Planters and their Components

Types, attributes, functional requirements, classification and description

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Foreword

Sustainable improvement in the livelihoods of poor farmers in developing countries depends largely on the adoption of improved, resource-conserving cropping systems. These systems will often be based on methods involving zero tillage bed planting, but adaptation is usually needed to suit local soils, crops and conditions. It is vitally important that this technology, already used in many parts of the world, be adapted easily to the low-resource situation.

A major constraint to adoption of improved resource-conserving cropping systems in developing countries is the lack of simple planting equipment. While most of the necessary components already exist, information on the availability, attributes and performance of equipment is lacking and effective communication between scientists can be difficult.

ACIAR is publishing this compendium to help address the problem. The authors combined the extensive planting equipment experience of Mr J R Murray from the School of Agriculture and Horticulture at the University of Queensland with the machinery systems knowledge of Dr J N Tullberg and the database skills of Dr B B Basnet.

An immediate obstacle to developing the manual was the absence of adequate, comprehensive and uniform terminology to describe both planting machines and their components. For example, all machines used for crop establishment from seed are referred to here as ‘planters’, although in some parts of the English-speaking world they are usually referred to as ‘seeders’ or ‘drills’. Machinery component terminology is even more complex, with many of the terms used meaning totally different things to different people, even within the same country. The inclusion of pictures helps solve this problem.

This manual provides a valuable reference for research and extension personnel engaged in the selection, adaptation and/or construction of complete planters appropriate to specific soil, crop, climate and residue conditions.

The manual may also be freely downloaded at www.aciar.gov.au.

Peter Core
Director
Australian Centre for International Agricultural Research

Acknowledgments

Many people have been involved in the lengthy process of initiating, encouraging, funding and executing this work. It started from a group discussion at the 2000 ISTRO conference in Fort Worth, Texas, and the subsequent formation of an ISTRO working group on the development of zero tillage bed planting equipment for lower resource areas. This involved about 20 scientists and engineers with major encouragement for a comprehensive database on planting machinery coming from Dr John Morrison (ISTRO president) and both Dr Ken Sayre and Mr Peter Hobbs of CIMMYT.

Dr Tony Fischer of ACIAR was similarly enthusiastic and arranged funding to support the work, which is closely aligned with an ACIAR objective of facilitating the introduction of more productive and sustainable cropping systems to improve the livelihood of rural communities. Dr Christian Roth subsequently took over administrative responsibility for the project and has shown considerable fortitude in the face of ongoing delays in bringing it to completion.

Contributions by way of constructive comments from Dr Willem Hoogmoed (Wageningen Agricultural University, the Netherlands) on the structure and from Dr Jack Desboilles (University of South Australia) on the content of this book are acknowledged.

A major aspect of this work was the capture, editing and enhancing of photographs to support the identification and classification of planter components. The authors acknowledge the significant assistance provided by Heather Murray (Lockyer Catchment Centre) in this regard.

The authors hope that this work makes a useful contribution to the ultimate purpose of facilitating discussion on, and the development of, improved planting equipment, particularly for more sustainable and productive cropping in low resource areas.

SECTION 1

Introduction

The planting operation is one of the most important cultural practices associated with crop production. Increases in crop yield, cropping reliability, cropping frequency and crop returns all depend on the uniform and timely establishment of optimum plant populations.

There are two broad areas in optimising plant establishment. First, plant breeders, seed growers and seed merchants have a responsibility to provide quality seed. Second, farm managers must be aware of the agronomic requirements for optimum plant establishment and be able to interpret this information in a meaningful way so as to assist with the selection, setting and management of all farm machinery, especially planters.

In this book, the agronomic requirements for plant establishment are reviewed and their implications for planter selection and management noted. On the basis of this information, the functional requirements of a complete planting machine are listed, with elaboration of the soil-engaging, depth control, seed metering and seed delivery components. The types of devices used to accomplish these functional requirements are then described and their relative attributes for crop establishment discussed. Throughout the book, the emphasis is on planter components for crop rather than pasture production.

SECTION 2

Crop establishment

2.1 Overview of crop establishment

In biological terms, crop establishment is the sequence of events that includes seed germination, seedling emergence and development to the stage where the seedlings could be expected to grow to maturity.

Establishment depends on the complex interaction – over time – of seed, soil, climatic, biotic, machinery and management factors (Wood, 1987).

Considering machinery and management (as inputs), climatic constraints (as risk) and the duration of establishment (as rapid or protracted), Gramshaw *et al* (1993) postulate a family of establishment probability curves for Australian crop and pasture production systems (Figure 1). This illustrates that the nature of planting system changes from 'low input – high risk – protracted establishment' to 'high input – low risk – rapid establishment'. Extensive dryland (high risk) pasture establishment (protracted) using over-sowing without seedbed modification or seed treatment (low input) is near the origin (curve 1). Intensive, irrigated (low risk) crop establishment (rapid), using precision planters and water injection (high input) represents the other extremity (curve 6). The intermediate curves (curves 3 and 4) are typical of the establishment outcomes for dryland, broadacre sorghum and sunflower production in the major grain growing areas of Queensland, Australia (Radford and Nielsen, 1985).

The consequences of sub-optimal crop establishment on farm profitability include yield reductions, replanting costs, foregone sowing opportunities, reduced weed suppression, and the direct and indirect effects of secondary germinations (Blacket, 1987).

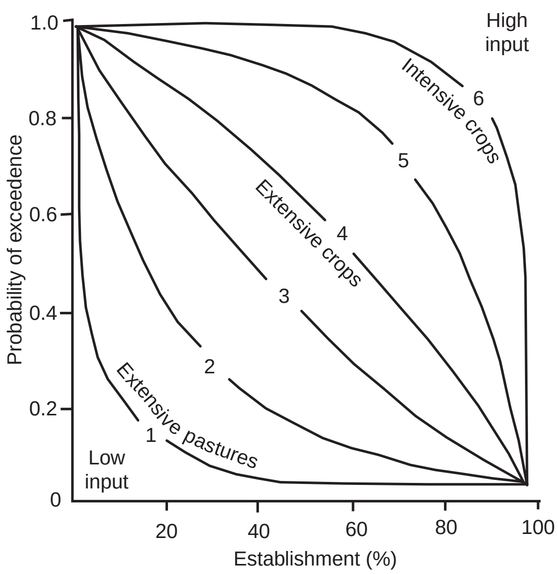

Figure 1: Generic family of probability curves for plant establishment (Source: Gramshaw et al., 1993)

The variables influencing plant establishment can be broadly grouped as:

- seed/species characteristics;
- the external physical, chemical and biotic environment; and
- management.

The environmental and management variables are closely interlinked. Many management actions (e.g. irrigation, fertiliser application, pesticide application, etc) modify the environment and some (e.g. harvest technique, seed storage method, pre-plant seed treatments, etc) may directly modify seed properties (Gramshaw *et al.*, 1993). The selection, setting and operation of planting machinery directly influence seedbed conditions and may modify seed properties through, for example, mechanical damage.

In crop production systems, establishment potential is primarily dependent on the conditions prevailing immediately prior to planting (essentially, the quality of the seed lot to be used and the seedbed environment as determined by the interaction of soil, climatic and biotic factors) and weather influences during the establishment period (Wood, 1987; Miller *et al.*, 1993). The planting machinery is usually critically important in crop establishment. Planting machines modify the pre-existing seed and soil conditions, and dictate seed placement within the seedbed. The pre-existing conditions can be improved or impaired as a result.

An essential requirement of effective machinery management is to identify the main components of these machine-soil-seed interactions. By understanding these relationships, those responsible for the planting operation can select, set and operate the machines to best meet the agronomic requirements for establishment (Tessier *et al*., 1991a).

The following section discusses the agronomic requirements for crop establishment. The purpose is not to make an exhaustive study but rather to identify the principal machine-seed/soil interactions so as to provide a basis to:

- identify the functional/operational requirements of planting machinery;
- select machine components in relation to cropping system requirements; and
- set and manage planting machines.

2.2 The agronomic requirements for crop establishment

Establishment involves a continuum of phases and processes. In the broadest sense, the continuum starts with seed production and ends when the next generation is established (Gramshaw *et al*., 1993). Dividing the continuum into the distinct phases of germination, emergence and establishment over-simplifies the establishment process. It is done here partly because germination and emergence are readily identifiable points in the continuum and partly for convenience of discussion. A limitation of this approach is that seed factors, in particular, exert a major influence over all phases (Fenner, 1992).

2.2.1 Agronomic requirements for germination

Germination is the stage of seedling development when active growth first becomes evident. The germination process begins with the uptake of water by the seed (imbibition) and culminates with the start of elongation of the embryonic axis, usually the radical (Bewley and Black, 1982). In practice, a seed is considered to have germinated when the radical has emerged 2–3 mm from the testa (Wood, 1987). Seeds initially absorb water by a physical process and, while oxygen demand increases towards the latter stages of the germination phase, no soil-derived nutrients are required (Collis-George, 1987). Both germination and the rate of water uptake are temperature dependent. The major agronomic requirements for germination can be grouped as either seed factors or as environmental factors influencing water and oxygen availability and temperature.

Seed factors

Seed quality and pre-sowing seed treatments are the major seed factors influencing germination.

Seed quality

Purity, viability, vigour and health are the four facets determining seed quality for planting (Brocklehurst, 1985). Purity, the proportion by weight of intact seeds of the species to be planted, (Perry, 1982) and seed health, the freedom from pests and disease, (Brocklehurst, 1985) have obvious effects on germination. In addition to a potential reduction in viability, damaged seed is more likely to be invaded by pathogens while in storage or in the field because one of the important barriers to infection – the seed coat – is not intact (Murray *et al*., 1987). Cracked testae can reduce germination because of the leakage of electrolytes from the seed during imbibition (Brocklehurst, 1985).

Viability is a measure of the percentage of seeds in the seed lot that are capable of producing normal seedlings under optimum conditions. Viability is quantified by a standard germination test conducted under laboratory conditions. However, there is often a poor correlation between germination test results and subsequent field performance. Heslehurst and McDonald (1987) conclude that germination tests could provide a good basis for legislation in the seed trade, but their role in production agriculture is largely restricted to assessing whether or not a seed lot is worth sowing.

Seed vigour is defined as the sum total of those seed properties that determine the potential level of activity and performance of the seed or seed lot during germination and seedling emergence (Perry, 1992). Vigour testing provides information that can be used to help manage seed lots in storage and under specific sowing conditions (Heslehurst and McDonald, 1987). Research has shown that seed vigour is influenced by a myriad of factors, including the planting date of the parent plant, the environmental conditions during seed development, harvest date, harvest technique, seed storage conditions, age of the seed and pre-sowing seed treatments (Brocklehurst, 1985; Perry, 1982; Adam *et al*., 1989). While predictive vigour tests are still being developed, seed size is known to have an important influence on seed vigour (Brennan and Henry, 1987).

Most species show considerable variation in seed size and shape and many studies have shown that the larger seeds exhibit marked establishment advantages. The reviews of Benjamin (1990) and Fenner (1992) show that, within species, larger seeds tend to produce bigger, more competitive seedlings that emerge earlier, establish faster and often produce more seed at maturity. Large seeds have enhanced likelihood of emergence because of their ability to successfully establish from a greater sowing depth.

Pre-sowing seed treatments

A diverse range of pre-sowing seed treatments are used to remove several soil, climatic and hydrological constraints. Physiological treatments that improve or enhance seed performance are based primarily on seed hydration, with or without the addition of chemicals. Non-physiological treatments can remove mechanical, soil and environmental constraints and they directly or indirectly improve seed germination and plant establishment. Such treatments include seed scarification, pelleting and treatment with bioactive chemicals (Khan, 1992). In all cases, these treatments aim to mobilise the seeds' own resources or to augment them with external resources to maximise establishment outcomes.

As a group, these seed and seed-related factors dictate the potential for, and influence the rate of, germination. As environmental conditions for germination deteriorate, the rate of germination has a significant influence on the final outcome because the intervention of pests, diseases and, in many situations, low moisture availability are all time dependent.

Environmental factors

For successful germination the microenvironment around the seed must provide a suitable temperature regime and adequate supplies of both water and oxygen. Light is a requirement for germination in only a few plant species (Unger and Stewart, 1976).

The seed must imbibe water at a sufficient rate to reach critical water content before other environmental stresses, such as soil drying or insect/disease infestation, affect the germination process (So, 1987).

The oxygen requirement for germination varies among plant species. Those with a low surface-to-volume ratio (e.g. peas) are the most susceptible to low concentrations (Unger and Stewart, 1976; Cannell and Jackson, 1981). Initially, the oxygen requirements are low and can be supplied from air retained in the seed tissue or the soil, even under waterlogged conditions. Just prior to germination the respiration rate increases and any oxygen in the soil is quickly consumed. If adequate supplies are not replenished by diffusion, through pores connected to the soil surface, the emerging embryo or radicle will die. Nevertheless, most seedbed conditions provide adequate oxygen concentrations for rapid germination. Exceptions would include very dense or waterlogged seedbeds or seedbeds with wet surface crusts (So, 1987; Collis-George, 1987; Unger and Stewart, 1976).

The rate and duration of moisture supply to the seed are of prime importance to successful germination. The rate of supply depends on seed and soil factors as well as soil moisture content. Essentially, the rate of supply to the seed increases with increasing soil moisture content but depends on the moisture characteristic for the specific soil, i.e. the relationship between moisture content and moisture potential (Unger *et al*., 1981). Soil density has important implications for moisture transfer in the soil. In saturated conditions, conductivity is higher at lower bulk densities due to the larger pore spaces available but, as the soil becomes unsaturated, the conductivity becomes dependent on the number of contact points between soil particles. On this basis, So (1987) concludes that, for a particular soil type and physical condition, there is an optimum soil density that will best service the seed's requirement over the range of soil moisture expected in the field. The rate of water movement into the seed depends on factors such as its internal moisture potential (relative to that of the soil), the permeability of the seed coat and the surface area of the seed that is in contact with the soil. While the effect of seed/soil contact is still unresolved (So, 1987; Rogers and Dubetz, 1979), it is generally agreed that the transport of moisture to the seed in the liquid, rather than vapour, form is more rapid (Collis-George, 1987).

