

CHAPTER 3

Principal integrated zero tillage crop–livestock systems

GENERAL CONSIDERATIONS

Zero tillage is not sustainable without crop rotation, always with a different crop in the same season of the subsequent year. Rotations comprise a number of single-year crop successions. In tropical Brazil a second crop may be sown in the second half of the rainy season: where rainfall is inadequate a fallow is used. Examples of typical rotations are found below and others are detailed in the case studies (Chapter 5).

Soybean-millet is a common crop succession in one year, but soybean-millet followed by soybean-millet is not a rotation, it is a crop succession repeated. The greater the number and the higher the diversity of crops and genera involved in a rotation, the higher the biodiversity and the greater the potential for biological control of diseases, pests and weeds, through cutting the build-up of inoculum or populations; even nematodes can be efficiently controlled by some pasture grasses (Vilela *et al.*, 2004) and leguminous cover crops. A pasture phase in a rotation builds up SOM, improves soil structure, nutrient and water availability (Vilela *et al.*, 2004), and allows reductions in the levels of pesticides and fertilizers used. High SOM and crop residue levels reduce the potential pollution of aquifers and surface water by acting as chemical and physical buffers (Amado and Costa, 2004).

Crop successions within the rotation must be balanced so as to maintain an average of over 6 tonnes/ha of dry matter in crop residues. Production of adequate biomass to build up SOM and maintain profitability is helped by a pasture phase. Cover crops can assist when

late or winter rains are adequate. Sá *et al.* (2004) demonstrated increases of root mass of between 11 and 76 percent at 5 and 10 tonnes DM/ha of residues with a positive regression on hybrid maize yields.

Table 3 shows the impact of the cover crop on the yield of the following crop in Minas Gerais (the performance of sunflower depends on low soil pathogen levels and absence of free aluminium) and Table 4 shows which main crops can follow which preceding crops from the point of view of soil diseases and plant nutrition. The table also shows recommended and unsuitable following crops, illustrating the principle of rotating crop families. In Table 3, with results from Minas Gerais, yields varied significantly for different preceding crops with both maize and soya, with a general advantage for dicotyledonous preceding crops, except for black oats (*Avena strigosa*) preceding soya.

TABLE 3: EFFECT OF COVER CROPS ON MAIZE AND SOYBEANS (1997-98) IN MINAS GERAIS

MAIZE		SOYBEANS	
COVER CROP	YIELD (KG/HA)	COVER CROP	YIELD (KG/HA)
Pigeon pea	6 628 a*	Sunflower	3 558 a*
Niger oil**	6 367 ab	Black oats	3 521 ab
Sunflower	6 195 bc	Forage radish	3 440 ab
Pearl millet	5 981 bcd	Sorghum	3 437 ab
Maize	5 964 cd	Pearl millet	3 258 b
Sorghum	5 727 d	Maize	3 002 c

* Letters indicate statistical differences at the 5% level (Tukey)

** *Guizotia abyssinica*

Source: Lara Cabezas, unpublished data (2003).

Table 5, with data from Roraima, 3° N, shows that soybean following pigeon pea was very inferior to soybean following a graminaceous crop (with or without another legume). This has been corroborated by Döwich (2002) for Bahia and Kluthcouski *et al.* (2003) at several sites, indicating the fundamental nature of this principle. The sources of these yield increments are still to be elucidated.

Biological activity in the soil is increased under ZT. The most important discovery in this area, using *Brachiaria* spp. as a cover crop, has been the reduced incidence of soil pathogens, as shown by Da Costa and Rava (2003), who measured reductions in *Rhizoctonia* (*R. solani*) and White

TABLE 4: RECOMMENDATIONS FOR CROP SUCCESSIONS IN ZERO TILLAGE ROTATIONS

PRECEDING CROP		MAIN CROP	FOLLOWING CROP	
Not recommended	Recommended		Recommended	Not recommended
forage radish, phaseolus bean, pigeon pea, hairy vetch, mucuna, lab lab, trefoil, and sunflower	maize, sorghum, finger millet, wheat, rice, oats (<i>A. sativa</i>), maize + mucuna and maize + phaseolus bean	SOYBEANS	maize, sorghum, finger millet, forage radish, sunflower, rice, oats, hairy vetch and wheat	
sorghum, rice, finger millet and wheat	soybeans, oats, phaseolus bean, mucuna, maize, sunflower, sunn hemp, forage radish, hairy vetch, maize + mucuna and lab lab	MAIZE	oats (<i>A. sativa</i>), forage radish, sunflower, finger millet, wheat and soybeans	
forage radish, bean, hairy vetch, pigeon pea	maize, soybeans, finger millet and oats	COTTON	oats, forage radish, wheat, soybeans, maize, sorghum, finger millet and rice	sunflower, phaseolus bean, hairy vetch and trefoil
forage radish, mucuna, pigeon pea, trefoil, hairy vetch and lab lab	forage radish, mucuna, pigeon pea, trefoil, hairy vetch and lab lab	SUNFLOWER	maize, sorghum, rice, finger millet, oats, wheat, and forage radish	soybeans, cotton and phaseolus bean
trefoil, pigeon pea, soybeans, forage radish, lab lab, hairy vetch and sunflower	maize, sorghum, rice, oats, finger millet and mucuna	PHASEOLUS BEAN	maize, sorghum, rice, finger millet, wheat and oats	forage radish, soybeans and sunflower
finger millet and rice	maize, pigeon pea, soybeans, forage radish, crotalaria and mucuna	SORGHUM	sunflower, oats, phaseolus bean, soybeans, trefoil, forage radish, mucuna, hairy vetch, pigeon pea and lab lab	wheat, maize, sorghum and finger millet
wheat, sorghum and finger millet	forage radish, crotalaria, pigeon pea, mucuna, trefoil, oats, maize, sunflower, lab lab and phaseolus bean	UPLAND RICE	sunflower, trefoil, phaseolus bean, hairy vetch, oats, soybeans, forage radish, mucuna, pigeon pea and lab lab	wheat, maize, sorghum and finger millet
rice, sorghum, finger millet and black oats for seed	maize, crotalaria, phaseolus bean, sunflower, pigeon pea, mucuna, lab lab, soybeans and cotton	WHEAT	mucuna, sunflower, crotalaria, cotton, phaseolus bean, maize, sorghum, finger millet, lab lab, pigeon pea and soybeans	maize and rice
none	any crop	OATS	any crop	wheat after black oats to seed
cotton, sunflower, wheat, sorghum and upland rice	soybeans, maize, phaseolus bean, oats and finger millet	PERENNIAL PASTURE	soybeans and phaseolus bean	cotton, oats, rice, sunflower, maize, sorghum and wheat

Source: Broch *et al.* (1997).

TABLE 5: EFFECTS ON SOYBEAN YIELDS OF GRASSES AND LEGUMES AS PRECEDING COVER CROPS, IN RORAIMA STATE

PRECEDING COVER CROP	YIELD (KG/HA)
<i>Brachiaria</i> spp.	3 775
Native grass + <i>Stylosanthes guianensis</i> cv. Lavrado	3 632
<i>Stylosanthes guianensis</i> cv. Lavrado	2 828
Pigeon pea	2 815

Source: Gianluppi (1999).

Mould (*Sclerotinia*) infections of 75 percent and also in *Fusarium solani*. This principle has revolutionized rainfed and irrigated Phaseolus bean production when planted into desiccated *Brachiaria*, sometimes leading to farm yields of over 3 000 kg/ha (corroborated by Kluthcouski *et al.*, 2003).

Dos Santos (2003) analysed different systems of ICLZT in terms of weight gain (in beef) and financial returns to the beef enterprise (see Figure 6). The introduction of a fast-establishing annual (hybrid forage sorghum), gives grazing 20 days earlier compared to conventional establishment of *Panicum maximum*. Alternatively, a mixture of pearl millet (*Pennisetum americanum*), or finger millet, (*Eleusine coracana*) with *P. maximum* can achieve the same result (A.B. van der Vinne, personal communication, 2003).

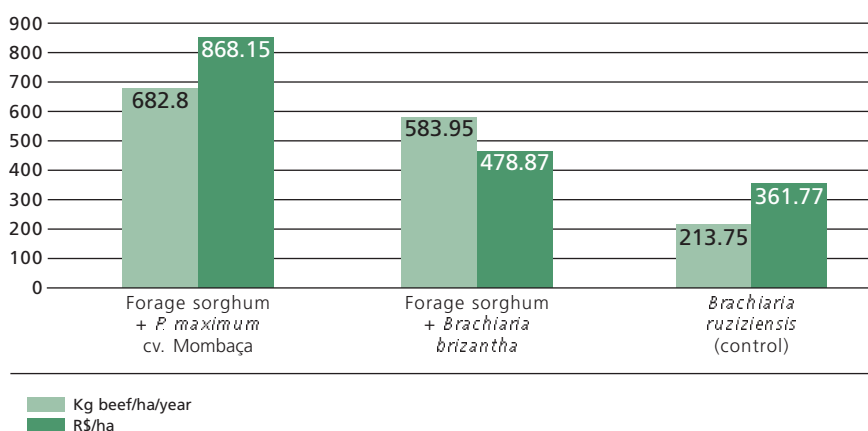
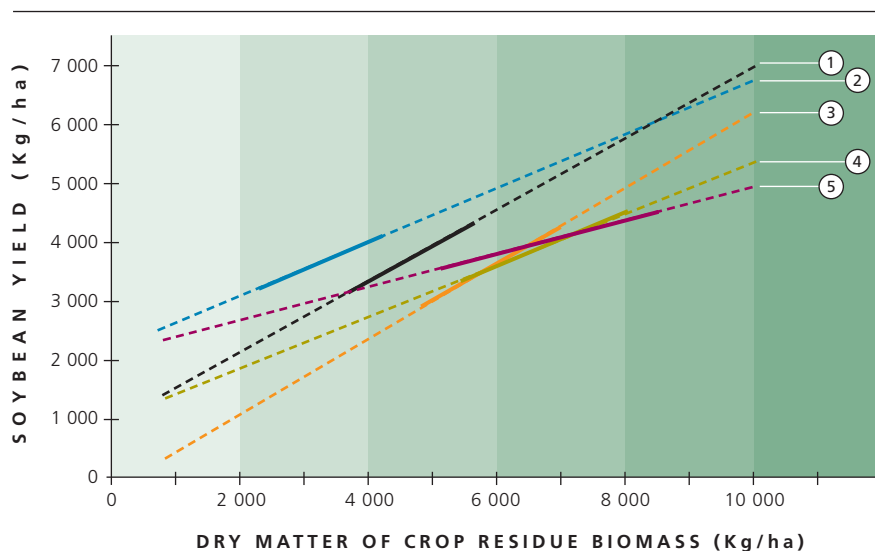


FIGURE 6: Performance of three systems of ICLZT in terms of weight gain and net profit in Brazilian reais*

* US\$ 1.00 = R\$ 2.91, average for Nov. 2003

Source: Dos Santos (2003).

