. A longer boot, exposing more of the knife point below the side plates of the seed delivery tube attachment to the boot, was required on steep compacted soils to help prevent more than one tyne running in the same seed slot. Tilth condition within the seed slot were noted to improve very quickly on damp soils, after several hours of sun and/or wind, with soils reaching a condition where they could be safely drilled using the offset tyne and knife-boot earlier than would have been possible using disc coulters, or other boots. With double box drills, oats and other forage cereals could be sown simultaneously through the front box and ryegrass through the rear box, with a useful degree of separation, the oats being placed deeper than the grass.

Where there was adequate soil moisture, clover and other small seeds (e.g. chicory and plantain) established successfully where they had been broadcast directly onto the tilth created by the vibrating tynes following either a single or double pass, especially when combined with cover harrows and a roller. At the same time, some farmers drilled their grass mix and broadcast clovers, brassica and other small seeds, with good results. This approach worked particularly well for no-till and reduced till seeding after fodder crops where there was little residual material. It also worked in cultivated ground (as would be expected), and directly out of old pasture, provided there was adequate soil mixed with turf.

The most consistently successful method of renovating old pasture with an excessive turf mat, even under moderate to severe moisture stress, was to plant fodder cereal (oats, ryecorn, forage barley, or triticale), followed by brassica short rotation ryegrass, permanent pasture or other small-seeded crops. Old browntop turf benefited from prior light and shallow cultivation with a light spring tyne cultivator or a double pass with the drill, often used together with a double (autumn and spring) spray regime combined with utilizing the field as a winter runoff – sacrifice area.

A surprising number of farmers throughout the survey area were, without any spraying, using the drill, to "stitch" new grass into old or grass grub affected pasture, gateways, races and areas where stock had camped, with considerable success. In the High Country, forage cereals, pasture grasses, legumes and herbs had been direct drilled into thousands of hectares with exceptionally good results where fertilizer was also used at the time of sowing (generally around 120 to 150 kg/ha of DAP – sometimes up to 250 kg/ha).

End-tow options for the drills had wider application than first anticipated on the 3 m as well as the 3.6 m wide model; for road transport behind tractors and pick-ups, to get through narrow gates, along narrow tracks, and over narrow bridges. End-tow increased the appeal of the drill for group ownership, and for farmers with separate parcels of land connected by busy roads. Drills fitted with end-tow kits could be brought up to road-worthy standards, allowing drills with fixed axle end-tow kits to be towed legally on the road at speeds up to 40 km/h. Drills fitted with suspension kits could be towed legally at speeds up to 80 km/h behind light vehicles, and 90 km/h behind trucks having a mass vehicle weight rating of 8 or more tonnes. That is, of course, subject to the drill being registered and warranted, and the towing vehicle meeting required road safety standards.

When questioned about the quality of seed sown, most respondents reported that they were aware of the germination of the seed lot they sowed, but usually had no other seed quality information such as seed size (to calculate sowing rates), seed purity (were they sowing weed seeds), or seed vigour. Many of the crop establishment problems encountered following no-tillage or reduced tillage sowings are directly attributable to seed lots which have good germination but low seed vigour (Hill pers. comm. 2004) because the sowing environment can exert more stress on the seed than a conventional seed bed. It is important therefore that seed quality becomes an important part of this whole package for plant establishment, and as a component of the agronomic advice available to the farmer. For this to occur, information transfer among farmers and the industry must, in addition to the pros and cons of machinery and methods of establishment, focus on the correct use of quality seed, on an understanding of the environment around the seed and the impact this may have on performance, and the measures needed to combat the predations of insects and other pests. Insecticide boxes need to be fitted to drills since prills and granules tend to separate out in the seed.

Conclusions

The offset tyne has proved to be a useful intermediate level of technology. As one farmer put it: "The lower power requirement of this drilling system is notable. As fuel costs escalate, this advantage will increase. The environmental advantages of direct drilling are notable in our situation. These include (i) the elimination of soil erosion risk by wind in our windy climate, (ii) the rapid improvement of soil structure (and consequently water holding capacity), (iii) the consequent improvement in load bearing ability which is important for both machinery and especially dairy cows which are often run on our arable farms during the winter." However, further advances in this drill are possible, perhaps by fitting press wheels to avoid the need to roll separately, and also improving the flow of trash through the machine.

New Zealand has over the past 20 years, emerged as a major global exporter of intermediate and advanced no-tillage and reduced-tillage seeding equipment along with associated technologies. A major factor behind this success story has been the high degree of agro-ecological overlap between agricultural, horticultural and viticulture systems in New Zealand and many of those countries where these drills are now working. In many instances this overlap has been used as a common basis for crop and livestock improvement using New Zealand seed and seed drilling technologies. The use of demonstration areas and monitor farms in NZ and overseas has been important in the transfer of these technologies. Around these activities various informal user networks have emerged, involving plant breeders, seed scientists, agronomists and farmers working with drill designers and manufacturers This interaction has helped significantly with the development, refinement and promotion of a New Zealand seed drill and associated technologies, targeting local and international users. With increased levels of global participation and co-operation via the internet and otherwise, we predict that these new technologies will rapidly expand in the future, using small and medium scale multi-purpose seed drills built locally and internationally, suitable for arable, reduced tillage and no-tillage.

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