The duration of water availability to the seed will depend on the soil's initial water content in the seed zone and subsequent changes due to infiltration or drying. There are a range of strategies to extend the availability of moisture to the seed and so improve the prospects for germination, emergence and establishment. For example, reducing soil disturbance at time of planting reduces the potential for moisture loss in the seed zone. First, disturbance tends to mix the drier surface layers into the seed zone. Second, wet soil deposited on the soil surface dries rapidly due to a reduction in drying constraints. Third, disturbance reduces the bulk density of the seedbed. At low densities, i.e. loose or cloddy soil, the large surface results in high evaporative losses, but the upward flow from the underlying layers is limited by the low conductivity associated with low bulk density. When seeds are sown at a depth that corresponds to the interface between the area of high evaporative loss and the area of low conductivity, they will have limited water availability (Hayes, 1985; Wilkins *et al*., 1981).

Residue mulches have the potential to increase infiltration and reduce evaporative losses. Their effects on both improving germination and establishment and prolonging the available planting time after an effective rainfall are well documented (Hayes, 1985; Radford and Nielsen, 1983a; Unger and Stewart, 1976; Martin and Felton, 1983). Planting techniques that enable seeds to be planted deeper in the seedbed while maintaining optimum depth of cover have also demonstrated advantages (Ferraris, 1992). The moisture content is usually greater at depth and planting deeper in the bed insulates the seed from the adverse effects of drying. Planting deeper and optimising soil density in the seed zone also improves seed/soil contact and aids in the transfer of moisture to the seed (Ferraris, 1992).

Soil temperature is a significant factor influencing all phases of crop establishment. In the broadest sense, temperature dictates crop suitability to a particular geographic region and the planting period within that region. More specifically, all stages of crop growth have a well-defined minimum, optimum and maximum temperature range for growth and development. The usual responses are an approximately linear increase in rate with increasing temperature from a threshold to a maximum, with or without a plateau, followed by a linear decline (Benjamin, 1990). During the initial stages of imbibition, the uptake of water is temperature dependent, as is the initiation of shoot and root growth (Collis-George, 1987). Temperature strongly influences the transformation of nutrients in the soil and the subsequent uptake and assimilation in the plant.

Surface mulches, tillage, irrigation, etc, form the basis of management strategies to modify soil temperature.

In practice, greater diurnal variation occurs at shallow depths and the mean temperature at depth lags behind mean surface temperature. Temperature fluctuations may be a requirement for germination in some pasture species, but have little influence on most cultivated species within the minimum/maximum acceptable range (Benjamin, 1990).

Soil strength and the presence of toxic substances in the soil can have detrimental effects on germination. For example, in soils with high bulk density in the immediate seed zone, soil strength may restrict seed expansion during the imbibition stage and reduce the rate of germination (So, 1987).

Fertiliser placed close to the germinating seed can retard the rate of germination or even kill the seedling. The main factors influencing fertiliser toxicity are the type and rate of fertiliser, proximity to the seed, soil moisture level, soil texture and the seed species (Carter, 1969; Cook and Scott, 1987).

Leachates from decomposing crop residues can also be toxic to plant growth. This phytotoxicity appears to occur when residues decompose on the soil surface close to the seed or growing seedling. Wheat sown through cereal residue is particularly susceptible. Uniform spreading of residues over the soil surface or displacement of residue away from the seeded row are sometimes recommended to reduce the adverse effects (Elliott *et al*., 1978).

Implications for planter performance

The implications of the agronomic requirements for germination on aspects of planter performance are discussed below.

Seed factors

Seed quality has major implications for seed metering devices. Substantial increases in planting rate to compensate for low seed viability can impair the performance of seed meters, particularly precision seed metering devices (Norris, 1982; Halderson, 1983; Agness and Luth, 1975).

Variations in seed size and shape can also influence planter performance. Some precision seed metering systems (e.g. plate type) require uniformity in both size and shape for optimum performance; others (e.g. vacuum disc type meters) will tolerate a range of seed size and shape without a significant reduction in metering performance (Heyns, 1989; Zulin *et al*., 1991). Large and/or fragile seeds may be more easily damaged by seed metering devices. For example, Fenner (1992), discussing the advantages of large seed with respect to vigour, etc, reports that the largest 10% of bean seeds often suffer mechanical damage so the mid 80% are the most productive. Evaluating rotary cone, inclined plate, vacuum disc and finger pick-up metering systems for peanut production, Norris (1982) concluded that:

- seed damage increases with meter speed and/or seed size;
- seed meter performance is reduced as meter speed and/or seed size increases; and
- the maximum recommended operating speed of vacuum and finger pick-up units severely limits operating speed when planting large seeds, such as peanuts, at the recommended spacing.

Pre-sowing seed treatments can improve or impair seed metering performance. Pelleting small or light seed to increase their size or weight can improve performance and is particularly useful for precision planting (Scott, 1989). Pre-sowing treatments can be used to improve the seed metering performance when planting ‘chaffy’ seeds (Lock, 1993). However, pre-soaking seed before planting may impair metering performance if the seeds tend to cling together or become more susceptible to mechanical damage (Radford, 1983b). Some material used in seed treatment may directly reduce the performance of seed metering units. For example, residue accumulation in the holes or cells of the metering plates or discs may increase friction, accelerate wear or simply reduce the efficiency of seed selection/pick-up.

Environmental factors

Planter soil-engaging components have a major influence on optimising environmental factors for germination. The discussion here is restricted to the influence of planter components on the soil immediately adjacent to the seed.

To optimise moisture availability to the germinating seed, the planter must open a furrow, place the seed in the furrow, cover the seed and firm the seedbed. Opening a furrow enables the seed to be planted at a depth where moisture conditions are generally more favourable than those at the soil surface. It is of particular importance in regions where high evaporation rates after rainfall promote rapid drying of the surface layer (Maiti and Carrillo-Gutierrez, 1989). Covering the seed and firming the soil around it helps to stabilise temperature and moisture availability conditions, and protects the seed from predators such as birds and ants.

The degree of soil disturbance in the seed zone during the furrow opening process has a major influence on moisture availability to the germinating seed. The nature and degree of disturbance is largely a function of furrow opener design (Wilkins *et al.*, 1981). When crop establishment is the first priority, the degree of disturbance should be restricted to that necessary to obtain sufficient tilth to help cover the seed, ensure sufficient seed/soil contact, and, where necessary, ameliorate the growth-retarding effects of hard soil (McLeod *et al*., 1992; Mead *et al*., 1992; Payton *et al*., 1985). In general, smaller seeds require finer seedbed tilth for optimum germination and establishment (Hadas and Russo, 1974). Disturbance in excess of these requirements increases the potential for:

- moisture loss from the seed zone through increased evaporation (McLeod *et al*., 1992);
- mixing of wet and dry soil in the immediate seed zone (Wilkins *et al*., 1981); and
- reduction in water conductivity from lower in the profile (Hayes, 1985).

In deep, loose seedbeds, the opener can be selected so as to firm the base of the furrow, as this tends to confine seed to a narrower vertical band and improve the prospects for the upward movement of water from the subsoil.

Opener design should be such that:

- the seed is placed in or on the moist soil at the base of the furrow; and
- dry soil is not placed immediately on the top of the seed during the covering phase.

When planting through crop residues, the furrow opener and/or covering device should not incorporate residue in the seed furrow. The incorporation of residue in the furrow can reduce the degree of seed/soil contact (Unger and Stewart, 1976), interfere with the seed-covering process and increase the possibility of phytotoxic effects.

Seedbed firming devices should be selected and set so as to optimise soil density in the seed zone for seed/soil contact, the movement of water to the seed and the minimisation of net moisture loss from the seed zone (Hayes, 1985; Radford and Nielsen, 1985; Schaaf *et al*., 1981). Firming the seedbed can also reduce the incidence of insect damage (Murray *et al*., 1987) and prevent the seeds from being pushed out of the soil by the elongating radicle (Unger and Stewart, 1976).

Major disturbance to the seedbed occurs when full-width cultivation is needed for weed control at the time of planting. To avoid sowing the seed at the interface between the tilled and untilled layers, the tillage and planting functions should be separated by depth. The ground tools acting as furrow openers should be modified or set slightly deeper than those performing tillage only (Blacket, 1987). This ensures that the seed is placed below the tillage depth and in relatively undisturbed conditions. The general concept of separating tillage and seeding depth is illustrated in Figure 2.

From research to date, it would appear that opener design has little direct effect on temperature in the seed zone (Tessier *et al*., 1991a; Wilkins *et al*., 1981).

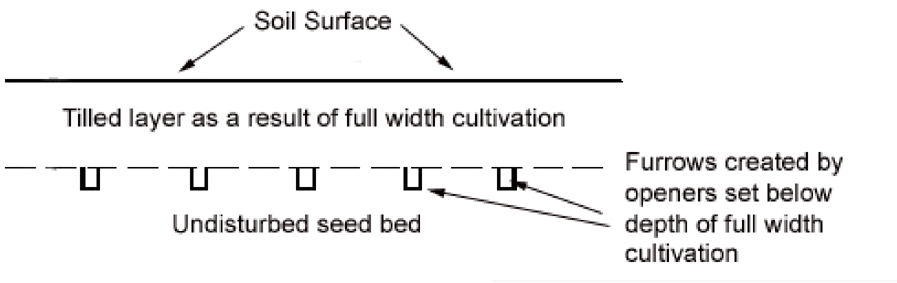

Figure 2: The concept of separating tillage and seeding functions

2.2.2 Agronomic requirements for emergence

Emergence, when the developing seedling emerges through the soil surface (Wood, 1987), is one of the most easily observed events in crop development (Benjamin, 1990). Between germination and emergence, the seed must contain enough stored mineral nutrients to sustain growth until the developing root system has made sufficient contact with the soil to take over the nutrient supply function. The seed must also contain enough stored carbon assimilates to sustain growth until the shoot has emerged and an effective photosynthetic area has been established (Asher, 1987).

Many of the agronomic requirements for germination continue to play an essential role in this and subsequent stages and are included in discussions below. The dominant features of this stage are root and shoot growth and development. Factors influencing the growth and movement of roots and shoots in soil adjacent to the seed zone become important, as do factors influencing nutrient supply to, and uptake by, the developing root system.

Root development/elongation

Radical and root development/elongation are subject to a similar range of limiting factors as germination. Even if temperatures are suitable and nutrients adequate (given the importance of seed reserves), there may be limitations as a result of inadequate supply of water and oxygen, excessive soil strength and the presence of toxic substances (So, 1987).

Soil structure is known to influence the size and shape of roots (Braunack and Dexter, 1989) but there are few correlations between crop performance and soil structure. This is because root systems do not respond to changes in bulk density or porosity unless they are associated with changes in water content, air content, soil temperature or root impedance (Brown, 1970; Braunack and Dexter, 1989).

Once germination is completed, the pattern of water use changes. The moisture potential of the seed has approached that of the adjacent soil and the rate of imbibition has reduced (Asher, 1987). The water required for shoot and root growth is now largely obtained via the seminal, and subsequently nodal, roots. As the demand for water and nutrients increases, the roots have to explore new soil. To move in the soil, the roots exploit existing soil pores of suitable size or create new pores by overcoming soil strength as the growing tip moves forward. In general, under all but favourable conditions, the survival of the developing seedling depends on root elongation proceeding faster down the soil profile than the drying front. Soil properties known to restrict root growth include mechanical resistance, coarse dry layers, inadequate aeration and extreme acidity (Heinonen, 1985). Under field conditions, mechanical impedance or a dry layer of soil are the more common restrictions to root growth. Mechanical resistance, or soil strength, increases with bulk density and this increase is more rapid at lower water contents. Therefore, decreasing water content in the soil affects root growth indirectly, largely through the effect of increased soil strength (So, 1987). The incidence of high soil strength and dry soil layers has significant implications for the selection and management of planting machinery.

Shoot development and emergence

Elongation of the shoot towards the soil surface is subject to limitations similar to those for root elongation. Shoots are, however, more sensitive to soil mechanical resistance (So, 1987) so depth of planting and soil strength are major factors affecting both the rate of emergence and the final emergence percentage.

Until the seedling has emerged and developed an effective photosynthetic system, growth depends on seed reserves. If planted too deep, the seed reserves are depleted before emergence can occur and the seedling dies. Further, as the length of the developing shoot has to increase with the depth of planting, the combined effects of a reduced cross-sectional area and the increased tendency to buckle, reduce the effective axial force the seedling can exert. Limited by both energy reserves and the reduced capacity to exert axial force, seeds planted at depth have little chance of emergence through high strength soil surface layers.

The ability of seeds to emerge from depth and/or of seedlings to penetrate high strength soil layers is somewhat dependent on the type of organs present in the embryo. Emergence results from either coleoptile or mesocotyl elongation in the monocotyledonous species or by epicotyl or hypocotyl elongation in dicotyledonous species (Brennan and Henry, 1987).

The post-germinal processes in, for example, barley and wheat involve the extension to the surface of the coleoptile, the protective cover over the first leaf. If the coleoptile fails to reach the surface before splitting, to allow leaf emergence, the prospects of emergence are small because the leaf has little ability to penetrate soil. Coleoptile length is genetically controlled and is correlated to established plant height (Brennan and Henry, 1987). Emergence failure with short wheat varieties has been widely reported and attributed in many cases to excessive planting depth (Blacket, 1987; Radford, 1982; Riethmuller, 1990).

In sorghum, the coleoptile is less well developed and extension of the mesocotyl is the important emergence method. Sorghum genotypes show a large variation in mesocotyl length and therefore their ability to emerge from greater planting depths (Maiti and Carrillo-Gutierrez, 1989). Further, mesocotyl elongation is sensitive to soil temperature, a reduction in length occurring at higher temperatures. Higher seedbed temperatures can therefore influence final emergence percentage, particularly in the case of deeper plantings (Brennan and Henry, 1987).

In dicotyledonous species, the developing seedling reaches the surface through elongation of either the epicotyl (hypogeal emergence) or the hypocotyl (epigeal emergence). In the former, the cotyledons remain below the surface and in the latter, they are pushed through the soil surface during emergence. Pushing the cotyledons through the surface of higher strength soils is difficult for the establishing seedling and is a recognised limitation to the establishment of crops such as soybean (Brennan and Henry, 1987).