There is a direct correlation between the amount of crop residue dry matter and the yield of the following crop, as shown by Séguy and Bouzinac (2002). The farmer must know this to gauge the opportunity cost of the pasture consumed (see Figure 7), but this requires a level of cost analysis beyond that of most farmers. Pasture renovation with ZT can be done without a crop phase, by desiccation of the old pasture, re-seeding with fertilizer and liming, using part of the technology described on the following pages.



Regressions* of yield of a medium cycle soybean variety FT-114 on quantity and type of biomass of the preceding crop. 1997/2000, Agronorte, Sinop, Mato Grosso, Brazil

① --- Finger Millet - Y_{pg}	$Y_{pg} = 0,5957X + 948,76$	$R = 0,91$
② --- Pearl Millet - Y_{mi}	$Y_{mi} = 0,4528X + 2181,6$	$R = 0,90$
③ --- Sorghum - Y_{so}	$Y_{so} = 0,629X - 154,63$	$R = 0,97$
④ --- Sorghum + <i>Brachiaria R.</i> - $Y_{so} + B$	$Y_{so} + B = 0,4327X + 978,98$	$R = 0,80$
⑤ --- Pearl Millet + <i>Brachiaria R.</i> - $Y_{mi} + B$	$Y_{mi} + B = 0,2787X + 2110$	$R = 0,70$

↑ Biomass (dry matter) production interval

* 6 replications x different fertilizer levels each year

FIGURE 7: Correlation between total annual dry matter generated by the preceding crop and the yield of the following soybean crop

Source: Séguy and Bouzinac (2002).

Systems typology

Livestock systems in ICLZT are independent of the crops grown; the main ones are:

- (i) Fattening steers to slaughter weight;
- (ii) Rearing operations selling steers to (i);
- (iii) Combined rearing and fattening operations;
- (iv) Cow calf operations selling weaners to (ii) and (iii);
- (v) Breeding-to-slaughter integrated operations;
- (vi) Intensive dairy operations;
- (vii) Small, non-intensive, dairy operations.

All may or may not include supplementary feed with silage, cut fodder and concentrates. In beef-from-pasture operations this is confined to the dry season and creep (supplemental) feeding of calves at high management levels. Use of salt or mineral mixes is general, even in the most extensive systems, and mineral supplements usually include protein or urea to improve digestibility of dry season forage. Feedlot fattening can be grafted on to (i), (iii) and (iv), considerably increasing intensity of land use. Pure feedlot fattening is not discussed here as it is an independent alternative to fattening on pasture.

There is no over-arching crop system typology. The chief distinction is between rainfed and irrigated cropping, which is rarely without a rainfed area. Few farmers change their basic cropping pattern when adopting ICLZT, although they may undersow maize or oversow soybeans with grasses or grow earlier varieties to allow greater winter pasture production as a second crop. Some advanced farmers irrigate intensively-grazed pasture. Cattle farmers adopting ZT cropping (a lesser trend) usually choose soybeans or cotton as their main cash crop. The latter is late-sown in December, which allows time for early bite grazing at the onset of the rains with pearl millet, finger millet or forage sorghum.

Basic ICLZT systems have a crop and a pasture phase in rotation and comprise:

- (i) Winter stubble grazing on summer cropland;
- (ii) Summer crops with winter pastures (undersown or oversown);
- (iii) Summer crop plus second crop plus stubble grazing in winter;
- (iv) Crop production for feed supplement (silage, sugar cane, elephant grass, hay, green forage), usually a minor area within another system;
- (v) Some combination of these.



Common rotations

Soybeans are often mono-cropped for several years during the low disease-weed-pest pressure period after land clearing and are universally dominant in rainfed farming, with maize in rotation, when practised, every two to four years. Soybeans do not return enough biomass to the system for long term sustainability. While physical soil degradation has been severe under conventional soybean cultivation it has been hardly noticeable under ZT, leading many farmers to disregard a pillar of CA, crop rotation.

Maize is essential for adequate biomass generation in a CA rotation, but in frontier areas the market is weak; higher transport costs per unit value and higher storage requirements (both double those of soybeans) severely limit its use in rotations. In such regions rice is often grown as a pioneer crop after clearing (Séguy *et al.*, 1998), or in pasture renovation (Kluthcouski *et al.*, 1999). New rice cultivars can exceed 5 tonnes/ha (Séguy *et al.*, 1998). Cotton and Phaseolus beans have the advantage of late sowing, allowing more grazing on winter pasture. In the western Cerrado and in Amazonia a second crop of maize can be highly profitable. Alternatives to maize as a second crop in lower rainfall areas are pearl millet (*Pennisetum americanum*), sorghum (*Sorghum bicolor*) and finger millet (*Eleusine coracana*), or pasture grasses sown in association with the main or second crop.

A common starting point for adoption of ICLZT would be a 10 to 20 year-old degraded pasture. The most generalized ICLZT rotation would be: Yrs 1, 2 and 3 soybeans in summer and stubble grazing in winter; Yr 4. maize, undersown with *Brachiaria brizantha* or *B. ruziziensis*; years 5–7 or 5–8 pasture.

The most sophisticated rotation would be: Yr 1 cotton-winter fallow, Yr 2 soybeans-second crop maize, Yr 3 soybeans-second crop maize undersown with finger millet and *Panicum maximum*, Yr 4 one-year *P. maximum* ley. This maximises the stocking rate on the pasture up to 4–5 AU/ha, resulting in 75 percent of the farm in crops (Vinne, 2001).

The simplest rotation would be that of Case Study 5, a predominantly cattle operation, with: 6 year-old pasture converted to Yr 1 maize for silage and/or grain, undersown with grass, Yr 2–7 pasture (enriched, or not, with pigeon pea).

Crop successions used as building blocks for rotations

Crop successions, which are the building blocks for any desired rotation, can be classified as follows:

- Crop establishment in degraded pastures;
- Pasture establishment in, or immediately following, an annual crop (for permanent or temporary pasture). This could include dual use of a cover crop both for grazing and subsequent soil cover;
- Use of crop areas for silage or green chop production as supplement for cattle;
- Enrichment of existing pastures with legumes. This is practically limited to sowing pigeon pea directly into existing pasture;
- Sowing annual crops into a permanent grass or legume sward;
- Opportunity grazing of crop stubble in the dry season.

SUMMARIES OF THE TEN MAIN ICLZT TECHNOLOGIES

1. Crop establishment in degraded pastures

Excessive impediments to mechanized cultivation, or toxic aluminium levels in the 0–20 cm layer, may require full land preparation to remove irregularities and incorporate lime. When necessary, operations should be carried out towards the end of the rains and an annual fodder sown immediately to provide enough winter grazing to more than compensate for loss of the old pasture. This removes the chief concern of the rancher (i.e. lack of winter forage). These fodders must be grazed to suppress flowering or they will mature and die back. If they set seed, it will fall to the ground and germinate with the first rains. Either from regrowth or seed, ground cover can be generated and ready for desiccation prior to sowing the annual crop (see Box 5). In the case of subsoil deficiency in calcium or sulphur deficiency, gypsum can be applied along with lime, whether incorporated or not.

If no impediments exist the degraded pasture is desiccated at the beginning of the rains with a systemic, non-selective herbicide (glyphosate, or ammonium gluphosinate). Specialized ZT planters (Plates 19, 21 and 23–25) place seed and fertilizer below the residue. A narrow in-row tine or special fertilizer boot behind the cutting disc (Plates 26 and 27) is necessary in old, degraded pasture to break the compacted surface layer, allowing deep fertilizer placement and penetration of crop roots.

BOX 5. Critical points: Crop establishment in degraded pastures

- (i) Pasture should be heavily grazed or cut prior to desiccation, which is done when leaf area has recuperated enough to absorb the herbicide;
- (ii) Clumps (tussocks), if not well rotted, will cause the planter to jump and leave seed exposed on the surface even after rotary chopping;
- (iii) An interval of up to 21 days is needed after desiccation to allow root fermentation – a light second desiccation is usually required just prior to sowing.

Where there is no compacted layer or excessive residue to clog the tines, offset double discs of different diameters for both seed and fertilizer are used (Plates 26 and 27; more information in Baker, 2007). Thereafter selective herbicides are used *ad hoc* in the crop. A one-year pasture ley maximizes the proportion of crops in the rotation for a given herd size, which is an option when crop prices are high.