Loose soil over the seed can, by virtue of light penetration, promote sub-surface leaf emergence (Blacket, 1987). Once the coleoptile splits and the leaves are exposed, emergence failure is common because of the inability of the leaves to exert sufficient force to penetrate the surface layer.

Particular problems arise where soils have a tendency towards hard-setting or surface crusting.

Hard-setting is a condition associated with soils with high silt and fine sand fractions and low organic matter (So, 1987). Aggregation is weak and, on wetting, these soils tend to slake or disperse, the fine particles filling the pore spaces between bigger aggregates to form a dense matrix. On drying, the surface quickly develops high strength and this impedes or restricts emergence and subsequent infiltration.

Crusting is a similar condition generally resulting from aggregate breakdown due to raindrop impact. On drying, a hard, thin crust develops on the soil surface.

When hard-setting and crusting conditions set in before emergence, poor plant stands usually result (Awadhwal and Thierstein, 1985; So, 1987). A stratified seedbed with finer aggregates in the seed zone covered by coarser aggregates near the soil surface reduces both the drying rate and the hazards of surface crusts (Awadhwal and Thierstein, 1985).

Implications for planter performance

For rapid and successful germination, planting depth and soil conditions in the immediate seed zone need to be optimised, primarily to ensure moisture availability to the seed. While moisture availability remains crucial during the establishment phase, planting depth and soil conditions are important factors for root elongation and shoot emergence. The implications of these aspects for planter performance are discussed below.

Control of planting depth

Planting depth is a major determinant of seedling emergence and hence one of the most important operational requirements of a planting machine (Rainbow *et al.*, 1992). Inadequate depth control accuracy is recognised by farmers (McGahan and Robotham, 1992) and researchers (Riethmuller, 1990) as a major deficiency of current broadacre planting machines. Providing planting machines capable of maintaining uniform depth under field conditions is a major challenge for equipment designers (Thomas, 1984; Janke and Erbach, 1985), particularly under direct drilling conditions because of the greater surface roughness and variability of soil structure and residue levels (Baker, 1977; Morrison and Gerik, 1985).

Optimum planting depth has two essential components: the depth of the furrow relative to the original soil surface and the depth of soil covering the seed. The depth from the original soil surface has implications for the level and likely duration of moisture availability to the seed. The depth of soil cover over the seed has implications for emergence. When there is adequate moisture in the surface layer, furrow depth can be set to optimise depth of cover for emergence. However, when it is necessary to plant deeper to ensure seed is placed in moist soil the resultant depth of cover can limit emergence. A number of techniques can be used to resolve this conflict. For example, soil in excess of that required to optimise depth of cover can be moved into the inter-row space by a suitable device preceding the opener. Figure 3 shows the general concept of this approach.

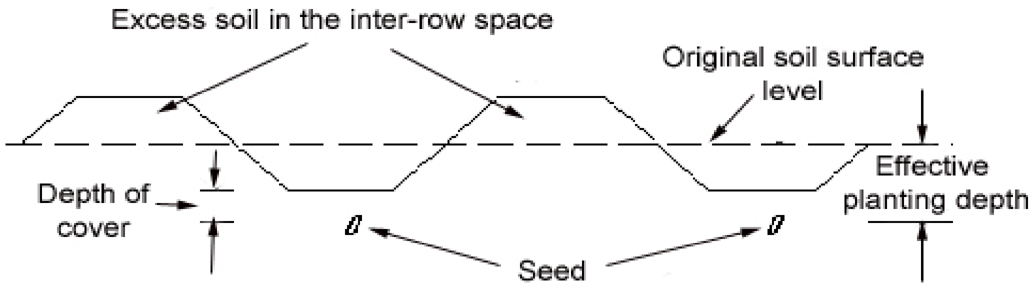

Figure 3: Alteration of soil surface profile to facilitate planting deeper to moisture

When a crop is to be planted on raised beds or ridges the ability to effectively remove dry surface layers is enhanced because the excess soil can be placed into the inter-bed or inter-ridge space. Conversely, under cold or wet conditions the ridges tend to warm up and dry earlier than would be the case with flat land planting and planting can proceed earlier than otherwise possible (Hayes, 1985).

Press wheels can also be used to modify the depth of cover in addition to firming the seedbed, particularly where full-width cultivation for weed control is performed at time of planting. Under these conditions, the press wheels substantially reduce the depth of cover and give a higher degree of uniformity in the depth of cover (Blacket, 1987; Rainbow *et al.*, 1992; Ward, 1987). The depression over the seeded row as a result of press wheel action can have an additional advantage. Where there is low-intensity, short-duration rainfall after planting, the surface profile tends to concentrate runoff in the depression immediately above the seeded row and improve the moisture status around the emerging seedling (Blacket, 1987; Ward, 1987). Where more significant rainfall events occur, the concentration of moisture above the seeded row may kill seedlings as a result of waterlogged conditions. Further, if soil is moved into the depression as a consequence of side-wall slumping or erosion, the resulting depth of cover may restrict emergence (Rainbow *et al*., 1992).

Where full-width cultivation is practised or where close row spacings are required at planting, the interaction of soil displacement between adjacent openers can cause uneven depth of cover between adjacent rows. On a multi-bar machine, soil movement from adjacent openers on subsequent bars can influence the depth of cover over the seed sown by openers on preceding bars (Slattery and Rainbow, 1992). The use of narrow openers to reduce sideways movement of soil is one solution. Where the average planting depth and the optimum depth of cover are similar, re-levelling the seedbed surface after seed placement is another solution (Palmer *et al*., 1988).

An additional confounding factor is the differing ability of opener designs to place seed in a defined zone relative to the base of the furrow created (Wiedemann *et al.,* 1971; Rainbow *et al*., 1992; Choudhary *et al*., 1985). Seed displacement or vertical scatter about the mean depth results from the shape of the furrow created and the design of the seed delivery/placement system (Agness and Luth, 1975; Norris, 1978; Norris and Ryan, 1983).

Soil conditions

The furrow opener modifies conditions in the seedbed. The aim of opener design and selection is to ensure these modifications improve, rather than impair, conditions for emergence. In most cases, this is achieved by ensuring disturbance to the seedbed is kept to a minimum.

In firm seedbeds, the opener should be selected so as not to compact the base or walls of the furrow to the extent that root extension into the adjacent soil is restricted. In wet seedbeds, particularly in soils with high clay content, smearing of the base and walls of the furrow should be avoided. Smeared layers tend to dry quickly and form a thin layer of high strength. In extreme cases the roots of establishing plants are largely confined to soil within the bounds of the furrow (Choudhary and Baker, 1981). Without follow-up rainfall to reduce the strength of the smeared layers the prospects for plant establishment are poor.

Over-compaction of the soil covering the seed can restrict emergence (Schaaf, *et al*., 1981), particularly where the surface layer has a tendency to set hard on drying. Press wheel design and setting, in relation to the shape of the furrow and to seed and soil type, are the major factors influencing optimum soil conditions above the seed (Ward and Norris, 1982). To obtain the maximum benefit from press wheels it is important that the wheels track the planted row (Morrison and Abrams, 1978) and have a cross-sectional profile compatible with the furrow shape created by the opener.

Where rainfall immediately after sowing causes hard-setting of the surface layer, management techniques, such as a shallow harrow operation, can minimise the effects on emergence (So, 1987).

2.2.3 Agronomic requirements for establishment

During the establishment phase the seedling becomes independent of seed reserves. A seedling's survival now largely depends on its ability to adapt to changes in its above- and below-ground environment and to compete with other plants for water, nutrients and light. The effects of prior land preparation methods can have a substantial influence on this stage of development. For example, the effects of compacted layers, induced by tillage or traffic, below the seed zone can restrict root growth and moisture movement. Soil nutrient status is dependent on fertiliser applications and previous cropping history.

Plant competition

Competition between plants for water, nutrient and light resources has important implications for establishment. In his review, Benjamin (1990) concluded that the spread in time for seedling emergence accounts for a major portion of the variation in mature plant weight because differences in emergence time have a large effect on seedling size at the point where plants start to compete for growth resources. Time of seedling emergence has the largest effect when the spread is large, the seedlings have a high relative growth rate, the plant density is high and growth to harvest time is short.

Plant population and spacing requirements

The plant population (i.e. the number of established plants/ha) influences the degree to which competition influences crop establishment. In practice, the needs of the individual plants have to be balanced against the requirement to maximise crop yield (Wollin *et al*., 1987). Agronomic trials have shown that the yield potential of many crop species is dependent on both the established population and the uniformity of spacing of plants within that population.

Many factors have to be considered when determining the optimum population and the spacing (i.e. the distance between rows of plants and the spacing of plants within a row) for a particular crop. The factors affecting potential yield include climatic conditions, time of planting, soil type and soil moisture status. Other factors to be considered relate to the ease of performing cultural practices. For example, row spacing may affect the ease of inter-row cultivation and harvesting. Populations and row spacing may affect weed growth and control, the degree of crop lodging, the size of the seed heads, etc, all of which may have implications for crop growth, yield and harvest. In crops such as cotton and sugar cane, the row spacing may be dictated by the design of the harvest machinery available.

With some crops (usually uniculm types, e.g. sunflower and maize), there is a comparatively narrow range of plant populations from which optimum yields could be expected, given the particular climate, soil type, soil moisture, etc, conditions. For other crops (particularly those that have the ability to tiller, e.g. wheat, barley, oats) there appears to be a wider range of populations over which potential yield does not vary appreciably; the principal requirement from a yield point of view is for a population greater than the minimum value required for the particular conditions.

Spacing of plants, within and between rows, can be important. Many crops can tolerate reasonable variations in the uniformity of plant spacing without a loss in yield potential, provided the overall population is within the required range. With some crops, however, e.g. sunflower, sorghum and most horticultural crops, the yield potential can be improved with uniformity of plant spacing within the optimum population range.

Particular combinations of populations, spacing requirements and placement methods give rise to distinct planting patterns. The range of possible planting patterns used to describe the spatial orientation and placement of seeds planted in the field are briefly discussed blow. They include:

- broadcast planting;
- drill planting;
- precision drill planting;
- hill drop planting;
- check row planting; and
- dibble/punch planting.

Broadcast planting

The pattern resulting from the random scattering of seeds on the soil surface (Figure 4).

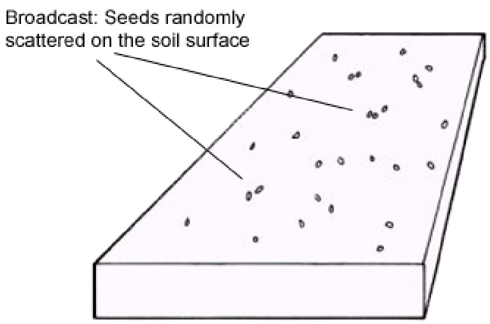

Figure 4: The 'broadcast' planting pattern

Drill planting

The pattern resulting from the random dropping (and subsequent covering) of seeds in furrows to give definite rows of randomly spaced plants (Figure 5).

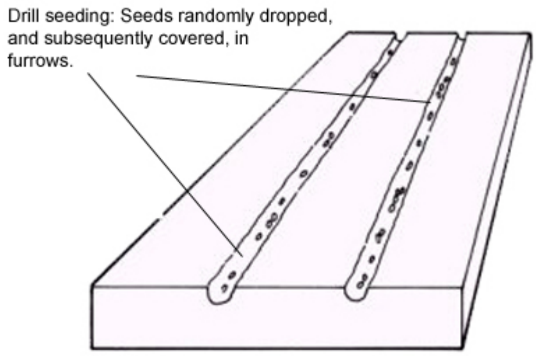

Figure 5: The 'drill' planting pattern

Precision drill planting

The pattern resulting from the accurate placement (and subsequent covering) of single seeds in furrows at about equal intervals to give definite rows of almost equally spaced single plants (Figure 6).

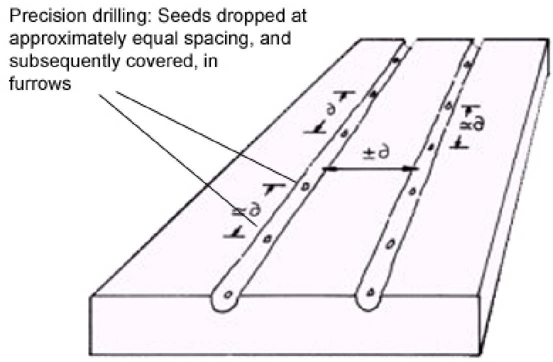

Figure 6: The 'precision drill' planting pattern

Hill drop planting

The pattern resulting from the accurate placement (and subsequent covering) of groups (or hills) of seed in furrows at about equal intervals to give definite rows of almost equally spaced groups of plants (Figure 7).

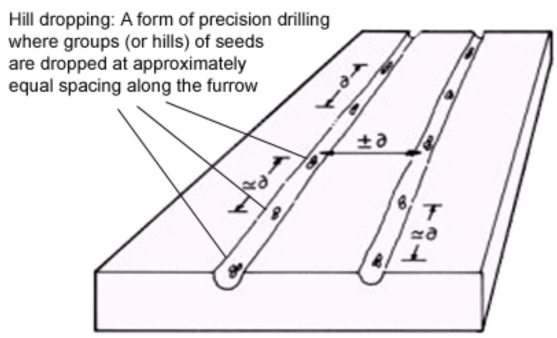

Figure 7: The 'hill drop' planting pattern

Check row planting

The square-grid planting pattern resulting from the accurate and indexed placement (and subsequent covering of seed) of individual seeds or groups of seed. Individual plants, or groups of plants, are spaced equidistant apart and aligned in perpendicular rows (Figure 8).

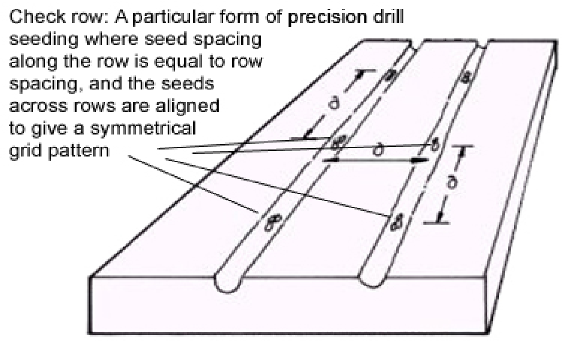

Figure 8: The 'check row' planting pattern

Dibble or punch planting

The pattern resulting from placing single or multiple seeds in individual holes that have been 'punched' or otherwise dug in the seedbed. As Figure 9 shows, the holes are usually aligned to form rows of established plants. Nevertheless, when hand, rather than machine, planting methods are used the holes may be randomly placed over the seedbed surface.

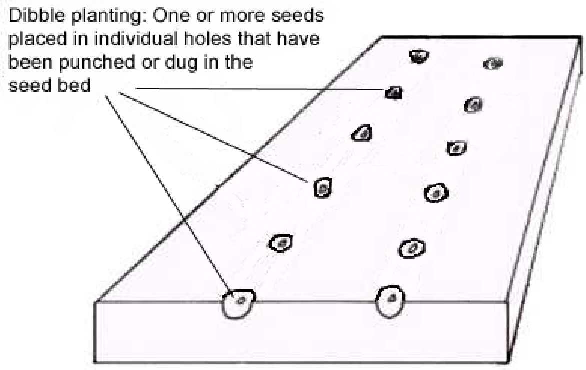

Figure 9: The 'dibble' planting pattern

The need for hill drop and check row planting patterns has diminished over time as a result of improvements in plant breeding, seed harvest and storage techniques, etc. While drill and precision drilling patterns are extensively used, considerable research and development is being directed towards the improvement of dibble or punch planting techniques. In general, this aims to exploit the potential residue-handling benefits that may be gained from punching holes, rather than digging continuous furrows, to enable seed placement within the seedbed.

Where the inter-row space is sufficient to allow cultural practices such as inter-row cultivation, side dressing of fertiliser, etc, the overall system of planting is generally referred to as 'row crop' planting. Where the rows are not this wide, the system of planting is generally referred to as 'solid' planting. Solid-planted crop stands generally result from the use of mass flow seed metering devices that give rise to the 'broadcast' and 'drill' planting patterns. Row crop stands generally result from precision seed metering devices that give rise to 'precision drill', 'hill drop' or 'check row' planting patterns.

The implications of these establishment parameters on planter design and performance are briefly discussed below.

Implications for planter performance

The major implications resulting from plant competition, plant population and plant spacing on planter performance are related to the ability of the machine to meet the inter- and intra-row spacing requirements for establishment.

Inter-row spacing requirements

Inter-row spacing depends on the effective spacing between furrow openers and the horizontal spread of seed within the furrow. Furrow shape and the design of the seed placement components are the major variables. To enable the planter to sow a range of crops it is desirable that row spacing can be adjusted. On wide drill planting machines this is usually accomplished by altering row spacing as a multiple of the overall opener spacing, e.g. blanking off the seed flow to every second opener across the width of the machine effectively doubles the row spacing. On precision type planters, the spacing of the individual openers can usually be adjusted by sliding and repositioning the furrow openers on the toolbar/frame.

Intra-row spacing requirements

Intra-row spacing is a function of the planter's seed meter, seed delivery system and seed placement device.

The seed meter selects seeds from the seed lot and discharges them at a predetermined rate (output) and spacing (accuracy). As previously discussed; the type of seed meter, the quality of the seed lot and the rate of seed metering all influence the actual metering rate and accuracy.

The function of the seed delivery tube is to convey the seed to the opener/placement device, while maintaining as much metering accuracy as possible. The length, cross-sectional shape and area, material of construction and rigidity of the delivery tube all influence the degree to which metering accuracy is maintained (Norris, 1978).

Finally, the seed placement components should place the seed on moist soil at the base of the furrow with minimum bounce/displacement so as to maintain metering and delivery accuracy.

As previously discussed, the design of the furrow opener, the soil type and condition and the speed of operation all influence the accuracy of seed placement.

2.3 Planter functional requirements for crop establishment

To successfully establish crops over the range of conditions likely to exist at planting, a planter should be able to:

- open a furrow;
- meter the seed;
- deliver the seed to, and place the seed appropriately in, the furrow;
- cover the seed in the furrow;
- firm the seedbed; and
- perform other functions as required, e.g. weed control, apply crop chemicals, etc.

These functions must be performed at an acceptable forward speed and with a high degree of reliability. Not all planting machines are capable of performing, nor necessarily need to perform, all the functions. Nevertheless, the ability to perform all functions improves planter flexibility and crop establishment prospects, particularly when sub-optimal crop establishment conditions exist at the time of planting.

The functions performed by the planter's soil-engaging components and its seed metering and distribution system largely determine its overall performance under particular conditions. The types of devices used to perform these functions, together with their functional and operational requirements, are discussed below.

The planter functions undertaken by the soil-engaging components include those associated with 'opening the furrow' (i.e. residue cutting, row preparation and furrow opening devices), 'covering the seed' (i.e. seed firming and seed covering devices) and 'firming the seedbed' (i.e. row and non row specific seedbed firming and levelling devices). Planter functions undertaken by the seed metering and seed distribution components include those associated with 'metering the seed' (i.e. seed metering devices) and 'delivering the seed to the furrow' (i.e. seed distribution and/or seed delivery devices).

2.4 Planter classification and description

Equipment for planting crop and pasture seeds can be broadly classified on the basis of:

- the number of rows planted by one pass of the machine (if applicable);
- the nature of the power source used to propel the machine;
- the method of attaching the machine to the power source (if applicable); and
- the type of planter, based on the resultant planting pattern.

To fully describe the planter, additional machine-specific information is required about:

- soil-engaging components;
- furrow opener depth control mechanism;
- seed metering system; and
- seed delivery components.

To be meaningful, the method of classifying and describing planting machinery needs to be:

- consistent in the approach adopted;
- consistent in the terminology used; and
- readily understood by all with an interest in the area.

Both the classification of planters and the description of their major component parts are discussed in the following sections and proposed 'standard' classification and description keys presented.

Wherever possible the terminology is compatible with existing, related 'standard' information, such as the various standard documents by ASAE (2005).

SECTION 3

Planter classification

Planting machinery can be broadly classified on the basis of a combination, where applicable, of:

- the number of rows planted in one pass of the machine;
- the method of attachment to and the type of power source used to propel the machine; and
- the type of planting machine based on the resultant planting pattern.

These parameters are briefly discussed below and the section concludes with an example of each type.

3.1 Classification parameters

3.1.1 The number of rows planted

The number of rows planted/holes punched per pass of the machine is directly related to how many furrow openers it has. Machines can be classified as single row, five row, 40 row, etc, depending on the number of furrow openers. On multi-row machines, the furrow openers are typically uniformly spaced across the full width of the machine.

3.1.2 The method of attachment to, and the type of, power source

On the basis of the power source used to provide the draft (i.e. the horizontal component of the force required to propel the machine through the soil), planters can usually be classified as:

- human;
- animal; or
- tractor-powered.

Methods of attachment are those that typically see the planter pulled by, pushed by or carried and pulled by the power source.

Human-powered planters

Human-powered planters can typically be categorised as being either:

- hand-held/carried; or
- pulled or pushed.

Animal-powered planters

Animal-powered planters are typically categorised as:

- pulled.

Tractor-powered planters

Tractor-powered planters can generally be categorised as being:

- trailed;
- semi-mounted; or
- front/mid/rear mounted.

Trailed planters are attached to, and pulled by, the tractor's drawbar hitch point. The machine requires its own transport/depth control wheels to provide the additional support required.

Semi-mounted planters are those that are pivotally attached to the tractor's two lower three-point linkage points but also require transport (or depth) wheels positioned towards the rear of the machine's frame to provide additional support.

Mounted planters are attached to, and are capable of being fully supported by, the tractor. Typically, these machines are attached to the tractor via a three-point linkage system located in front of the tractor's front wheels, between the front and rear wheels or behind the rear wheels (front, mid or rear mounted respectively).

3.1.3 The type of planter

Planters can be broadly classified as being:

- broadcast;
- drill;
- precision;
- dibble; or
- specialised.

Broadcast planters

Broadcast planters randomly distribute seed on the soil surface. As the seeds are deposited on the soil surface (i.e. not in furrows created by a furrow opener) an additional operation (e.g. harrowing) may be needed to cover seed. The use of a broadcast fertiliser spreader to distribute seed on the soil surface is the most common example of the broadcast planter. This type of planter is useful for establishing small seeds, particularly those with light requirements for germination (such as some pasture grasses. Broadcast planter types are not generally appropriate for cash crops because of the obvious limitations to controlling or meeting agronomic requirements.

Drill planters

Drill planters randomly drop seeds in furrows to form definite rows of established plants. This type of planter uses a mass flow type seed meter and is extensively used for the establishment of both winter and summer crops where there is no need to place plants equidistant down the rows. For example, almost all cereal crops (oats, wheat, barley, etc) are planted by drill type planters. Reasonably accurate control over the planting rate per hectare can be attained. Drill type planters are often known as solid crop planters because of the narrow row spacing typically used.

Precision planters

Precision planters accurately place single seeds or groups of seed almost equidistant apart along a furrow. They are typically used to plant crops that require accurate control of plant population, and spacing between and along the rows. Crops in this category include almost all the horticultural crops and field crops such as sorghum, maize, sunflower, soybeans and cotton. Precision seed metering systems giving a precision drill, hill drop or check row planting pattern are used on this type of planting machine.

Many of the crops requiring the use of precision planters are grown in summer, are planted in wide rows and have individual seed boxes and associated seed meters for each row. Accordingly, precision planters are often referred to as summer crop planters, row crop planters or unit planters, respectively.

Dibble/punch planters

Dibble planters place a seed or a number of seeds in discrete holes, rather than furrows, dug in the seedbed. Typically, although not necessarily, the holes are equally spaced and aligned so as to form rows. Hand-operated dibble planters are commonly used to establish crops (particularly inter-crops) in small-scale, low-resource agricultural crop production systems. Tractor-mounted, dibble type planters are commonly used in horticulture to plant seeds into seedbeds covered with plastic mulch. To date, few commercial dibble planters have been available for large-scale production systems, particularly where there are crop residues on the seedbed surface at planting. Considerable research is being undertaken to develop such machines because of the potential benefits in improving the ability of planters to handle residue and reducing planter energy requirements.

Specialised planters

Specialised planters are those that do not plant seeds but rather whole plants (i.e. seedling transplanters), plant stems (e.g. sugar cane whole stick or set type planters) or tubers (e.g. potato planters), etc. While specialised planters have many components in common with those that plant seed they are not further discussed in this book.

3.2 Examples of planter classification

The examples of planting equipment shown below are based on the classification parameters described in the preceding section. For consistency, the approach used is to identify and state, where applicable, the number of rows planted, the method of attachment to the power source, the power source then the type of planter. Not all the parameters can always be clearly identified in a single photograph.

3.2.1 A broadcast planter

Figure 10: A hand-held, human-powered, broadcast planter

3.2.2 A drill planter

Figure 11: A 14-row, trailed, tractor-powered drill planter

3.2.3 A precision planter

Figure 12: A single-row, hand-pushed, human-powered, precision planter

3.2.4 A dibble planter

Figure 13: A single-row, hand-held, human-powered dibble planter

SECTION 4

Planter component parts

Planting machines can be considered as an assemblage of components, each designed to meet a particular function, e.g. open a furrow, meter the seed, deliver the seed to the furrow, close the furrow and firm the seedbed.

Planter components can be logically grouped by function into the following categories:

- soil-engaging components;
- furrow opener depth control components;
- seed metering components; and
- seed delivery components.

Identical components can perform different functions (e.g. a disc coulter can be used to cut residue, open a furrow or close a furrow). Further, a given component may be set to achieve different outcomes while performing a specific function (e.g. open a furrow, but able to be adjusted to give varying degrees of soil disturbance). The accurate and meaningful description of planter components requires knowledge of the specific component's:

- type;
- functional characteristics/requirements; and
- operational requirements.

In the following sections, individual planter components are identified and their functional and operational requirements discussed.

SECTION 5

Planter soil-engaging components

The functions performed by the soil-engaging components include opening the furrow, placing the seed, covering the furrow and firming the seedbed.

Where there are high levels of surface residue and relatively unprepared seedbeds, devices to cut or otherwise manipulate soil and residue (row preparation devices) may be required in addition to the furrow-opening device. Similarly, firming/re-levelling the seedbed after seed placement and covering may require the use of a non row specific (i.e. full width) device (such as harrows or rollers) in addition to a row specific firming device (such as press wheels). Soil-engaging components sometimes have several functions, e.g. a single disc coulter used as a furrow opener may also perform a residue and soil cutting function.

The full range of soil-engaging components available for use on planting equipment is classified under seven functional groups:

- Group 1 Soil and residue cutting devices
- Group 2 Row preparation devices
- Group 3 Furrow opening devices
- Group 4 Seed firming devices
- Group 5 Seed covering devices
- Group 6 Row specific seedbed firming devices
- Group 7 Non row specific seedbed firming/levelling devices

The relative position or location of these soil-engaging component groups, in relation to the direction of travel of a planter, is shown in Figure 14.

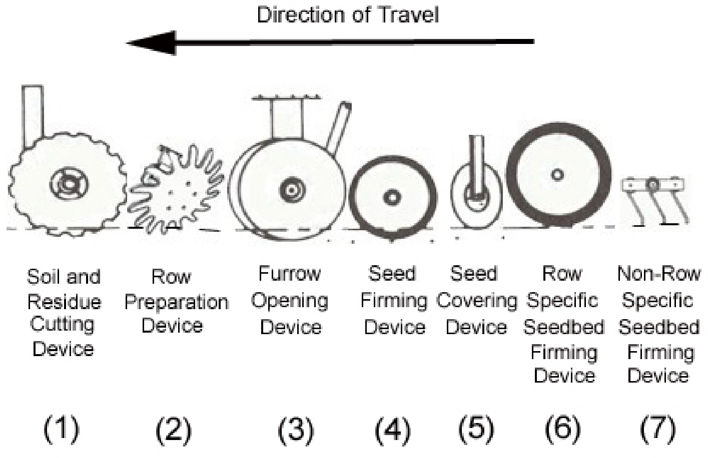

Figure 14: Planter soil-engaging component groups

Many machines are not designed to accommodate, nor have available, devices for all possible groups of components. Nevertheless, a number of more sophisticated, flexible and/or specialised planters used in conservation cropping systems do incorporate all seven groups. The horticultural planter shown in Figure 15 features five of the seven groups. In general, horticultural seedbeds are comparatively well prepared and devoid of high levels of surface residue, which overcomes the need for a dedicated soil and residue cutting device.