When soil conditions are adequate any annual crop can be sown with this technology – soybeans (see Plate 5), phaseolus beans, maize, cotton etc. There is a special bonus with phaseolus beans because of the low level of soil disease and nematodes after desiccating *Brachiaria* (Da Costa and Rava, 2003; and Vilela *et al.*, 2004).



PLATE 5: Adhemar Tietze, pioneer guacho farmer in Sinop, Mato Grosso state, shows desiccated *Brachiaria* residue in ZT soybeans.

2. Establishing pasture in annual crops

The most common options for establishing pasture in annual crops are: undersowing (see Plate 6), intersowing and oversowing.

Rainfall availability is greatest with undersowing and least with sowing after harvest. CAT Uberlândia (2005) has shown no difference in maize yield when 9 kg/ha of *Brachiaria ruziziensis* seed was sown at the two and four leaf stages of maize, but the two leaf sowing gave quicker establishment and allowed earlier grazing. Kluthcouski *et al.* (2003) affirm that *Brachiaria* undersown in maize can be shaded to the



PHOTO: I. DOWICH

PLATE 6: Nelore cattle on *B. brizantha*, established under maize.

point of not requiring herbicide to check it (tropical grasses are C_4 plants, hence shade intolerant). For manual systems, a jab planter can be used, mixing seed with fertilizer or some inert granular material, but if the stand is not uniform shading will be inadequate and some yield loss will occur from competition from *Brachiaria* in the unshaded areas.

Oversowing can gain up to three weeks on same-day sowing after harvest, which is crucial because the amount of rainfall after germination is correlated with establishment and dry matter yield. However, conditions for establishment with oversowing are not always adequate and this risk must be accepted against the potential benefit and low cost factors. Intersowing is carried out by planting in the inter-row of the crop after emergence (see Plate 7 and also Plate 8).

PLATE 7: *Brachiaria* spp. intersown in maize at 20 DAP.

Maize undersown or intersown with *Brachiaria* is the most important method for establishing pastures (see Box 6 for more details), and may have nurse crops other than maize e.g. rice (Kluthcouski *et al.*, 2003). Grass may be undersown, mixed with fertilizer at sowing, dropped onto the row in front of the trash disc from additional seed hoppers or by shallow drilling two rows in the inter-row at the 2–4 leaf stage of the maize. Excessive



PLATE 8: *Brachiaria* intersown in maize; note the height of the grass shortly before maize harvesting.

BOX 6. Critical points: Establishing pasture in annual crops

- (i) *Brachiaria* seed mixed with fertilizer should be sown in maize 7–10 cm deep in lighter soils and 3–4 cm deep in heavier ones to delay emergence (Cobucci and Portela, 2003); some farmers have reported up to 10–20 percent yield depression in very wet years (about 1 in 10 frequency) with this method, using *B. brizantha*, but little with the less aggressive *B. ruziziensis*;
- (ii) Seed mixed with fertilizer should be sown the same day or vigour may be affected, especially with fertilizers containing high K or N levels (Kluthcouski *et al.* 2003). Experience indicates a possible problem of seed burn if, in a dry spell, the soil has inadequate moisture to dilute the fertilizer;
- (iii) Unless the soil is very well structured, the ZT planter or drill must be equipped with a narrow in-row sub-soiling tine to break the 5–10 cm compacted zone in the old pasture – alternatively, larger diameter fluted trash discs might be tried;
- (iv) Panicums and other small-seeded grasses are unsuited to deep planting and must be shallow-drilled, about 1 cm; at present insufficient information is available to define the parameters for undersowing small-seeded grasses in general.

grass growth can be checked with sublethal doses of Nicosulfuron of 8–12 gm a. i./ha (Cobucci and Portela, 2003). Experiments in several locations and years showed little or no significant difference in maize or sorghum yields (Kluthcouski *et al.*, 2003), see Table 6.

In upland rice, undersowing has been common under conventional tillage and works well with ZT when the grass is sown in the rice row to control shading. Although some yield reduction of rice has been observed (Kluthcouski *et al.*, 2003) – the same depths of sowing should be observed as for maize. undersowing is possible in soybeans: reduced post-emergent applications of haloxyfop-methyl are promising and Cobucci and Portela (2003) recommend one quarter of the full application to check *Brachiaria* spp., but this technology is not well field-tested and results will be very dependent on the metabolic activity of the grass.

3. Sowing pasture after early harvest

Usually, but not always in the Cerrado, there will be sufficient rain to establish a pasture up to late February (see Box 7). The ideal method for sowing is with a ZT drill in closely-spaced rows (approx. 15 cm), straight after harvest (i.e. behind the combine on the same day). Drilling is preferred, but most farmers do not have a drill and broadcast the seed with

TABLE 6: EFFECT OF UNDERSOWING BRACHIARIA SPP. ON MAIZE CROP YIELDS

CROP	YIELD (kg/ha) ¹	
	PURE STAND	UNDERSOWN WITH GRASS
Maize ^{2 and 3}	6 354–6 877	6 401–6 795
Forage maize ²	48 367	48 467
Grain sorghum ⁴	3 687	3 581
Forage sorghum ⁴	32 333	32 867
Soybeans ^{2 and 5}	2 971–3 056	2 677–2 414
Rice ^{6 and 7}	1 968–2 072	1 503–1 859

¹ Average of six repetitions;

² Average of four locations;

³ Average of two locations: Santa Helena de Goiás-GO e Luziânia-GO.

Refers to application of 6g of a. i./ha of nicosulfuron in maize undersown with grass;

⁴ Average of two locations: Santa Helena de Goiás-GO, Luziânia-GO and Mimoso-BA;

⁵ Average of three locations: Santa Helena de Goiás-GO, Campo Novo dos Parecis-MT and Mimoso-BA. Refer to application of 24 g of a. i./ha of haloxyfop-methyl in soybeans undersown with grass;

⁶ Average of two locations: Luziânia-GO and Mimoso-BA;

⁷ Average of Luziânia-GO. Refers to application of 120g of a. i./ha of clefoxydin in rice undersown with grass

Source: Adapted from Kluthcouski *et al.* (2003).

BOX 7. Critical points: Sowing pasture after early harvest

- (i) Adequate rainfall to get through the dry season should be guaranteed by early sowing;
- (ii) Local trials are necessary to optimise sowing date with variations in rainfall, soils, varieties, etc.

a fertilizer spreader, covering it by running a closed levelling disc harrow over the stubble. This low-cost method leaves about 40–60 percent cover, but it oxidises organic matter and increases the evaporation of precious moisture. In addition, it only has a moderate chance of success after February (i.e. it is best after an early harvest, but then the farmer's choice would be for a second cash crop, so pasture establishment with this system will always be in moisture-short situations). Finally, care must be taken to minimize soil and residue disturbance – ideally, over 70 percent cover should be maintained to guarantee erosion control.

An innovative São Paulo farmer's solution to this problem was the adaptation of a levelling disc, welding angle iron bars across old, worn, discs, which leaves the cover practically intact. A chain harrow, or light anchor chain, between two tractors, are superior solutions and faster operations, incorporating the broadcast seed into the crop residue with minimal disturbance. Desiccation may be unnecessary if the weed burden is very low. Previous history of the field, plus spot observations should determine this option – persistent weeds, such as *Sida* spp., *Cassia rotundifolia*, *Commelina* spp. and *Digitaria insularis* should not be present. As much starter fertilizer at planting as the farmer can afford (emphasizing P) will assist in promoting good weed suppression and providing early bite. The amount of winter pasture in the first year will be governed by rainfall and overgrazing should be avoided.

4. Grass oversown in soybeans or maize

Oversowing can be done with a fertilizer broadcaster or by aerial seeding after field-testing to check the required overlap. Commonly-used forages in soybeans at full grain maturity are: pearl and finger

millets and *Brachiaria* spp., but Guinea and Molasses grasses have also shown some success (Landers, 1994). This system is cheap (just the seed plus application), offset by high risk of failure if rain does not follow shortly after seeding; the Cerrado and Amazon transition forest regions experience short dry spells of ten days or more during January-March (Goedert, 1985) when soybeans are maturing. Oversowing into maize increases the risk since there is no leaf-fall to cover the seed; it should be carried out at the beginning of canopy senescence, when more light penetrates to ground level. With any main crop, the earlier it is sown and the shorter its cycle, the greater amount of rain will fall on the second (oversown) crop (see Box 8). Rarely will the conditions exist for oversowing of the whole cropped area. However, the cash value of additional dry season grazing is very high. Beware of ants, beetles, other insects or birds reducing establishment by removing seed – an increase in seed rate may be required. Seed dressing with insecticide in this sowing mode is dangerous for birds and small animals, and should be avoided. However, fungicidal dressing can be useful to combat high pathogen pressure in the surface litter. *B. ruziziensis* germinates better on the soil surface than *B. brizantha*.

BOX 8. Critical points: Grass oversown in soybeans or maize

- (i) The best chance of success is when soil is moist at sowing and rain falls within a few days;
- (ii) The risk/benefit ratio must be clearly understood, or an eventual failure will lead to abandoning this practice;
- (iii) Seed rates must be 2.5 or 3 times higher than for drilling – for seed rates with drilling see Table 7;
- (iv) The best time to oversow in soya is between seed maturity (when the green grain comes easily away from the pod) and beginning of leaf fall and, under favourable circumstances, with at least light rain, up to 50 percent leaf fall (Landers, 1994);
- (v) Pelleting to improve germination potential has not been promising, but new hygroscopic materials would be superior to rock phosphate pelleting (W. Lara Cabezas, personal communication, 2003).