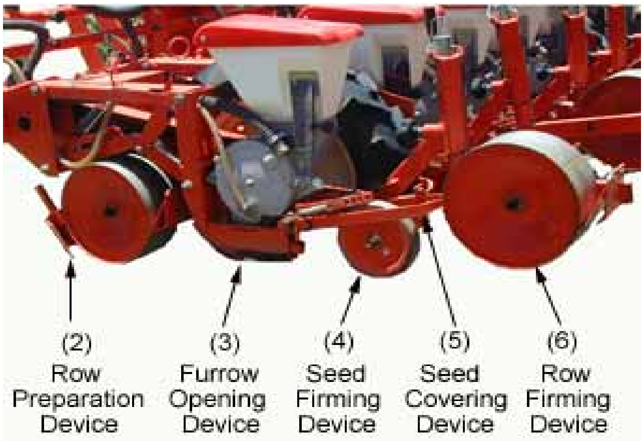

Figure 15: A horticultural planter featuring five of the seven soil-engaging component groups

The functional and operational requirements for each group and range, design and relative advantages and disadvantages of the devices commonly deployed in each group are discussed in detail in the following sections.

5.1 Group 1 – Soil and residue cutting devices

Soil and residue cutting devices are primarily designed to cut soil and/or residue in the row area without significantly disturbing the seedbed. Where required, these devices precede all other planter soil-engaging components. They may be required to orient residue or loosen soil to enhance the performance of the row preparation, furrow opening, seed covering or seedbed firming devices that follow. The nature and extent of the soil and residue manipulation required in addition to the cutting action depends primarily on device selection and, to a lesser extent, setting.

A vertically mounted disc coulter, drawn parallel to the direction of travel, is almost universally used as the soil and residue cutting device on planting machinery. These coulters are most commonly used on planters for conservation cropping systems, particularly where high levels of residue and relatively unprepared seedbed conditions are expected.

There are a range of disc coulter types; their general functional and operational requirements are briefly discussed below.

5.1.1 Functional requirements of soil and residue cutting devices

Essentially, the soil and residue cutting device facilitates the planter's overall performance by cutting and/or otherwise manipulating soil and residue in the row area ahead of the planter's other soil-engaging components.

The major *functional requirements* of disc coulters used as soil and residue cutting devices are to:

- cut crop/weed residue to enable its subsequent removal from directly over the row area or to improve the machine's ability to operate through high levels of surface residue without blockage;
- cut and/or disturb hard soil layers to assist the opener achieve and maintain optimum furrow depth or provide additional soil disturbance (tilth) to improve the operation of planter seed covering and seedbed firming devices; and
- cut soil and/or plant root material to reduce the subsequent seedbed disturbance caused by the furrow opener (particularly positively raked openers).

The residue-cutting function is particularly useful where, for example, residues are to be removed (displaced sideways) from the row area to help manipulate soil temperature or where tine type openers are used under high levels of surface residues. Under conditions where high levels of long residue exist, the performance of tine type openers can be severely restricted by the residue wrapping around, and accumulating on, the standard to which the ground tool is attached. Effective residue cutting by a disc coulter preceding the opener is one solution to overcoming this limitation of tine type openers.

The soil cutting and/or disturbance function is particularly useful where negatively raked furrow opener types (e.g. runner and double disc types) are used under high strength soil conditions or where the furrow opener action does not provide adequate tilth to permit effective soil movement back into the furrow to provide cover after seed placement. Under high strength soil conditions, negatively raked furrow openers have difficulty achieving and maintaining optimum furrow depth. Simply adding weight, i.e. increasing the vertical downwards force, to achieve penetration by such openers can result in over-compaction of both the side walls and the base of the furrow. Effective cutting and disturbance of the soil by a disc coulter preceding these openers can alleviate penetration difficulties and reduce the potential for over-compaction of the side walls and base of the furrow. Increasing soil tilth, particularly through the use of fluted type disc coulters, can improve the ability of soil to flow or be moved back into the furrow after seed placement and the potential for the seedbed firming device to achieve adequate seed/soil contact.

Pre-cutting soil and plant root material can reduce the subsequent seedbed disturbance caused by furrow openers, particularly positively raked types. The controlled fracture of the soil can substantially reduce the sideways displacement of soil during the furrow-opening process. Pre-cutting root material reduces the possibility of the increased disturbance that may result if plant material wraps around the below-ground portion of the opener, increasing its width and reducing its scouring ability.

5.1.2 Operational requirements of soil and residue cutting devices

The *operational requirements* of disc coulter type soil and residue cutting devices include:

- The design must provide for cutting depths up to twice the optimum seed placement depth, i.e. twice the depth required to be met by the planter's furrow opening components.
- Disc coulters require adequate vertical force, a sharp cutting edge and firm, dry surface-soil conditions to effectively cut residue. In soft soil conditions there is inadequate resistance to achieve the cutting function. Residues are 'hair-pinned' or pushed into the soil rather than cut and retained on the surface. Hair-pinning is exacerbated by a blunt cutting edge and, as well as reducing the performance of the furrow opener, it may seriously reduce germination. Higher soil moisture content, particularly in clay soils, reduces the disc's scouring ability and both its cutting and disturbance performance.
- The diameter of the disc coulter needs careful thought. It is a compromise between achieving effective soil and residue cutting/manipulation and optimising the cost, vertical force and draft requirements. Essentially, the latter requirements increase with disc diameter. However, the disc's ability to perform its residue-handling and cutting ability is limited at both small and large diameters. Under heavy residue conditions, small diameter discs tend to push, rather than cut, residue and large discs have limited penetration capabilities. The compromise is to select a diameter that provides for a rake angle of about 45 degrees at the soil surface when the disc is operating at its intended depth. Optimisation of disc performance usually occurs at diameters about 450 mm.
- The type (shape) of the disc coulter largely determines the balance between the cutting and disturbance functions. In general, discs with a straight cutting edge have lower vertical force and draft requirements and tend to cut soil and residue with minimum disturbance to the seedbed. Disc coulters with a sinusoidal cutting edge have higher vertical force and draft requirements and cause greater disturbance, with an associated reduction in cutting ability.
- For optimum performance, disc coulters should usually be mounted forward of, aligned centrally with, and have provision for vertical adjustment relative to, the opener. A swivel type mounting may be required to reduce the side forces on the disc and to improve 'opener tracking' where planting machinery is not always operated in a straight line of travel.
- The performance of disc coulters can be severely restricted by soil adhesion to the disc, particularly in soils with high clay and moisture contents. While scrapers can be fitted to plain discs (i.e. flat disc coulters) there is no similar option for discs with sinusoidal cutting edges.
- The vertical force required to achieve disc penetration increases with disc diameter and should not be under-estimated, particularly under zero tillage conditions.

5.1.3 The types of disc coulter soil and residue cutting devices

Disc coulter types can be broadly classified on the basis of their diameter and the profile of their cutting edge. While there is no uniformly agreed nomenclature, seven types of disc, classified on the basis of the profile of the cutting edge, have been identified: 'plain', 'notched', 'bubble', 'ripple', 'fluted', 'wavee' and 'turbo' (Figure 16).

Figure 16: Types of disc coulter soil and residue cutting devices

While all are used for soil and residue cutting and disturbance, the actual cutting edge on the first three, i.e. the plain, the notched and the bubble types, is straight and narrow in the direction of travel and their primary function is cutting. The sinusoidal cutting edge of the remaining four, i.e. the ripple, fluted, wavee and the turbo types, provides greater disturbance. The major distinction between the four is the number and overall width of the convolutions. Ripple disc coulters have numerous, narrow convolutions and wavee disc coulters have few, wide convolutions. While the cutting edge of the turbo type is fluted, it differs from conventional fluted types in that the grooves are spiralled, not radial. Figure 17 shows the typical profile of the cutting edge on each general type. Their relative merits are discussed below.

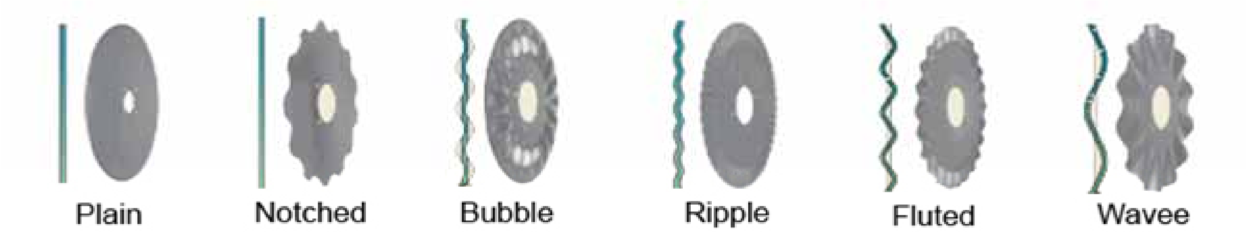

Figure 17: Typical cutting edge profiles for each general disc coulter type

Plain disc coulters

Plain disc coulters are flat circular discs with a sharpened circumference. They have good penetration and residue cutting ability and cause minimum disturbance to the seedbed. However, compared to other types they have a greater potential to stop turning and 'bulldoze' residue, particularly under low soil strength/high residue seedbed conditions. Figure 18 shows a plain disc coulter preceding a dedicated tine type furrow opener. The disc has a scraper attached to facilitate operation in moist clay soil types.

Figure 18: A plain disc coulter type soil and residue cutting device

Notched disc coulters

Notched disc coulters are flat circular discs with a sharpened, notched circumference. They have similar characteristics to the plain disc coulter except they are arguably more suited for use in very hard soils and very heavy residue situations. Figure 19 shows a notched disc coulter preceding a dedicated tine type furrow opener.

Figure 19: A notched disc coulter soil and residue cutting device

Bubble disc coulters

Bubble disc coulters are circular discs with offsets recessed from the circumference but with a flat sharpened cutting edge. These have similar characteristics to the plain disc coulter but have reduced penetration ability and cause moderate disturbance to the seedbed. Figure 20 shows a bubble disc coulter preceding a double disc coulter type furrow opener.

Figure 20: A bubble disc coulter type soil and residue cutting device

Ripple disc coulters

Ripple disc coulters are circular discs with numerous offsets extending radially inwards from the circumference providing a narrow sinusoidal shaped cutting edge. These types have good penetration and cutting ability and provide for moderate disturbance/tilling over a relatively narrow width. Figure 21 shows a ripple disc coulter preceding a narrow tine type furrow opener.

Figure 21: A ripple disc coulter type soil and residue cutting device

Wavee disc coulters

Wavee disc coulters are similar to the ripple disc except the offsets are larger and fewer so the disturbed width is greater. These discs have reduced penetration and cutting ability but cause more disturbance over a greater width compared to ripple disc coulters. Figure 22 shows a wavee disc coulter preceding a dedicated tine type opener.

Figure 22: A wavee disc coulter type soil and residue cutting device

Fluted disc coulters

Fluted disc coulters have a shape and penetration, cutting and disturbance abilities that lie somewhere between those of the ripple and wavee type disc coulters. Figure 23 shows a standard fluted disc coulter preceding a double disc coulter type furrow opener.

Figure 23: A fluted disc type soil and residue cutting device

Turbo disc coulters

Figure 24 shows the principle of operation of the 'turbo' type fluted disc coulter. The flute grooves enter the soil vertically and leave horizontally. This action is claimed to aid penetration on entry and provide additional tilth on exit.

Figure 24: A turbo type fluted disc soil and residue cutting device

Disc coulter soil and residue cutting devices are considered essential for use in many conservation-cropping systems. However, they significantly add to the cost, mass and draft requirements of planting machinery. They should only be used where necessary and not simply used to compensate for poor management practices.

Implementing good soil (e.g. controlling traffic) and residue (e.g. cutting and spreading residues at time of harvest) management practices can significantly reduce the need for, and/or difficulties associated with, the use of planter soil and residue cutting devices.

5.2 Group 2 – Row preparation devices

Row preparation devices are primarily designed to alter surface residue and/or soil conditions to facilitate the operation of the planter's furrow opening device or otherwise improve the prospects for crop establishment. If required, the row preparation devices precede the planter's furrow opening device. When used in conjunction with a soil and residue-cutting device, the row preparation device is fitted between it and the furrow opener.

Row preparation devices may be used on flat, hilled or bedded field surfaces and some incorporate the ability to cut soil and residue. However, row preparation devices incorporating this function are usually capable of causing far more significant displacement of soil and/or residue from the row area than a dedicated soil and residue cutting device.

A large range of row preparation devices is available and they are commonly fitted to planting machines used in both conservation and conventional cropping systems. Their general functional and operational requirements are discussed below.

5.2.1 Functional requirements of row preparation devices

Row preparation devices assist the operation of the planter's furrow opening device or otherwise improve the prospects for crop establishment by performing one or more of the following functions:

- level and/or firm the immediate row area to facilitate furrow opener action and depth control;
- remove dry soil from the immediate row area to allow planting to moisture without excessive soil cover over the seed;
- remove residue from the immediate row area to facilitate the operation of the furrow opener or to, for example, increase in seedbed temperature; and/or
- cut and displace both soil and residue from the immediate row area to achieve a combination of these functions (i.e. the typical action of 'concave disc' type row preparation devices.

The seedbed levelling and firming function is particularly useful when planting small seeds into very friable seedbeds, e.g. a typical horticultural application. The levelling action helps improve depth control and the firming action helps reduce seed displacement (both horizontally and vertically) by closing larger voids and helping prevent soil flowing back into the furrow before seed placement. In conservation cropping systems, the application is similar but more focused on levelling rough, relatively unprepared seedbeds. 'Roller', 'blade' and 'harrow' type row preparation devices are commonly used to perform this function.