TABLE 7: RECOMMENDED SEED RATES FOR SOME TROPICAL GRASSES

GRASS SPECIES	SEED RATE (kg/ha PLS)*	SEEDS PER GRAM (No.)
<i>Andropogon gayanus</i>	2.5	360
<i>Brachiaria brizantha</i>	2.8	150
<i>Brachiaria decumbens</i>	1.8	200
<i>Brachiaria humidicola</i>	2.5	270
<i>Brachiaria ruziziensis</i>	2.0	230
<i>Paspalum guenoarum</i>	1.5	300
<i>Paspalum notatum</i> cv. <i>Pensacola</i>	1.5	610
<i>Panicum maximum</i> cv. <i>Tanzânia 1</i>	1.6	960
<i>Panicum maximum</i> cv. <i>Tobiatã</i>	2.5	680
<i>Panicum maximum</i>	1.2	1 900
<i>Setaria anceps</i> cv. <i>Kazungula</i>	1.2	1 490

* Pure live seed (= germination % x purity %).

Source: Adapted from Kluthcouski *et al.* (2003).

5. Grass regenerating during the first crop after ZT planting of a crop in old pasture

As the crop canopy thins, seeds will germinate from the surface seed bank (see Box 9). Under rainfed conditions *Brachiaria* spp. will not be daylength-triggered to flower before it is time to desiccate for a second

BOX 9. Critical points: Pasture regenerating from surface seed during the first crop after ZT planting of a crop in old pasture

- (i) It is important to achieve a full canopy quickly to suppress any grass which germinates;
- (ii) Graminicides should not be used in the summer crop, except at sub-lethal doses, to check competition from the grass, if necessary (Cobucci and Portela, 2003); this may have variable results due to differential response at varying levels of metabolic activity;
- (iii) Longer cycle crops or harvest delay due to rain may cause excessive grass growth which hampers harvest – maximum combine speed is achieved by removal of the row divider points, except the lateral ones (see Plate 9).



PLATE 9: Removal of row separator points reduces the quantity of grass passing through the combine and permits high speed harvesting.

crop, so the seed bank will dwindle. The decision to leave for winter pasture or desiccate post-harvest with a half dose of systemic desiccant will depend on the grass stand and the weed load. Dense stands of *Brachiaria* are good at weed suppression.

6. Planting forages on crop land for silage, green chop, dry season grazing or as a cover crop

Forage sorghum, pearl millet or finger millet can be drilled with ZT as a second rainfed crop for green chop forage, silage, grazing or cover crop biomass (see box 10). Sowing in January, or first half of February, will maximise rainfed dry-matter production, but this is seldom done, since the forage would compete with an economic second crop. Drought-resistant crops are usually sown after March 1st. Drilling is the preferred method for millets. Because of high residual nutrient levels from the preceding crop, little, if any, fertilizer is used.

Irrigated silage and green chop, if possible, should be scheduled away from competing with beans or other high value crops in the dry winter, when these are grown – there is inevitably a conflict with green-chop for fattening yards whose demand is constant. Seed rates for forage sorghum are between 8 and 12 kg/ha in 50–70 cm rows, for pearl millet 15–20 kg/ha and finger millet 10–15 kg/ha, both in 15–25 cm rows. Seed depth for sorghum should be 3–4 cm and <2 cm for millet. In high fertility conditions under irrigation, for silage production, specialised sorghum hybrids can out-yield maize (up to 70 tonnes of silage/ha), at reduced fertilizer rates, while maize reaches about 45 tons/ha under the same conditions (farm data, S. Conrado, Cristalina – GO 2003).

Some intensive systems have been producing two crops plus dry-season grazing: Séguy and Bouzinac (1997) report soybean yields of 4 000–4 600 kg/ha, 1 500–3 500 kg/ha of second crop grain plus 1–1.5 AU/ha for 90 days in the dry season with a mixture of the three forages. This gave a total gross margin for the annual succession of US\$ 150–350/ha.

7. Pasture renovation with forages sown jointly with grasses, for early grazing

A specially-designed ZT combination drill has three hoppers (grass seed, forage seed and fertilizer). A set of trash discs cut through crop

BOX 10. Critical points: Use of crop land for silage or green chop as supplement to cattle, for dry season grazing or a cover crop

1. Rainfed areas:

- (i) Taking maize silage may allow a second crop to follow or, with sorghum x Sudan grass hybrids, a second cut;
- (ii) Harvesting may leave ruts or compaction which require conventional tillage to remove, but where *Brachiaria* is undersown, its root development can counter the compaction; planting the silage/green chop crop on desiccated pasture would be ideal in this respect;
- (iii) Regrowth from sorghum after the last cut can give valuable dry season grazing or biomass as a cover crop, to be desiccated prior to the next crop. Note: in frost-prone areas, cattle must be removed after frost, to avoid possible hydrocyanic acid poisoning;
- (iv) For grazing, these forages should not be allowed to initiate flowering – this will maximise regrowth and tillering.

2. Irrigated areas:

- (i) Silage and green chop are best cut in the drier months of April to September (silage to June only), to avoid soil compaction and formation of ruts;
- (ii) Phaseolus beans are the prime irrigated crop and are grown from May to July (90 day cycle); rotation with a grass (especially *Brachiaria*) is highly beneficial for disease control (Nasser *et al.*, 2001; Da Costa and Rava, 2003) and soil structure improvement for the bean crop. Light grazing may be started as early as 30 days, but on loose soils care must be taken that the cattle do not uproot the plants.

residue, followed by a narrow fertilizer boot with scarifier tine in the row (to cut through the 5–10 cm surface-compacted zone in the old pasture and place the fertilizer about 15 cm deep), as shown in Plate 10 (detailed view in Plates 26 and 27). This is followed by alternate sets of offset double disc furrow openers with different size discs for the grass and the forage sorghum, respectively, at about 15–18 cm spacing with open clod-busting rollers behind.



PHOTO: M. SCALEA

PLATE 10: A seeder-scarifier for sod seeding.

8. Pigeon pea sown into existing pasture to improve winter grazing quality

For sowing pigeon pea into existing pasture (see Box 11), the seeder-scarifier (Plate 10) is used or a normal ZT planter is used with a fertilizer knife to break the surface-compacted layer, and not a double disc. Fertilizer (especially phosphate) applied in planting will also renovate the grass and the pigeon pea can fix up to 150 kg/ha of N, also improving grass vigour (Dos Santos, 2003). The extra protein of the legume allows cattle to utilize poor quality winter grass efficiently. Pigeon pea seed rate should be 50 kg/ha and planting depth 4–5 cm. This technology can be adapted for *Leucaena leucocephala* and other legumes, although there is little local experience. *Leucaena* suffers from severe leaf drop in the dry season, and did not fulfil early promise (C. U. Magnabosco, personal communication, 2003).

BOX 11. Critical points: Pigeon pea sown into existing pasture to improve winter grazing quality

- (i) The lime and aluminium status of the soil should be adequate for pigeon pea, otherwise liming is required;
- (ii) Lime should be surface applied, with, at the very least, four months of rain prior to sowing;
- (iii) Cattle trails should be scarified, termite mounds and erosion gullies removed;
- (iv) Grazing management should allow time for the pigeon pea to resprout;
- (v) A pigeon pea variety should be selected with characteristics similar to the Brazilian “Bonamigo Super N”, which is usually avoided by the cattle until the grass protein content falls below the critical 6 percent for maximum rumen activity;
- (vi) On many soils, the pigeon pea nodulates with native rhizobia, however performance may be enhanced by inoculating with a specific strain.

9. Sowing perennial legumes into maize

This technology has good potential, but requires more development of control mechanisms to check established perennial legumes (sub-lethal doses of selective herbicides, or for small farmers, mechanical treatments);

(see Box 12). A forage legume is established by undersowing in maize either using a pelleted insecticide applicator coupled behind the seed discs or by mixing the seed with phosphatic fertilizer and directing the fertilizer spout towards the soil falling back in the furrow after the seed disc (Landers, 1994). This implies pre-planting fertilization for the maize and topdressing of K and N, or a combination planter with three hoppers. The most compatible legumes were Siratro (*Macroptilium atropurpureum*) (see Plate 11), followed by centro (*Centrosema pubescens*), but kudzu (*Pueraria phaseoloides*) and glycine (*Neonotonia wightii*) were more competitive.



PHOTO: H. M. SHELTON

PLATE 11: Siratro (*Macroptilium atropurpureum*), a deep-rooted perennial forage legume, is very compatible for sowing into maize.

BOX 12. Critical points: Sowing perennial legumes into maize

- (i) A selective herbicide compatible with both maize and legumes (e.g. alachlor), can be used in the establishment year to control weeds at normal dosage rates for maize;
- (ii) 2,4-D is not effective on vigorously growing perennial soybean and some Stylos, while some maize hybrids may be susceptible to stalk breakage;
- (iii) Local tests are required to find the best companion legume – non-climbing ones might be better e.g. *Stylosanthes* spp., but not *Arachis pintoi*, which is too vigorous;
- (iv) The legume may be a bit weedy in the establishment year, but after that it comes away fast after the first rains and smothers annual weeds;
- (v) Care must be taken not to allow the legume to compete excessively with the maize, when severe yield depression will result;
- (vi) Legume tendrils on the maize may slow combine speed for grain harvest but do not affect silage choppers, and the legume enhances the quality of the silage.

For silage, this system is excellent, leaving a full soil cover and giving high quality winter grazing which can be used as a protein bank. Also, the legume and surface litter will reduce surface compaction from machinery. A double straight disc between the rows, at about 10 cm from the maize row, can cut the tendrils and prevent the legume from climbing on the maize.