Removing dry soil to permit planting in or on moist soil is a common practice in both intensive and extensive cropping systems. This practice is often referred to as 'moisture seeking' or 'planting to moisture' and is used to improve soil water management and/or (particularly in dryland cropping systems) enable an extension of the planting window. By removing dry soil to the inter-row or inter-bed space, the furrow opener can place seed onto the moist sub-surface layer without leaving excessive soil cover over the seed. 'Blade' and 'tine' type row preparation devices are commonly used to perform this function.

Removing residues from the soil surface in the immediate row area is particularly useful in conservation cropping systems where higher levels of residues impede furrow opener performance or depress soil temperatures. Removing the residue with little seedbed disturbance can improve opener performance and increase soil temperatures without excessive moisture loss from the seedbed. The removal of residue from the immediate row area can also reduce the potential for residue-induced phytotoxic effects in the seed zone. ‘Finger wheel’ and ‘horizontal disc’ type row preparation devices are commonly used to perform this function.

Where large amounts of long residue and/or significant levels of dry soil exist, a combination of residue cutting and soil displacement may be required to achieve similar outcomes. Single or double concave disc type row preparation devices can cut and significantly displace both soil and residue.

5.2.2 Operational requirements of row preparation devices

The diversity of row preparation devices precludes a detailed discussion on their operational requirements. Nevertheless, the following generally apply:

- adequate provision must be available to enable incremental vertical and horizontal adjustment of the device in relation to the furrow opening device and the soil surface;
- with double concave-disc and double finger-wheel types, provision is needed to adjust the discs and wheels independently of each other; both horizontally and laterally;
- with finger harrows, the ability to adjust finger rake angle provides flexibility in both the degree of soil disturbance and the ability to handle a range of surface residue conditions; and
- availability and inter-changeability of types (i.e. finger wheel, disc coulter and tine types) provides flexibility in selecting devices to meet specific soil and residue management requirements.

The ability to quickly and conveniently fit, remove and interchange types and make relatively fine adjustments to their vertical and/or horizontal position cannot be over-valued. For example, the difference between ‘residue displacement’ and ‘residue displacement and soil disturbance’ depends on being able to fine tune the device vertically. On a twin concave disc or twin finger wheel type device, the ability to align, offset or change the angle of the individual discs or wheels to the direction of travel can substantially influence their operational performance.

5.2.3 The types of row preparation devices

Based on their general form and function, row preparation devices can be broadly classified as 'blade', 'concave disc', 'finger harrow', 'finger wheel', 'horizontal', 'tine' and 'roller' types (Figure 25). The use of horizontal disc type row preparation devices have been investigated but not used commercially to date. The general role and design variation within each of these general types is briefly discussed below.

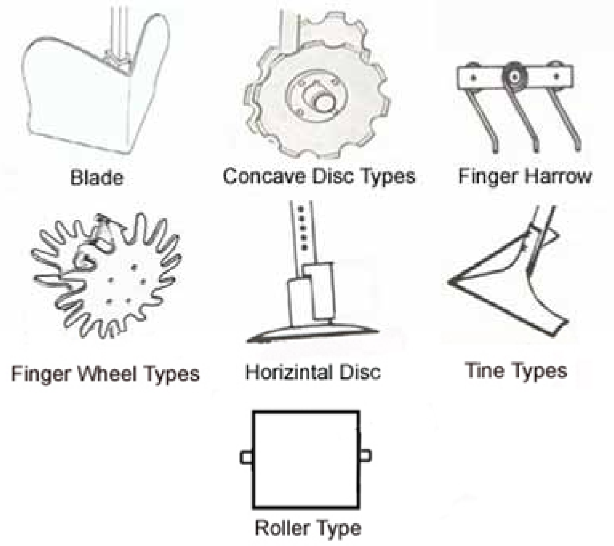

Figure 25: General types of row preparation devices

Blade type row preparation devices

Blade type row preparation devices are essentially used to either level the row area to facilitate opener depth control or remove dry soil to the inter-row space to permit planting to moisture. Most blade type row preparation devices are 'V'-shaped in the direction of travel (Figure 26).

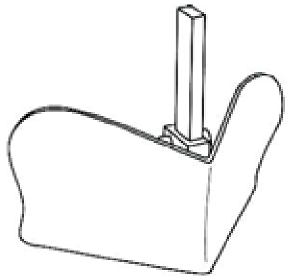

Figure 26: A blade type row preparation device

The use of blade type row preparation devices is usually restricted to intensive cropping systems where well-prepared, weed- and residue-free seedbeds exist.

The blade's inability to cope with hard soil conditions or any significant level of surface or incorporated residue generally precludes their use in conservation cropping systems. Where there is a requirement to remove dry soil to the inter-row space in conservation tillage systems a double disc type row preparation device is usually used because of its ability to cut and displace both soil and residue.

Figure 27 shows an example of a blade type row preparation device. It shows the front view of the blade mounted in front of a double disc coulter type furrow opener.

Figure 27: Example of a blade type row preparation device

Finger wheel type row preparation devices

Finger type row preparation devices are primarily used to displace residue from the immediate row area to improve the performance of the furrow opening device, reduce the potential for residue induced phytotoxic effects or assist in raising seedbed temperature by removing the residue cover. Often referred to as ‘residue managers’ or ‘trash wipers’, these devices can be either single or double wheel types (Figure 28).

While there are diverse finger designs, the principle of operation is similar. The wheels rotate as a result of contact with the soil and the residue is displaced to one or both sides of the row.

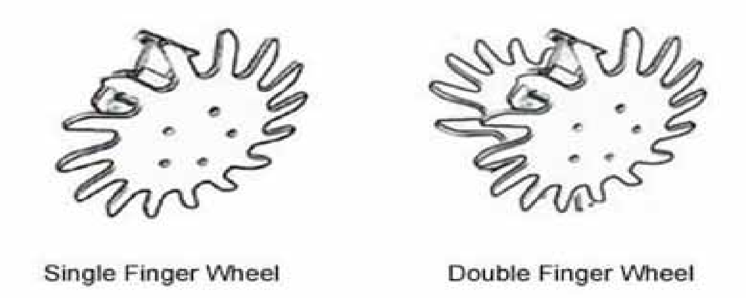

Figure 28: Typical single- and double- finger wheel configurations

While the overall capability and performance of finger type row preparation devices is largely dictated by soil and residue type and condition, the performance under specific condition depends on the particular type of finger wheel and the flexibility of the design to allow for wheel adjustment. Incremental vertical adjustment is required to ensure the optimisation between providing adequate contact with the ground to power the wheel and reducing soil disturbance. The general aim is to provide maximum residue displacement with minimum soil disturbance. For a given forward speed, the angle of the wheel to the direction of travel influences both the speed of wheel rotation and the width of residue displacement. The ability to adjust wheel angle to the direction of travel, the relative position of the wheel or wheels to the centreline of the opener and the relative position of the wheels to each other provides for maximum flexibility to suit specific conditions. The ability to adjust wheel positions on one particular design is shown in Figure 29.

Figure 29: Top views of a finger wheel row preparation device showing the optional wheel positions

The design shown in Figure 30 allows the device to be configured as a single or double wheel type as well as catering for various wheel positions within each configuration.

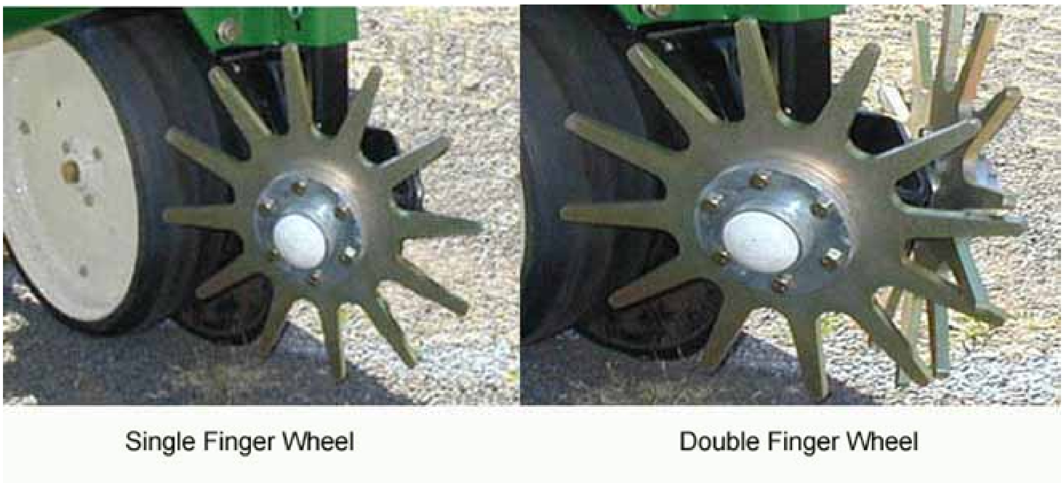

Figure 30: Examples of single and double finger wheel type row preparation devices

Both of the finger wheel types shown in Figure 30 precede a double disc coulter type furrow opener and are optional settings within the one design. While a diversity of finger shapes and sizes are available most operate in a similar fashion. The fingers on most finger wheels used as row preparation devices are rigid, however some manufacturers use spring steel rods (Figure 31).

Figure 31: Spring steel finger wheel row preparation device

To ensure adequate depth, most finger wheel row preparation devices are mounted directly to the frame that controls the depth of the furrow opener or on a separate, pivoted frame mounted forward of the opener frame (Figure 32).

Figure 32: Spring steel finger wheel row preparation device

Concave disc type row preparation devices

Concave disc type row preparation devices are used to cut and displace both soil and residue from the row area. The cutting and displacement action of the concave disc allows for the combined actions of a blade and a finger wheel type row preparation devices under a combination of hard soil and high residue conditions. While primarily used in conservation cropping systems to facilitate opener operation when planting to depth in hard soil and high residue conditions, it may be used in well-prepared seedbeds when gross soil movement is required. A typical example would be to permit a runner type opener to operate at depth, such as required when planting potatoes.

Concave disc type row preparation devices can be single or double disc units. On single units, the discs can be plain or notched (Figure 33). On double concave disc units, the discs can be plain or notched and aligned or staggered (Figure 34). A combination of plain and notched discs may be used sometimes.

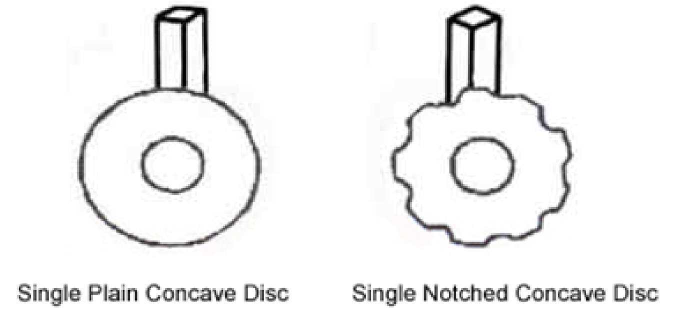

Figure 33: Types of single concave disc row preparation devices

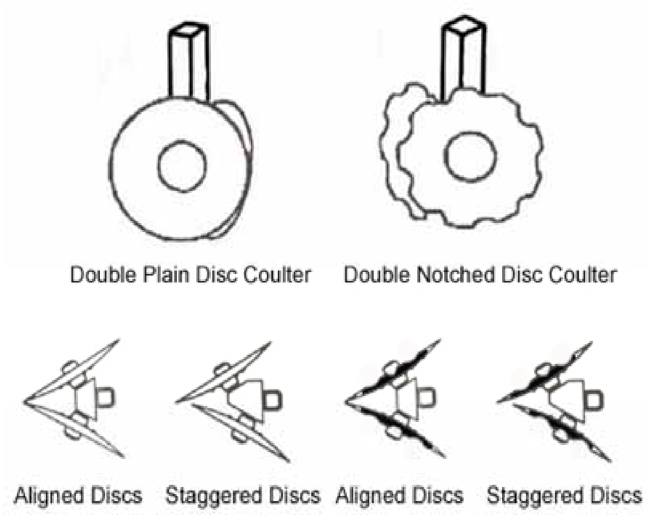

Figure 34: Disc types and alignment for double concave disc type row preparation devices

In general, while notched concave discs have better soil penetration and residue-handling ability than plain concave discs, the wear rate is greater due to the reduced length of the cutting surface in contact with the soil. Given the relatively small diameter of the concave discs used on row preparation devices, a small reduction in diameter due to wear can significantly reduce the disc's residue-handling ability.

When aligned double disc types are used, a section of uncut and undisturbed soil remains in the central row area. While this may have little consequence for the operation of a furrow opener in deep, well-prepared seedbeds, a tine type opener with a positive rake angle is better suited for use in hard soil conditions.

The adjustments required to facilitate use of concave disc coulters over a wide range of conditions are similar to those required for finger wheel types, i.e. provision for both vertical and horizontal adjustment relative to the soil surface and/or furrow opener as well as the ability to adjust double disc alignment and overlap.

Figures 35 and 36 both show examples of double concave disc type row preparation devices. The unit in Figure 35 has a pair of aligned plain discs; the unit in Figure 36 has a pair of staggered notched discs.

Figure 35: An example of an aligned, plain double concave disc coulter type concave disc coulter

Figure 36: An example of a staggered, notched double

Combination of concave disc and finger wheel types

Concave disc and finger wheel row preparation devices may be combined to achieve an action suited to a particular situation. Figure 37 is an example of a row preparation device that combines a notched concave disc and a finger wheel type.

Figure 37: An example combined concave disc and single finger type row preparation device

Finger harrow type row preparation devices

As a row preparation device (rather than a discrete machine or a tillage machine attachment, etc) finger harrows are generally narrow and mounted directly in front of the furrow opener on unit type planters.

When used in conventional cropping systems, i.e. those without surface residues, the main function is either to assist in the control of small weeds or to assist in re-levelling the seedbed to improve furrow opener depth control. In conservation cropping systems, the predominant use is to assist in breaking-up or otherwise spreading surface residues to facilitate overall planter performance. A typical three bar finger harrow unit is shown in Figure 38.