10. Sowing soybeans in a permanent grass sward

This technology has been tested in Mato Grosso (Séguy and Bouzinac, 2002); the idea is not to kill the grass (see Box 13), but to arrest growth up to soybean grain maturity. A Tifton cultivar of *Cynodon dactylon* was used with reported soybean yields of over 3 000 kg/ha. The grass, which can be grazed in the dry season, helps to suppress annual weeds and provides biomass for soil cover. The same authors obtained 90 days winter grazing for 1–1.5 AU/ha with this system and a total gross margin of US\$ 200–400 per ha for the annual succession.

BOX 13. Critical points: Planting soybeans in a permanent grass sward

- (i) Correct sub-lethal doses of graminicides may be necessary to check grass growth; effectiveness will depend on the physiological activity of the grass;
- (ii) The compatibility of other crops with this system needs to be tested, in order to obtain a sound rotation.

OPPORTUNISTIC GRAZING OF STUBBLE IN THE DRY SEASON Pigeon pea undersown in maize for stubble grazing

This is a traditional practice reported by Von Schaffhausen (1949). Pigeon pea seed is mixed with the fertilizer and deep sowing (10–15 cm) delays its emergence in the maize row, where it remains shaded until maize senescence (see Box 14). Manual jab planting in the row would follow planting of maize after 30 days. In the second year the pigeon pea should be rotary chopped before sowing and the regrowth sprayed

BOX 14. **Critical points: Pigeon pea undersown in maize for stubble grazing**

- (i) Pigeon pea seed may be mixed with the fertilizer and sown in the maize row – it must be of high vigour and sown the same day as mixed;
- (ii) Second year plants, if not wanted, are killed by ground level rotary chopping followed by a directed narrow band in-row application of glyphosate or sulfosate on the re-sprouts (if any) – this can be achieved by rotating fan nozzles to a diagonal position and adjusting application rates accordingly, giving a savings of over 50 percent on herbicide cost – application must follow the original planter rows and cover the same width as the planter.

with a systemic desiccant herbicide or a split dose of paraquat (1.5 and 1.5 L/ha of commercial product). If left to grow in the second year, it will need to be regularly grazed or it will become too woody for a combine cutter-bar or easy manual eradication. However, it could then still serve as a source of firewood or fodder for a small farmer.

Grazing stubble in the dry season

Nonavailability of fences and watering facilities can limit the use of stover by cattle. Electric fences are cheap, with an investment cost in Brazil of about US\$ 80–100 per kilometre. The ratio of stubble area to permanent pasture area is crucial to performance in this system. The greater this is, the more positive the impact on farm total carrying capacity (for more details, see Box 15).

PASTURE GRASSES

Pasture grasses need to be selected according to the soil fertility level and internal soil drainage, a problem mostly confined to wetlands. Table 8, for the Cerrado region, shows the fertility requirements of the principal pasture grasses used in the wet/dry Brazilian tropics. There is very little information on which grasses are suited to integrated crop-livestock rotations in the Amazon region, but this table would be a good starting point, except for poorly-drained soils, where of the recommended

BOX 15. Critical points: Grazing stubble in the dry season

- (i) Cattle compete with the ZT cropping system for the residue – incomplete soil cover leads to greater weed infestation, but a 70 percent cover is enough to prevent erosion in most circumstances;
- (ii) Soybean haulm is especially susceptible to untimely rains that accelerate its decomposition;
- (iii) Mineral salt with a protein additive is essential to effective rumen throughput and hence total feed assimilation, and is provided in roofed salt troughs, usually not removed during cropping – movable types on skids are preferable;
- (iv) Putting the cattle on the stubble also permits deferring grazing on permanent pasture to later in the dry season, with some recovery from residual soil moisture and late rains.

grasses, only *Paspalum atratum* and *Brachiaria humidicola* are suited (the native Pará grass, *Brachiaria mutica* is also suited to wetlands), while *Andropogon gayanus* and *Setaria anceps* are suited to drier climates.

In spite of the availability of a wide range of tested pasture legumes, there has been negligible uptake of mixed grass-legume pastures in Brazil, due to:

- (i) real or imaginary difficulties in grazing management of these pastures;
- (ii) excessive cost of seed, due to inefficient establishment of the legume and high market prices because of low demand; and
- (iii) lack of efficient establishment systems for mixed pastures, which could start by undersowing legumes in maize and direct drilling the grass at the onset of the following rains, when the legume would have the advantage of an established root system and be able to compete with the grass coming up from seed. Landers (1994) indicated how to establish pasture legumes with maize using alachlor as a selective herbicide for both. On-farm research is required on these aspects.

For pasture grasses, Table 8 can be used either for initial species selection, or to indicate when corrective P fertilization should be carried out. Full fertilizer and lime recommendations for these forages are found

TABLE 8: ADAPTATION OF GRASS SPECIES TO SOIL FERTILITY LEVELS

SPECIES	FERTILITY LEVEL DEMANDED	ADEQUATE P LEVEL*
<i>Andropogon gayanus</i> cv. Planaltina	Low	2 to 9
<i>B. decumbens</i> cvs. Basilisk, IRI 562	Low	2 to 9
<i>B. humidicola</i> cv. IRI 442	Low	2 to 9
<i>B. ruziziensis</i>	Low	2 to 9
<i>Paspalum atratum</i> cv. Pojuca	Low	2 to 9
<i>B. brizantha</i> cv. Marandu	Moderate to high	3 to 15
<i>Setaria anceps</i> cv. Kazungula	Moderate to high	3 to 15
<i>P. maximum</i> cvs. Vencedor and Centenario	Moderate to high	3 to 15
<i>P. maximum</i> cvs. Colônia, Tanzânia-1, Mombaça and Tobiata	Very high	5 to 21
<i>Pennisetum purpureum</i> cvs. Elefante, Napier	Very high	5 to 21
<i>Cynodon</i> spp. cvs. Coastcross and Tifton	Very high	5 to 21
Sugar cane	Very high	n.a.

* Mehlich (g/m³) Low value corresponds to <15% clay and high value to >60% clay i.e. lower P demand on soils with lower C.E.C.

Source: Sousa and Lobato (2003), with addition of some cultivar names.

in Sousa and Lobato (2003). The traditional Molasses and Jaraguá grasses (*Melinis minutiflora* and *Hyparrhenia rufa*), adapted to poorer soils, have been out-performed by the Brachiarias and their use is now rare. Quinn *et al.* (1963) showed the inferior performance of Molasses grass compared to Colonial Guinea Grass in all situations, and inferior performance of Jaraguá in high fertility situations, but holding its own under low fertility.

COVER CROPS FOR GRAZING

Pearl Millet, *Pennisetum americanum*. This can be used purely for biomass production, for high-quality grazing, for hay or for seed, although rarely yielding more than 500 kg/ha of grain in late autumn sowings, due to rainfall limitations; the protein content of its grain is almost twice that of maize (Scalea, 1999). Harvest is by combine harvester (by hand on small areas) and most farmers produce their own seed. Breeding programmes have still not released hybrids; these should make millet a good option as a grain crop for very late summer plantings as it can extract nutrients from depth and can be sown on residual fertility, with just a small top-dressing of N.

Pearl millet can be a host for army worm, but it controls nematodes well and its residues apparently encourage less slugs in irrigated conditions than those of maize. Millet is a slow starter, accelerating development from about 30 days after sowing. After the first month, in spring it can produce over 100 kg DM/day, but much less as days get shorter. Millet can smother weeds sufficiently to eliminate, or reduce, post-emergent herbicide use and has a similar effect in autumn once a good cover is achieved. Under grazing it should not be allowed to initiate flowering, in order to continue in vegetative mode.

Black Oat, *Avena strigosa*. This is not widespread in the tropics and is limited to latitudes close to the tropic of Capricorn (São Paulo, Paraná and Mato Grosso do Sul states) or altitudes above 1 000 m, as it does not take well to heat. It dies back in summer and only requires rolling, obviating pre-plant desiccation and often eliminating the need for post-emergence herbicides, besides acting as a good recycler of nutrients and incorporator of calcium in depth by translocation to its roots. When grazed it should not be allowed to initiate flowering to maintain it in the vegetative phase.

Forage Radish, *Raphanus sativus*. This crop has a deep tap root and is a good recycler of N and other nutrients and has excellent forage value. It is more a subtropical crop and performs best near the tropic of Cancer, but has been used successfully at 16° S and 1 000 m altitude. Its small seed requires care in sowing. This crop is a good precursor for maize. Forage radish's thick, carrot-like roots act as biological sub-soiling agents. It may advantageously be mixed with other cover crops, especially black oats, giving complementary cover, with a different growth cycle. The Instituto Agronômico do Paraná has released improved varieties of both black oats and forage radish.

Cut forage and silage crops

Commercial hybrids of maize and forage sorghum or sorghum x Sudan Grass hybrids are the principal forages used for silage, and some open-pollinated varieties from the Guinea coast of Africa have shown promise (Séguy and Bouzinac, 2002). Resprouting ability after the dry season is

an important quality to evaluate in sorghums. Sugar cane, elephant grass and recently, *Brachiaria brizantha* cv. Marandu are the most important plants for cut forage. The importance of the latter is that it can fit into a rotation as a catch crop, whereas sugar cane and elephant grass occupy the same land for several years of ratooning. Kepler (2000) recommends cutting maize silage no lower than 30 cm, leaving the potassium-rich, indigestible lower stems. The recommended stage for cutting maize for silage is full grain maturity (black layer at the base of the grain). Sunflower can also be used for silage.