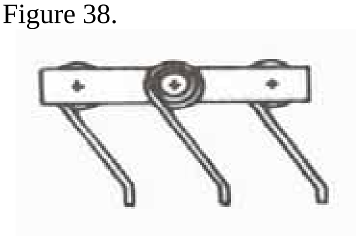

Figure 38: A typical three bar finger harrow unit

In most cases, the bars on which the finger harrow tines are mounted can be rotated to adjust the tine rake angle. Reducing the rake angle reduces soil disturbance and improves stubble handling ability. Figure 39 shows a three bar harrow type row preparation device mounted in front of a double disc coulter type furrow opener.

Figure 39: An example of a harrow type row preparation device

Tine type row preparation devices

The function of tine type row preparation devices is generally restricted to disturbing soil to facilitate the operation of a negatively raked furrow opener (e.g. runner and disc types, particularly aligned double discs); disturbing soil to facilitate weed control in the row area or displacing soil to allow planting to moisture. Because better options exist, tine type row preparation devices are usually restricted to performing these functions over a range of seedbed conditions (i.e. hard or well prepared) where there are low levels of surface residue at planting.

While a diversity of ground-tool types are available, sweep and knife types (Figure 40), are generally deployed as row preparation (as distinct from furrow opening) devices.

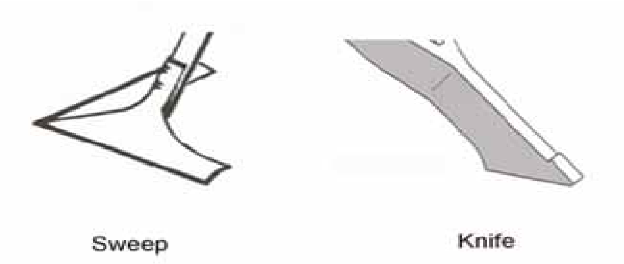

Figure 40: Typical tine type row preparation devices

The knife type is specifically used to disturb a narrow band of soil to depth, so as to allow disc and runner type furrow openers achieve and maintain depth under hard soil conditions.

Wide, low-profile sweeps may be used at a shallow depth to control weeds in the row area, while high profile sweeps can facilitate both weed control and soil displacement. In most cases, soil displacement is used to remove dry soil from the row and permit planting to moisture. Given the range of ground-tool shapes available, the major adjustment for operational performance is provision for vertical and horizontal adjustment.

Figures 41 and 42 show examples of the sweep and the knife type of tine row preparation device, respectively. The sweep precedes a narrow tine type furrow opener in Figure 41 and the knife precedes a double disc coulter type furrow opener in Figure 42.

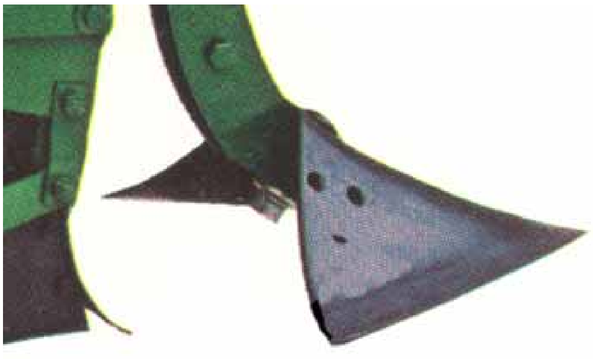

Figure 41: A tine type row preparation device preceding a double disc opener

Figure 42: A sweep type row preparation device preceding a tine type furrow opener

Roller type row preparation devices

The function of roller type row preparation devices is almost exclusively to level and firm deep, well-prepared seedbeds to facilitate opener operation and depth control. In most applications they are not used where there is any significant amount of surface residues. They are rarely used as a discrete device; in most cases the roller is used as part of the furrow opener depth control mechanism.

In the roller type row preparation device in the form of a front furrow opener gauge wheel in Figure 43, it is placed after a blade type row preparation device and precedes a runner type furrow opener.

Figure 43: An example of a roller type row preparation device

Horizontal disc type row preparation devices

The function of horizontal disc type row preparation devices is to remove surface residue and/or soil from the row area to facilitate furrow opener operation. These devices usually consist of a horizontally mounted concave disc combined with shank mounted residue deflectors (Figure 44).

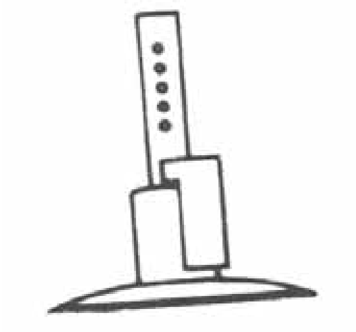

Figure 44: The general form of a horizontal disc type row preparation device

The plane of the sharpened cutting edge of the disc, which is free to rotate, is nearly parallel to the soil surface, but typically inclined at a 10 to 15 degree angle; the leading edge is lower than the trailing edge. As the machine moves forward, contact with the soil causes the disc to rotate. The path width from which residue and/or soil is removed is primarily dependent on the blade diameter, deflector settings and working depth.

The use of horizontal disc type row preparation devices has been investigated by a number of research workers but they are not readily available or frequently used on planting machines. A similar horizontal disc has been successfully used as a discrete device for cutting and removing cotton stalks from the row area. Figure 45 shows an example of one such device.

Figure 45: An example of a horizontal disc type row preparation device

5.3 Group 3 – Furrow opening devices

The furrow opener is the specific device that opens the furrow into which the seed is placed. The opener may incorporate or enclose a portion of the seed delivery system and/or the seed boot that facilitates seed placement in the furrow. Their general functional and operational requirements are discussed below.

5.3.1 Functional requirements of furrow openers

The *functional requirements* of a furrow opener are to:

- open a furrow to the required depth (consider depth in relation to seed type, seed size, soil temperature, soil moisture, light requirement, etc);
- maintain uniformity of depth along the length of the furrow and between furrows across the width of the planter (consider uniformity of furrow depth in relation to effects on rate and uniformity of germination, emergence and establishment);
- cause minimum disturbance to the seedbed (consider disturbance in relation to soil moisture loss, the mixing of wet and dry soil in the seed zone, etc);
- firm the base of the seedbed but avoid smearing or over-compaction of the base and walls of the furrow (consider firming in relation to moisture transfer and smearing and excessive compaction in relation to restriction of root growth, etc);
- prevent soil flowing back into the furrow before seed placement (consider the need to place the seed on the moist, undisturbed furrow base to maximise moisture transfer and availability); and
- promote the appropriate degree of soil flow back into the furrow after seed placement (consider the need to close the furrow to obtain good seed/soil contact, stabilise conditions and reduce the likelihood of seed loss by predators).

5.3.2 Operational requirements of furrow openers

To achieve the functional requirements, the *operational requirements* are that a furrow opener should:

- be rigidly held in its working position, although suitably protected from damage by obstructions, to maximise control over both furrow depth and seed placement;
- have provision for vertical adjustment (relative to the soil surface) to enable alteration of planting depth and horizontal adjustment (relative to adjacent openers) to allow alteration of row spacing if required;
- be suitable for the soil type and condition expected at time of planting and capable of operating successfully through the existing surface residues;
- have an effective depth control mechanism to ensure the seed is placed at a consistent depth relative to the soil surface;
- be as narrow as possible in the direction of travel because narrow openers cause less overall disturbance to the seedbed and have a lower draft requirement;
- be easily restrained or held in an effective working position;
- promote soil flow back into the furrow after seed placement; and
- reduce the potential to interfere with the operation of adjacent openers.

There are, however, limitations to the narrowness of openers because very narrow openers:

- are more prone to cause smearing of the furrow base and walls, particularly when they have large rake angles and are used in moist, high clay content soil types;
- may prevent good seed/soil contact by not allowing sufficient soil flow back into the furrow or by reducing the effectiveness of the seedbed firming device; and
- may not have sufficient strength for reliable operation.

5.3.3 Types of furrow opener

Most furrow openers can be broadly classified as 'runner', 'concave disc', 'disc coulter', 'bioblade', 'tine', 'punch' or 'powered' (Figure 46) or as derivatives of these types.

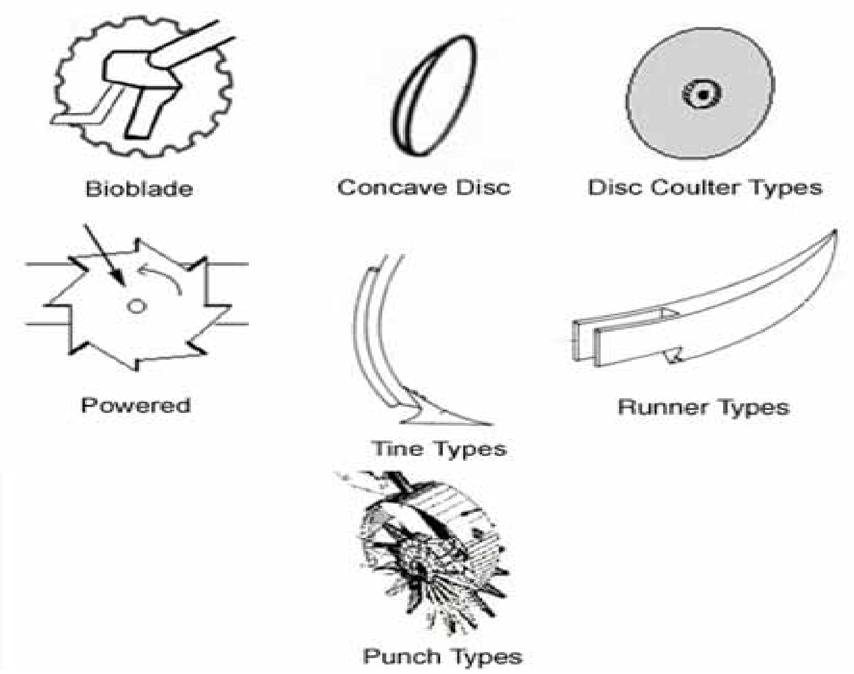

Figure 46: Common types of furrow opening devices

There is considerable design diversity within each type. The general action by which they create a furrow or a hole (into which the seed is placed) differs but can be broadly described as follows:

- runner type furrow openers tend to form a furrow by displacing soil downwards and outwards (i.e. press out a furrow);
- tine type furrow openers tend to open the furrow by displacing soil upwards and outwards on both sides of the furrow (i.e. dig a furrow);
- concave disc type furrow openers tend to open a furrow by cutting and displace soil upwards and outwards to one side of the furrow (i.e. cut and dig a furrow);
- disc coulter type furrow openers either 'cut', 'cut and dig' or 'cut and press' out a furrow depending on the particular type employed;
- punch type furrow openers do not create a furrow but rather 'punch' a series in individual holes into which the seed is placed (i.e. punch a hole by pushing small volumes of soil downward and outwards);
- powered type furrow openers tend to cut and till a narrow furrow into which the seed is placed (i.e. cut and till a furrow);

- bioblade type furrow openers tend to create a furrow by cutting and lifting soil; the soil essentially falling back into place after seed placement (i.e. cut and lift).

Quite accurate predictions in relation to the ability of the various types to successfully operate under specific seedbed conditions can be made from a general understanding of the ‘opening action’ deployed. For example, openers that press out a furrow as a result of a negatively raked opener sliding through the soil (e.g. a runner type opener) have little ability to handle less well-prepared seedbeds or seedbeds with a significant level of surface residue. Tine type openers that tend to dig a furrow by way of a positively raked tool moving through the soil could be expected to have excellent penetration ability and handle hard seedbed conditions with ease.

Knowledge of the opener type and action can allow predictions as to the likely shape of the furrow resulting from its use. Typical furrow cross-sections resulting from four opener types are shown in Figures 47 and 48.

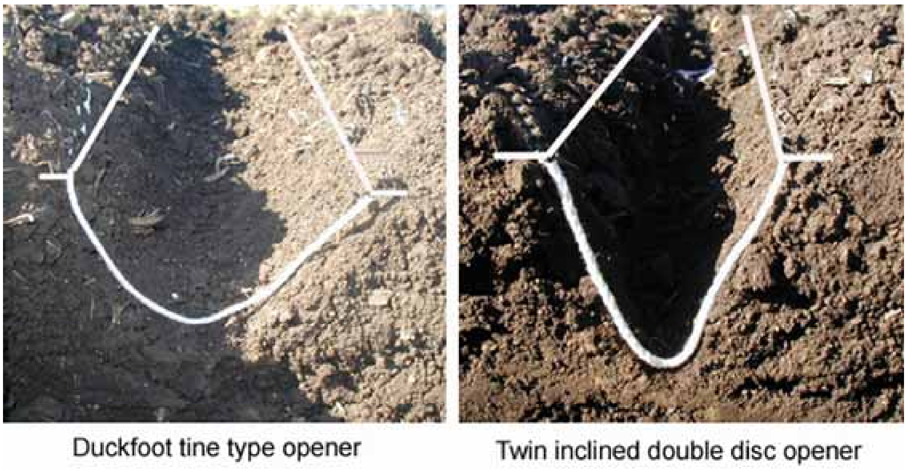

Figure 47: Typical furrow shapes made by a duckfoot and a double disc type furrow openers

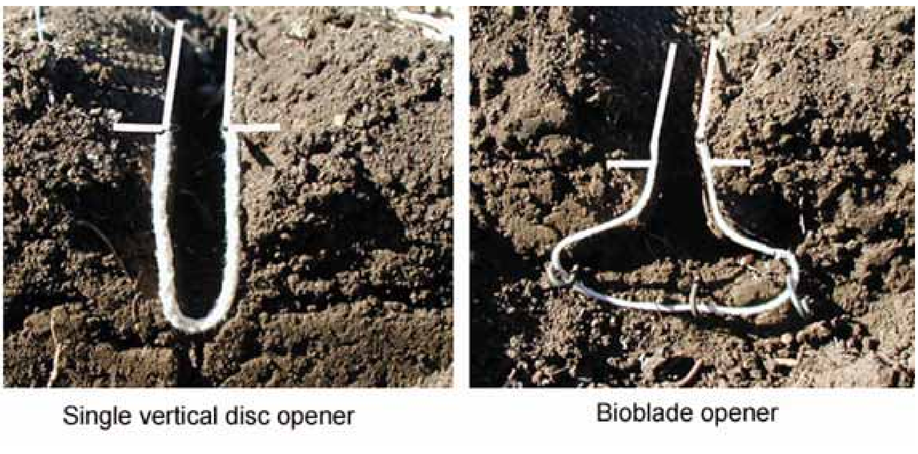

Figure 48: Typical furrow shapes made by single vertical disc and bioblade type furrow openers

The range of commonly available furrow opener types and the relative merits of particular designs within each type are discussed below.