Pasture and grazing management

The merits of continuous versus rotational grazing will not be discussed; in general, the former show superiority at lower stocking rates. Rotational grazing is generally preferred in ICLZT systems in tropical Brazil. Table 9 gives a guide to managing the main grasses. On a pasture which is still in

TABLE 9: GRAZING MANAGEMENT OF TROPICAL GRASSES

GRASS	HEIGHT AT ENTRY (cm)	HEIGHT AT EXIT (cm)	GRAZING PERIOD (days)	REST PERIOD (days)
<i>Andropogon</i>	40–45	15–20	1–3	28–30
<i>Brachiaria brizantha</i>	30–40, 50–60	15–20, 30	1–3, 1–7	28–30, 28–42, 30–35
<i>B. decumbens</i>	30–40, 50–60	15–20, 30	1–3, 1–7	28–42, 30–35
<i>B. ruziziensis</i>	30–40	20–25	1–7	28–42, 30–35
<i>P. maximum</i>	50–60, 80–100	25–30, 40–45	1–3, 1–5, 7, 7–10	35, 35–40, 35–42
<i>P. maximum</i> cv. Tanzânia	50–60, 70–80	25–30, 35–40	1–3, 7	35–42
<i>P. maximum</i> cv. Tobiata	50–60	25–30	7	35–42
<i>Pennisetum purpureum</i> Schumach. cv. Napier	110–120	50–60	1–3, 3–7	35–45, 45
<i>P. purpureum</i> cv. Elephant Grass	60–80	20–25, 30–40	1–3	45, 45–50
<i>Hyparrhenia rufa</i> (Nees) Stapf	30, 30–40	10, 15–20	1–3, 7–10	30, 35–40
<i>Digitaria decumbens</i> Stent	25–30	10–15	1–3	21–28
<i>Setaria</i>	30–40	15–20	1–3	30
<i>Cynodon nlemfuensis</i> and <i>Cynodon dactylon</i>	25–30	5, 10–15	1–3, 1–7	21–28, 25–30
<i>Melinis minutiflora</i> Beauv.	30–40	15–20	3–7	35 – 45

Source: Bonamigo (1999).

the maintenance phase, subdivision and rotational grazing on a 30–40 day interval can give a significant boost to production. In this situation, the investment in more animals to profit from the higher carrying capacity is greater than the investment in electric fences (now common) and watering facilities (Smith, 2004). See the example of Case Studies No. 1 and 6 in Chapter 5. Continuously grazed permanent pasture, or temporary winter pasture, both need to recover after the first rains; the latter to regenerate biomass for desiccation in order to provide adequate residue cover (at least 30 days). Temporary grazing on the crop area must allow grazing on part of the permanent pasture to be deferred until the onset of the rains, preferably in bottomland with better moisture availability (see Case Study 1 in Chapter 5). At this critical period beef prices are still high and stockyard or supplemental feeding with silage or green chop may be attractive alternatives (See Case Studies 1, 2 and 5).

Kluthcouski *et al.*, (2003) recommend an initial light grazing of grasses undersown in maize directly after harvest, to encourage tillering and to correct any etiolation problems. For mature pasture, these authors recommend grazing at the highest level of protein (flower initiation), however, in practice, as flowering is not year-round, the critical height in Table 9 can substitute for this criterion.

Weight gains of 1 kg/day were recorded between April and June on a sorghum + *B. brizantha* mix, stocked at 3.5 head/ha. This pasture also furnished maintenance grazing until the onset of the rains (Kluthcouski *et al.*, 2003). “Early bite” with forage sorghum intersown with a permanent pasture species gives grazing of the sorghum at 30–45 days after sowing. A comparison between the calendars of ZT and conventional tillage in crop–pasture rotations, using the above system, was made by Dos Santos (2003), as shown in Figure 8. The elimination of time for land preparation and the inclusion of forage sorghum for early bite gave a considerable advantage in pasture carrying capacity over the time of the comparison.

Adjustment of stocking to pasture production is necessary to avoid overgrazing and reduction of regeneration capacity. Martha Junior *et al.* (2004) have developed a methodology to calculate the grazing and rest periods in a rotational grazing system according to desired weight gain, forage availability and pasture recuperation capacity, based on the values

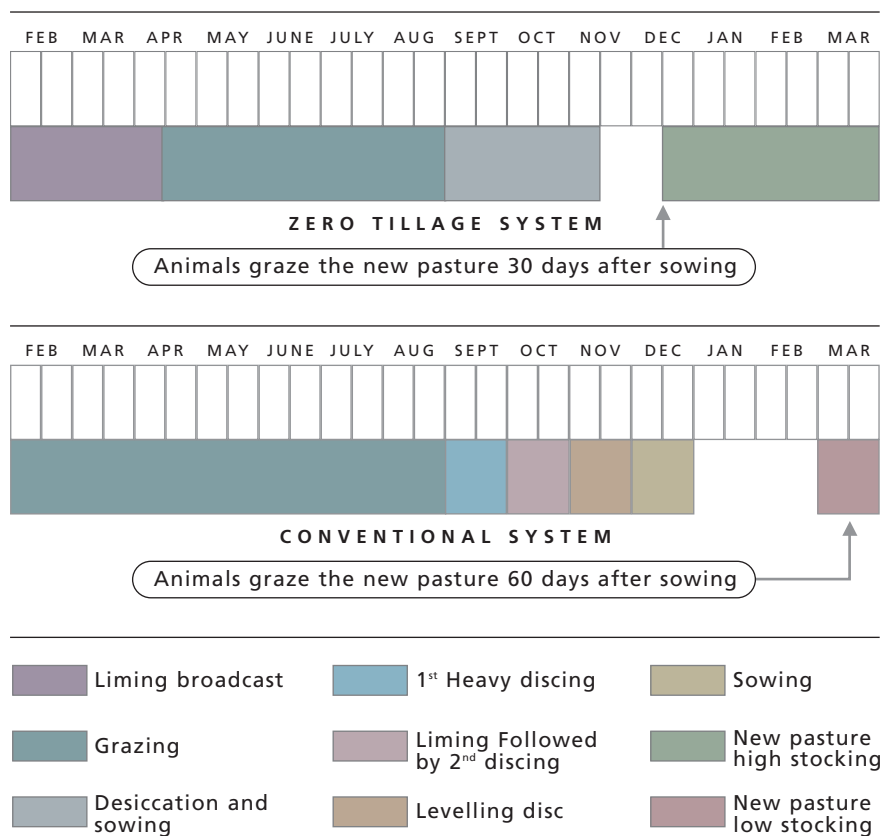


FIGURE 8: Comparison between the calendars of a ZT-based crop-pasture rotation and one based on conventional tillage

Source: Dos Santos (2003).

TABLE 10: PASTURE MANAGEMENT PARAMETERS AT DIFFERENT INTENSITIES OF LAND USE

PASTURE PARAMETERS	INTENSITY OF LAND USE			
	EXTENSIVE	SEMI-INTENSIVE	INTENSIVE	VERY INTENSIVE
Return period (days)	56	42	38	36
Forage Production (kg DM/day)	30	50	70	120
Grazing efficiency (%)	45	50	55	55
LIVEWEIGHT CLASS	STOCKING RATE (AU/HA)			
200 kg	1.18	2.18	3.36	5.75
300 kg	1.30	2.42	3.72	6.38
400 kg	1.41	2.61	4.03	6.90

Source: Martha Junior *et al.*, (2004).

in Table 10. The net offer of forage in a paddock, adjusted for grazing efficiency, is balanced by the total demand for a given number of animals and the number of grazing days in the rotation. This could be refined by using total digestible nutrients (TDN).

LEGUMES IN PASTURES

The establishment and management of grass-legume pastures have, so far, been beyond the management capacity of most farmers in tropical Brazil, although adapted cultivars and experimental results are available. Where it has been done, results are highly encouraging, see below, but management for legume survival is critical. Undersowing, oversowing, sowing the legume before the grass and seed pelleting or coating require more study.

Pigeon pea is a notable exception and its use in ZT sowing into pasture (or in maize, for stubble grazing — Von Schaffhausen, 1949), is well-established and increasing. The most successful perennial legume has been *Stylosanthes guianensis* cv. Mineirão, but it is slow to establish and its seed is high-priced (normal for a new cultivar with little outlet).

Liveweight gains on different pastures were maximized by using a *Stylosanthes guianensis* protein bank, with *Brachiaria brizantha*, giving gains of 577 kg/ha/year as compared to 258 kg/ha/year with *B. brizantha* alone. Another grass/legume pasture (*B. decumbens* + *S. guianensis*) gave an intermediate performance (Macedo, 1999). *Leucaena leucocephala* protein banks suffer from severe dry season leaf drop, making them only suitable to very restricted areas with a relatively high water table, but which do not become waterlogged in the rains. Protein banks avoid the complications of managing a mixed sward, and access once a week can be adequate.

CHAPTER 4

Mechanized operations in zero tillage and soil fertility management

Operations are described in order of occurrence, starting from managing residues, through pre-plant desiccation, planting-drilling and post-planting operations. This is followed by considerations of liming, gypsum application, summaries for N, P and K and a section on soil sampling under ZT. Liming and fertilizer application use conventional technology and are therefore not discussed in detail.

RESIDUE MANAGEMENT

The first rule in residue management is to ensure even distribution of crop residues after harvest; this helps to suppress weeds and facilitate planting/drilling operations. Combine harvesters should use a straw spreader or chopper to ensure this. Argentine rolls (knife rollers) are effective on some cover crops, especially black oats and should cross the direction of future planting rows. Vertical flail choppers and horizontal rotary choppers may be used to flatten maize or cotton stalks and break down clumps in pastures prior to desiccation. The latter tends to produce windrows, and planting diagonally across windrows reduces clogging.

SPRAYING DESICCANTS AND OTHER CHEMICALS

Pre-sowing desiccation is the most important operation in ZT. Weeds not properly controlled during desiccation are very costly to eliminate with selective herbicides. After sowing, the same selective herbicides are used as for conventional tillage; local or regional research-based information should be sought, with recommendations for the specific conditions of the farm.

Marking for desiccant application is absolutely necessary; besides surveying the fields and leaving permanent markers in fence lines, marking foam applicators at the tips of the spray boom are available and Brazilian farmers have developed a system (shown in Figure 9), which uses two tractors and a cable attached to the rear of the first tractor and the front end of the second. Since there is more weight on the rear wheels of the first tractor, it keeps the second in line. The first tramline is marked with poles at half the sprayer width from the field edge and as the first tractor goes along this line, the second leaves tracks in the stubble; the first tractor then follows the second tractor's tracks successively and the double passage leaves enough of a track to be followed during the spraying operation. Planting lines should be parallel to the tramlines (which help to keep tractor drivers straight), or may be transverse, accepting a minor loss of stand in the tramlines. Tramline spacing should be a multiple of planter row width.

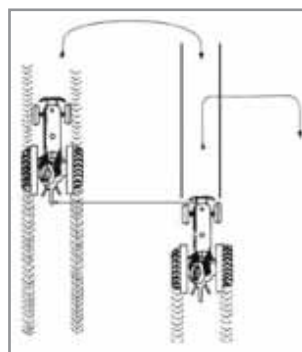


FIGURE 9: System of marking for pre-plant desiccation and later spraying operations, using two tractors and a cable for a gauge.

Sprayers range from 20-litre backpack, single-nozzle types to self-propelled versions with 24-metre booms and 2 000-litre tanks. Spray planes are widely used by large farmers.² Spray technology is a specialized affair and will not be dealt with in depth. Systemic desiccant herbicides must be applied as large droplets; low volume applications improve herbicide absorption and sprayer efficiency, but require higher skill in application. Reducing the amount of water applied from 200 litres/ha to 30 litres/ha substantially increases area sprayed daily and can permit reduction in chemical application rates. Stressed plants do not absorb herbicide effectively; the best timing is during vigorous growth, avoiding the middle of the day with its high temperature and low humidity.

An innovation for large farms is the drag system of applying chemicals. Two tractors drag a line of nozzles fed from a hose attached to

² Although application of desiccants (herbicides) by airplane is often done in practice, FAO does not recommend this technique, due to the environmental considerations involved.

a cable between them – the length of the cable can be up to 100 metres, giving a very high work rate for desiccant application.³

Desiccant application rates in pasture depend on the species involved. *Brachiaria ruziziensis* requires about half the dosage of glyphosate or sulfosate/ha compared to *B. brizantha*; *B. decumbens* is intermediate, while *B. humidicola*, panicums and other grasses require even higher dosages – a summary of manufacturers' recommendations for tropical Brazil is shown in Table 11.

TABLE 11: APPLICATION RATE CHART FOR GLYPHOSATE¹ FOR DESICCATION OF OLD PASTURE, ACCORDING TO GRASS SPECIES

HIGH SUSCEPTIBILITY	MEDIUM SUSCEPTIBILITY	LOW SUSCEPTIBILITY
<i>B. ruziziensis</i>	<i>B. brizantha</i> ² , <i>B. decumbens</i> ² <i>P. maximum</i> ² (except cv. Mombaça)	<i>P. maximum</i> ^{2,3} cv. Mombaça <i>Cynodons</i> ^{2,3} <i>P. notatum</i> ^{2,3} <i>A. gayanus</i> ^{2,3} <i>B. humidicola</i> ^{2,3}
1–1.5 kg/ha ⁴	2–2.5 kg/ha ⁴	2.5–3.0 kg/ha ⁴

¹ Wettable granules (commercial product) assumes 100 L/ha application rate of the spray mixture.

² For medium and low susceptibility grasses, apply ²/₃ of the dose and wait 15–20 days before applying the rest.

³ For the low susceptibility grasses apply ²/₃ of the application in autumn and the rest in spring.

⁴ For plants germinated in the same year, or still with a small root mass, rates can be reduced.

Source: Monsanto Brazil.

Choice of herbicide depends on a survey of the weed spectrum and stage of growth, leading to an evaluation of susceptibility. Selective herbicides may be mixed with the desiccant for specific weeds – check the local-regional weed control recommendations and a chart of compatibility for active ingredients and spreaders.

Spot-spraying, which can be very cost-effective to control isolated patches of problem weeds, should be done before the overall desiccation, or later as a complement to eliminate misses. This permits higher application rates or admixtures of specific herbicides for problem weeds. It can be done manually with backpack sprayers or with lances coupled to the tank of a boom sprayer (isolating, or removing, the booms), or even by hand-hoeing, or pulling, if

³ This drag system, although convenient for many farmers, is not technically recommended by FAO as a controlled quality application.

populations are small. In the case of a heavy green mass at desiccation (cover crop or weeds), up to three weeks should be allowed between spraying and sowing, to allow dissipation of allelopathic products from root decomposition (Constantin and De Oliveira Jr., 2005) which depress yields as they decompose, as shown in Table 12. For further information about spraying desiccants, see Box 16.

TABLE 12: EFFECT OF PLANTING 21 DAYS AFTER DESICCATION ON INCREMENTAL MAIZE AND SOYBEAN YIELDS COMPARED TO SAME DAY PLANTING AND PLANTING 7 DAYS AFTER DESICCATION

CROP	YIELD INCREASE OVER SAME DAY DESICCATION-PLANTING (Kg/ha)	YIELD INCREASE OVER PLANTING 7 DAYS AFTER DESICCATION (Kg/ha)
Maize	1 110	654
Soybeans	468	408
Local farmer average yield with ZT soybeans	674	Not determined

Source: Constantin and De Oliveira Jr. (2005).

BOX 16. Critical points: Spraying desiccants and other chemicals

- (i) Water must be clean and free of suspensions – clay and organic matter absorb the spray chemicals and reduce effectiveness;
- (ii) Fine sand or other particles can clog nozzles;
- (iii) Always test sprayers before use, for correct operating pressure, nozzle overlap, individual discharge (volume/time) and replace worn nozzles etc; calibrate for application volume;
- (iv) To judge application rate of chemical required, imagine the root reserves of the plant; the greater the live root mass, the higher the application rate;
- (v) Wait for dew to dry before spraying, or leaf runoff may reduce active ingredient absorbed;
- (vi) Do not sow before desiccation, as rain may not allow desiccant application before crop emergence;
- (vii) Recently germinated plants, with small root mass, are easily controlled with low dosages of contact herbicides.

PLANTING AND DRILLING

These operations are normally carried out on desiccated areas, with or without cover crops, or on rolled cover crops, such as black oats, which dispense with desiccation.

Manual jab planters have been adapted for ZT by reinforcing and narrowing the tips to give better penetration into untilled soil. They are commonly equipped with a double tip and apply fertilizer at the same time as the seed. Both fertilizer and seed flows are adjustable. Plate 12 shows a hand jab planter; to operate it is jabbed into the ground with the point closed and then the handles are pulled apart, allowing seed and fertilizer to drop into the planting hole. On closing, the seed and fertilizer points are re-charged. A normal work rate for maize planting in 1m rows would be 1 ha/man day.



PHOTO C. H. CASTRO ALVES

PLATE 12: Hand jab planter, commonly called a "matraca", with both fertilizer and seed hoppers.

Animal drawn planters. There are a variety of models in Brazil, mostly single row types, pulled by a single horse or mule or a pair of oxen (see Plate 13). Most have a trash-cutter disc up front, followed by a fertilizer knife and an eccentric double disc for the seed (see Plate 14). The simplest model with no trash disc and no furrow closing wheels is not suitable for heavy residues and can leave seed uncovered. Some versions have depth wheels for both seed and fertilizer, others only one for seed; their position and size are variable and furrow-closing mechanisms are also varied, sometimes absent, the most common being double-angled wheels.



PLATE 13: An animal drawn drill under demonstration, planting into desiccated pasture.



PHOTO C. H. CASTRO ALVES

PLATE 14: Details of construction of another model.

Fertilizer distribution is of variable quality between models and seed distribution is invariably with a horizontal perforated disc. Some models use discs commonly available from large manufacturers, which facilitates local availability when different spacings are required for new crops. A canola or sorghum disc works well with pearl and finger millets.

Tractor-mounted and tractor-drawn planters and drills. Tractor-mounted models are limited to small units (maximum five rows) as well as self-propelled walking tractor machines (see Plate 15), some with a rotary hoe furrow opener. Larger units are tractor-drawn with their own transport wheels and vary from 4 to 20 row units – they are usually hydraulically-operated.

Three basic types of seed distribution are available:

- planters using perforated disc or pneumatic seeders;
- small-grain drills using continuous flow distribution of seed, mechanical or pneumatic;
- multi-purpose machines for all grain sizes.



PHOTO: C. BATELLO

PLATE 15: A self-propelled single axle walking tractor, with attached two-row direct-planter, suitable for CA systems.

In tropical Brazil, the first category is overwhelmingly the most important. Since small grain production is minor compared to maize, soybeans and cotton, seed drills are restricted to rice, wheat and barley; extra investment in a drill is considered unprofitable for cover crops in the tropics. This is a short-term view, since the common practice of incorporating broadcast cover crop seed with a light discing incurs some loss of surface residues, which are difficult to maintain anyway, and which also wastes precious moisture, through evaporation and delayed planting.

Trash-cutting discs, which have been getting larger and vary from 40–56 cm in diameter, may be straight or fluted, (wavy) or rippled to ensure proper turning through good contact with the soil, with the fluted types more suited to sandy soils. The straight type is the most common in Brazil. Fertilizer coulters have three basic variants:

- the guillotine knife coulters closely coupled to the trash-cutting disc with a small vee-shaped guillotine attached to the knife, acting as a disc cleaner (the very small clearance is critical to performance and the size of the guillotine is smaller in heavier soils);
- a knife coulters some distance behind the trash-cutting disc following in the same furrow as the trash disc;
- offset double discs with different diameters receiving fertilizer in the gap between the discs.