Runner type openers

Runner type furrow openers essentially consist of a blade that gradually widens and then splits towards the rear to form a cavity through which the seeds are dropped (Figure 49).

The front section of the opener is 'V'-shaped (in transverse cross-section) and extends below the wider rear portion. As the opener is drawn forward (in a sliding action) it displaces soil downwards and outwards to form a distinctly 'V'-shaped furrow. The side plates of the wider, split rear portion of the opener helps prevent soil falling back into the furrow before the seed is placed.

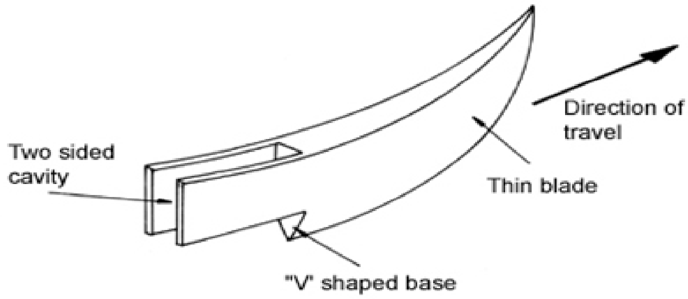

Figure 49: Full runner type opener

In general, runner openers can be classified as full runner types (Figure 49) or stub runner types (Figure 50) on the basis of the rake and included angle of the leading blade section.

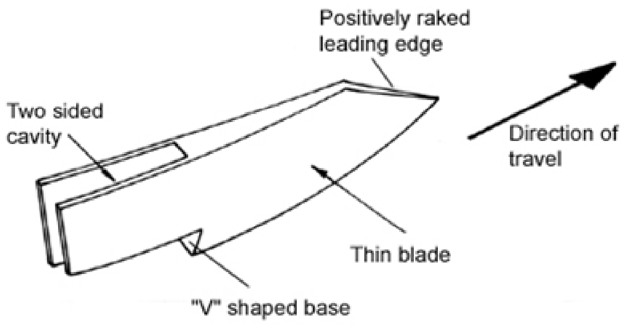

Figure 50: Stub runner type opener

Runner type openers are suited for use where deep, well-prepared seedbeds (i.e. seedbeds with good tilth to a depth below planting depth and free from weeds and residue, etc) have been created in more frictional soil types (i.e. sands to loams). As the runner travels forward, it displaces soil downwards and outwards (increasing both its strength and density) to form a neat, firm-walled furrow of uniform depth. Overall disturbance to the seedbed is slight and the seeds are placed on a firm furrow base.

The performance of runner openers is reduced or unsatisfactory when used in shallow or unprepared seedbeds or in cohesive/adhesive soil types (i.e. soils with high clay content).

In shallow or unprepared seedbeds, it is more difficult to obtain and maintain optimum furrow depth and if depth can be maintained over-compaction of the walls or base of the furrow may result. Runner openers do not operate effectively where surface residues exist unless the residue is short or cut into short lengths by a disc coulter preceding the opener. Uncut residues tend to build up around the leading edge or are forced down into the furrow, in both cases reducing the operational and/or functional performance of the opener.

Runner openers are generally not suited for use in soils with high clay content. Under wetter soil conditions, the sliding action of the opener tends to cause 'smearing' along the base and walls of the furrow to the extent that it can severely restrict subsequent root development. Further, when these soils are in a 'sticky' condition, soil tends to adhere to, and build up on, the runner to such an extent that it will not operate satisfactorily.

The actual shape of the runner opener can affect its performance under particular conditions. The draft, vertical restraining force, uniformity in furrow depth and shape, degree of soil disturbance, etc, are all influenced by the rake and included angles of the runner opener. A stub runner (Figure 50) tends to lift surface residue rather than rather than push it into the seedbed as does a full runner (Figure 49).

Runner type openers are best suited for use where deep well-prepared seedbeds (i.e. seedbeds with good tilth to a depth greater than that of planting and free from weeds and residue, etc), are created in the more frictional soil types (i.e. sands to loams). They are ideally suited to, and used commonly in, horticultural cropping systems, particularly vegetable crops.

Over-compaction and/or smearing of the walls of the furrow and soil adhesion to the opener are recognised operational problems associated with the use of runner type openers in moist clay soils. These limitations, together with the runner opener's inability to operate successfully through high levels of surface residues, severely restrict their use in conservation cropping systems.

Attachments to the runner opener can modify its performance under particular conditions. For example, depth gauges fitted to the sides of the opener can be used to assist in depth control in very soft soil conditions. Combining runner openers with, for example, concave disc or tine type row preparation devices may permit their use in shallow, less well-prepared seedbeds or where there are higher levels of surface residue at planting.

Figures 51 and 52 show examples of the full and stub runner types.

Figure 51: An example of a full runner type furrow opener

Figure 52: An example of a stub runner type furrow opener

While the runner openers shown in Figures 51 and 52 are typical for their respective types, a wide range of shapes and sizes are available. Most manufacturers provide a range of optional opener sizes and types to suit a particular makes and models of planting machine.

Seed placement on runner type openers is generally accomplished in one of two ways: directly dropped through the rear two-sided cavity of the opener from a seed metering unit positioned directly above or protruding into the cavity (Figure 48) or via a short dropper tube that delivers the seed from the meter to the rear cavity in the opener (Figure 53).

Figure 53: Seed delivery via a short dropper tube

The seed falls to, and tends to concentrate in, the bottom of the furrow by virtue of the usually well-formed ‘V’-shaped furrow created by this type of opener. There is no requirement for a specialised placement device; the runner opener performs both the furrow opening and seed placement functions.

Concave disc type openers

Concave disc openers essentially use a single, small-diameter concave disc that is drawn at an angle to the direction of travel to open the furrow into which the seed is placed (Figure 54).

As the disc moves forward, the soil is cut, displaced upwards and deposited to one side of the ‘U’-shaped furrow that results. The angle of the disc to the direction of travel enables a dropper tube, located towards the rear of, and protected by, the disc, to place seed before any significant amount of soil flows back into the furrow.

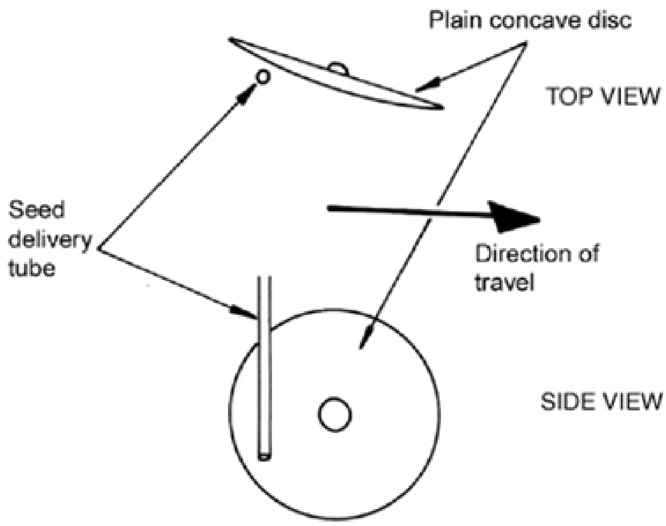

Figure 54: A concave disc type furrow opener

The cutting and digging action of the disc, as it moves forward with a rolling rather than sliding action, permits its use over a wider range of soil and residue types and conditions than the runner type openers.

Disc diameter, disc concavity, disc angle (to both the vertical and direction of travel) and forward speed of operation are the major determinants of the performance of concave disc type openers. Usually, small diameter (250 mm to 300 mm) discs with shallow concavity and fixed angles are used to reduce the cost, weight, penetration-force and seedbed disturbance. As a result, the concave disc opener is more suited for use in well-prepared seedbeds. While the concave disc opener may be used under firm seedbed conditions, the typical disc diameter and vertical restraining force available on machines with this type of opener severely restricts their use in reduced- or no-till situations, particularly when deeper furrows are required or where higher levels of surface residue exist. Figure 55 shows an example of a concave disc type furrow opener.

Figure 55: A single concave disc type furrow opener (rear side view)

Seed placement on single concave disc openers is accomplished via a dropper tube attached to a wedge shaped placement device positioned in close contact to the lower rear portion of the non soil-engaging side of the disc. In essence, this wedge follows in the shadow of the disc and is positioned such that it slightly displaces the disturbed soil and/or the furrow wall laterally and prevents this soil falling back into the furrow until the seed falls to the bottom of the furrow.

While the rear portion of this wedge shaped placement device is shown in Figure 52, its shape is similar to the seed placement devices used on single disc coulters as shown in Figure 61, except that the leading edge is moulded to suit the convex rather than flat profile of the disc.

Disc coulter type openers

Disc coulter type furrow openers utilise flat, rather than concave, discs and are available as single, double and triple disc types (Figure 56).

Although flat, plain and notched disc coulter types can be used independently as a furrow opener, they differ from soil and residue cutting type disc coulters in that they are drawn at an angle to the direction of travel so as to cut and displace soil to form a furrow.

Broadly classified as single, double or triple disc coulter types on the basis of the number of disc coulters used in the design, further classifications within each type can be made on the basis of the particular type and/or configuration of the discs used.

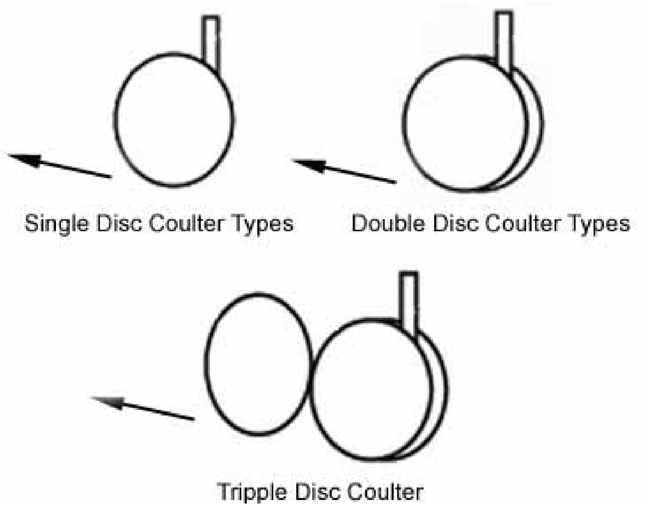

Figure 56: General types of disc coulter furrow openers

Single disc coulter types

Single disc coulter types (Figure 57) generally employ a large diameter (up to 600 mm), plain or, to a lesser extent, notched disc coulter to cut soil and residue and create the furrow into which the seed is placed. Single disc coulter type openers can be classified as aligned, single angle or compound angle types on the basis of the disc's angle to both the vertical (i.e. 'tilt' angle) and to the direction of travel (i.e. 'disc' angle).

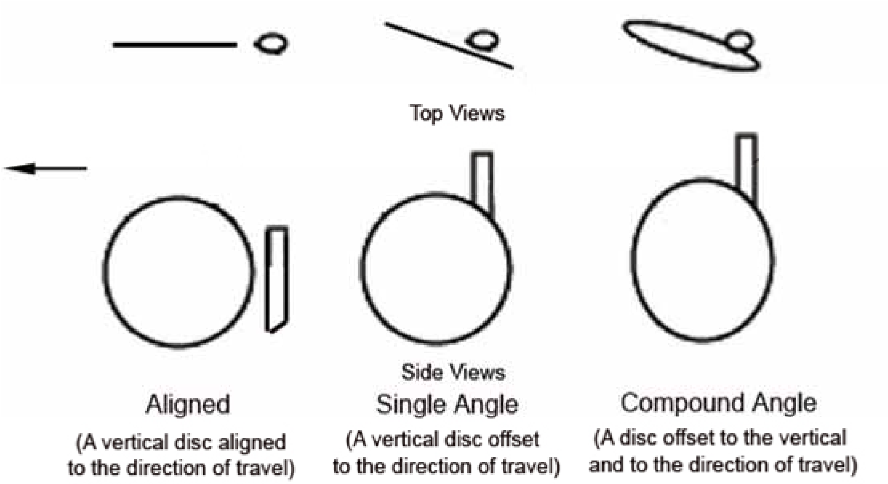

Figure 57: Types of single disc coulter furrow openers

On aligned single disc coulter opener types (Figure 58) the discs are mounted vertically and drawn parallel to the direction of travel (i.e. have neither tilt or disc angles).

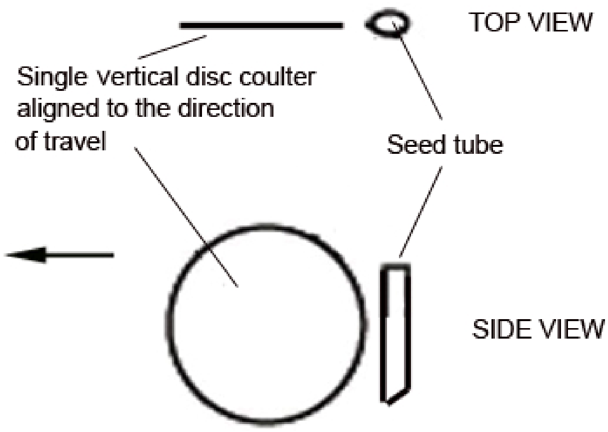

Figure 58: Single, aligned disc coulter opener type

This type of single disc coulter opener simply makes a vertical cut to the depth of seed placement then relies on the following narrow seeding boot to expand the cut to form a furrow into which the seed is placed. With this very simple opener design there is limited scope to make adjustments to suit particular soil conditions. This, together with the dependence on the sliding action of a 'wedge' shaped seeding boot to expand the furrow to effect seed placement, limits opener performance, particularly when operating under both hard soil and moist clay soil conditions.