Offset double discs should only be used when soils are well-structured (after 4–5 years of continuous ZT) and usually not for maize, cotton or sowing in desiccated pastures (see Plate 16). Since it is difficult to offset the seed disc from the fertilizer coulters, many farmers weld a small piece of chain, or wings, behind the coulters to improve the mix of fertilizer with soil and reduce the potential for seed burn from high K or N fertilizers. This problem can also be addressed by broadcasting most of these fertilizers after sowing, with potential gains in efficiency from reduced leaching and less down time for the planter. Normal fertilizer placement aims at a depth of 12–15 cm, usually directly below the seed. For irrigated phaseolus beans it has been advantageous to split the depth of fertilizer application, placing half at a shallower depth.



PLATE 16: A seed unit showing the double eccentric seed disc, adjustable depth control and furrow closing wheels – note that the units are offset to avoid clogging with surface residues.

Seed distribution mechanisms for planters are still dominated by the perforated disc, but pneumatic seeders are available at a higher price. Discs with a double row of perforations halve the disc rotation speed and improve distribution, allowing faster planter operation. A practical limit for planting speed is 6 km/hour, even for soybeans and pneumatic seeders (CAT Uberlândia, 2005). Uniformity of seed and fertilizer distribution is variable between planter-drill models and has become more crucial as different cultivars of maize and soybeans require different populations for top yields. Air seeders are not in general use in tropical Brazil and small grains are sown with the traditional drill mechanism or with multi-grain-size universal machines, most common on small farms in South Brazil.

Recent modifications have been: Increased trash disc diameters, pantographic suspensions for individual rows, independently hinged sections of the planter to allow better seed depth uniformity when planting in straight lines over the contour banks, folding planters for transport and easier manual adjustments. All tractor models use seed depth control wheels; the closer these are to the point where the seed enters the furrow, the better will be the uniformity of seed emergence. The principal types of furrow-closing wheels are:

- (i) Paired slanting wheels whose angle and pressure are adjustable;
- (ii) Single over-the-top rubber-covered press wheels; or
- (iii) A single slanted metal press wheel.

The use of paired opposite discs for furrow closing has been discontinued, but some farmers have replaced the wheels with a section of looped chain. Farmers still make their own modifications to facilitate field adjustment; many of these have been adopted by manufacturers, e.g. the guillotine disc cleaner.

On soils of over 40 percent clay, planter adjustment is especially tricky. It requires some persistence to obtain satisfactory performance, but this has been achieved on soils varying from 5–60 percent clay.

In Plate 17 is a farmer modification to plant pasture seed after soybean harvest or coincidentally with maize, using a pneumatic distributor to place the grass seed between the double seed discs – with the consequent in-row soil movement, most seed is covered by less than 2 cm of soil.



PHOTO: I. DOWICH

PLATE 17: Farmer modification to plant grass seed after soybean harvest (or for interplanting in young maize). The white boxes behind the planter are the pneumatic unit seed distributors – the delivery tube is inserted between the double seed discs.

Another farmer modification can be seen in Plate 18. In this case, an innovative farmer has attached a thick wooden pole to be dragged behind his planter. This modification is very helpful to assist with covering the seeds and redistributing the crop residue more evenly.

In Box 17 some specific points are given about using planting and drilling machines.



PHOTO: H. BARTZ

PLATE 18: Another farmer modification to improve seed and residue cover.

BOX 17. Critical points: Planting and drilling

- (i) Planters and drills must be levelled along the planting line before work, so that fertilizer and seed can be adjusted to the desired depths;
- (ii) "Hair-pinning" of residue below the trash disc often occurs with wet or wilted residues, or on very wet soils, and then planting must be suspended;
- (iii) Always use a fertilizer boot, guillotine or narrow tine, for maize or cotton or for planting into desiccated pastures;
- (iv) Check clearance of guillotine from trash disc according to manufacturer's specifications;
- (v) Check for irregularities and sharpness of discs to prevent clogging;
- (vi) Post-plant operations in the row must use the same number of rows as the planter and follow in its tracks.

SOIL FERTILITY CONSIDERATIONS

Liming. The effectiveness of broadcast lime application without incorporation has been long proven in ZT, as the lime enters the soil through old root holes and fauna-made galleries, more slowly through leaching of calcium and magnesium, and rapidly through translocation in the roots of black oats (Lopes, 2004; Bernardi *et al.*, 2003; Sá, 1993). Maintenance lime requirements are greatly reduced under zero, compared to conventional tillage, due to less anaerobic conditions for organic matter breakdown (Lopes, 2004). Farmers report going over 10 years without liming after adopting ZT, also due to earlier over-liming or large diameter lime particles taking longer to react. Care must be taken not to apply more than 0.5–1 tonne/ha (depending on soil texture and CEC), otherwise there can be an over-reaction at the soil surface, raising pH to above 7, when micronutrients, especially manganese, become less available. Manganese deficiency in soybeans shows as interveinal chlorosis and can easily be remedied by spraying nutrient solution containing Mn.

Excessive liming may also be responsible for cementation problems on silty sands (P. L. de Freitas, personal communication, 2005). Critical base saturation percentage (V percent) under ZT is 40; when it falls below this, apply lime to raise it to 50 percent (Sousa and Lobato, 2003). Sousa and Lobato (2003) also indicate that lime demand under ZT is reduced by 35–50 percent compared to conventional tillage; local recommendations for lime application often refer exclusively to the conventional situation and thus over-estimate the demand in ZT. There is increasing evidence that low base saturation levels are less limiting in soils with many years of ZT and consequently higher SOM and residue levels (L. Séguy, personal communication, 2004).

Planning the conversion of pasture to crops allows broadcast lime application one rainy season before planting the crop, ensuring longer reaction time and less likelihood of limitation to crop yield. In extreme cases, in-row applications of very finely ground lime (“filler”) of 150–300 kg/ha can be made in the crop row, with a third hopper (Séguy *et al.*, 1998), where liming may not have been adequate; local calibration of this rate would be necessary.

Gypsum. This is applied broadcast in small quantities to supply soluble calcium to penetrate to the subsoil and correct deficiencies of that nutrient,

or to reduce aluminium toxicity in the subsoil, or simply to correct sulphur deficiency throughout the root zone. According to Table 13, derived for latosols (Ferralsols), application levels rarely exceed 600 kg/ha.

TABLE 13: **RECOMMENDATIONS FOR GYPSUM APPLICATION TO CORRECT SULPHUR DEFICIENCY**

SULPHUR LEVEL IN SOIL	APPLICATION RATE (Kg/ha)
Low	10 x Clay %
Medium	5 x Clay %

Source: Sousa and Lobato (2003).

Higher application rates may be needed for in-depth correction of Ca deficiency and neutralization of subsoil Al. Gypsum may be applied with lime.

Phosphorus nutrition. Phosphate should not be broadcast together with surface application of lime in ZT since this causes reduced P availability due to a surface pH close to 7.0 (Sousa and Lobato, 2003).

Higher clay contents require increased P fertilization since a higher application rate is needed to shift the available P content.

Surface application of phosphatic fertilizer can only be made when the soil's P status is adequate to supply the needs of the present crop, the applied fertilizer being to maintain the system. Short cycle crops are more demanding in P than longer cycle ones, which have more time to extract it. Pasture grasses and legumes are more effective in extracting P from the soil than field crops: over seven years continuous cropping on a tropical latosol (Ferralsol), soybeans extracted 21 kg of P_2O_5 /ha, while two years of soybeans followed by five of *B. humidicola* extracted 50 kg of P_2O_5 /ha (Vilela *et al.*, 2004).

Nitrogen nutrition. High organic matter and crop residue levels under ZT mean that more of the N in the system is sequestered. Therefore, higher N fertilizer applications are needed in the first years until an equilibrium is reached (Sá, 1993). For maize, an extra 25–30 percent of N is required; this also applies to other non-leguminous crops and phaseolus beans.

There is evidence that the enhanced biological activity of CA systems requires earlier N application than conventional tillage; in some soils this can be 100 percent pre-plant, but in years of exceptionally heavy rains this may not be an advantage (Lopes, 2004). Many farmers consider the reduction in the weight of fertilizer carried in the planter as a sufficient operational gain to justify pre-plant application of N. Local research is required on this point.

Urea should always be incorporated and not top-dressed, since crop residues liberate urease which breaks urea down rapidly and N is lost by volatilization as ammonia – in extreme cases (high temperatures and no rain) such losses may approach 70 percent (Lara Cabezas, 1998).

Potassium nutrition. There is a build-up of K in the top 10 cm of soil under ZT and little evidence of leaching. Since K fertilizers cause seed burn and it is not usually possible to place fertilizer to the side of the seed in ZT, half, or all, of the K fertilizer can be applied broadcast. Split applications may improve efficiency. Alternatively, the fertilizer boot can be modified to apply the fertilizer at two depths; this has been effective in heavily fertilized phaseolus beans under centre pivot irrigation.

Soil sampling. Brazilian practice in ZT is to sample at 0–10 and 10–20 cm, to take account of the high nutrient concentration at the soil surface, due to nutrient recycling through surface residues. Further sampling is advisable at 20–40 cm to determine if there is a calcium deficiency or toxic aluminium levels which will impede root development. In ZT, soil sampling needs to span the whole row width, with a specialized broad, flat (vertical) sampler, otherwise fertilizer concentrations in the row will distort results, (unless a very high number of random samples are taken).