SILSOE RESEARCH INSTITUTE

Report on a visit to

PROMETA CIFEMA

PROYECTO MEJORAMIENTO TRACCIÓN ANIMAL
and
CENTRO DE INVESTIGACION FORMACION Y EXTENSION EN MECANIZACION AGRICOLA

Cochabamba, Bolivia, 9 February - 28 February 2001

Undertaken on behalf of the
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IDG/01/11

ENGINEERING for Life

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ABBREVIATIONS

ARA	arado reversible andalus (reversible mouldboard plough — Andalucian type)
ARC	arado reversible CIFEMA (reversible mouldboard plough — CIFEMA type)
CIFEMA	Centro de Investigacion Formacion y Extension en Mecanizacion Agricola
CIMMYT	Centro Internacional de Meyoramiento de Maiz y Trigo
IDG	International Development Group (based at the Silsoe Research Institute)
PROINPA	Promoción e Investigación de Productos Andinos
PROMETA	Proyecto Mejoramiento Tracción Animal
SRI-IDG	Silsoe Research Institute-International Development Group, Silsoe, UK

SUMMARY

The visit to CIFEMA and PROMETA lasted from 10th February 2001 to 27th February 2001. It followed on from three previous visits when prototype equipment, harnesses and implements, were brought out from the UK to be evaluated by PROMETA, and associated farmers, for potential adoption into its manufacturing programme, after further development as necessary. The first equipment introduced, in January 1998, was a 'high-lift' harness and lightweight plough with innovatory design features matching them to the work capabilities of single-donkey.

Successful introduction of the high-lift harness system led to the development of other implements - ploughs, ridgers, winged tine chisel cultivators and reversible ploughs - variously suited to a single donkey, horse or a pair of oxen. PROMETA design staff have been briefed on the procedures for designing implements to match the capabilities of specific animals and have used them to initiate further implement developments. The main purpose of the fourth visit was to assist in solving any problems which had arisen and to provide additional technical advice as necessary.

PROMETA's work is customer led with frequent visits to a number of farming communities representative of various crops and conditions, in order to review any problems requiring attention and to help in identifying future needs as a stimulus to further worthwhile developments. These visits are sometimes unpredictable but almost always lead to interesting, relevant and often unexpected insights. Visits made on this assignment were concerned with development of weeders, ridgers and the reversible mouldboard plough introduced one year ago.

The first visit, to a farmers' field day at Chuchulcani, was used to review the performance of a three-tine weeder, suitable for either a donkey or horse, which had already been selected by farmers as the most promising of three proposed designs. It was observed on this visit that cut weeds tended to accumulate and clog the weeder so that frequent stops were necessary to clear the blockages. PROMETA's workshop made changes aimed at improving the soil flow and subsequent field tests showed significant reduction in blockages. In addition PROMETA's design engineer suggested a weeder with a single wide sweep as an alternative design and this was built and tested with promising results. Comparative evaluation of the two weeders is to be made on farm. It was suggested that a more radical approach to weed control should be investigated: weed growth, and hence the need for mechanical weeding, might be reduced by changes in the crop production system.

The second visit, to farmers in the Capinota area, was made in order to investigate the effect of changes made to the design of PROMETA's ridger, following a request by potato growers for bigger ridges. Bigger ridges were produced, but due to equipment breakdown it was not possible to compare the draught of the old and the revised ridgers as had been intended. A 'pivoting wing' ridger was suggested as an alternative design, possibly more versatile and offering the same result for less draught. A clay model was made to indicate the proposed profile and the method of adjustment for the wings.

Development of the reversible mouldboard plough has been making good progress, but it was proving difficult to design the changeover mechanism. A possible arrangement was devised, built and worked satisfactorily in preliminary tests. The experience gained led to two further designs, potentially as effective but cheaper and more robust, which have yet to be built. The reversible mouldboard plough is a key implement in CIFEMA's product programme, aimed at replacing the current model which is pulled by a pair of oxen. It is suggested that the new model could be pulled by a single ox using a high-lift harness and proposals have been made.

MAIN RECOMMENDATIONS

Harnessing

1 For single-animal systems, work should be concentrated on designing, demonstrating, promoting and training for implement use with the chain-pulled high-lift harness. Sales prospects will be improved nationally, regionally and world-wide through its adoption. Comparatively, the two-pole arrangement is in very limited use and has many disadvantages.

2 A cheap and effective chain-pulled high-lift harness should be developed for single-ox use.

Crop production systems

3 PROMETA should investigate alternative crop production systems aimed at inhibiting weed growth, and hence the need for mechanical weeding, particularly by varying plant spacing between rows and along the rows while maintaining optimum plant populations and yields.

Implements

Weeders

4. Make a comparative evaluation in the potato crop of the PROM 1 weeder and the existing multi-purpose furrower/weeder/ridger in current production. Used with the chain-pulled high-lift harness.

5 Continue with trials of the three PROM weeder configurations and of the wide single-sweep weeder in a range of crops and soils types and conditions to which weeder performance is likely to be sensitive.

Ridgers

6. Develop a pivot-wing ridger of appropriate size and make objective trials to compare its performance and versatility in comparison with existing ridger(s).

7. Compare the adjustment and controllability of the two types of ridger when used with the two-pole harness and the chain-pulled harness.

Reversible mouldboard plough

8. Finalise design of the changeover mechanism.

9. Investigate the feasibility of using the plough with a single ox using a chain-pulled high-lift harness.

REPORT ON A VISIT TO PROMETA/CIFEMA

TERMS OF REFERENCE

1 Develop staff skills in design, construction and testing of animal-powered equipment related to PROMETA's present and future product range.
2. Demonstrate the application of appropriate theories and practices involved in the introduction and development of animal-powered implements.
3. Assist in the on-farm testing and evaluation of animal-powered implements as required.
4. Comment on CIFEMA's products and activities as appropriate.
5. Produce a report within one month of the visit.

2 BACKGROUND TO THE VISIT

The general background is given in report IDG/00/10 of the SRI-IDG[1] *viz.*

> *"PROMETA contributes to the work of CIFEMA through the development, demonstration and promotion of a wide range of animal-pulled implements. Following acceptance by farmers, manufacture is undertaken according to their expressed demand, working through commercial agencies and their local dealerships. Production of implements and/or machines not in CIFEMA's production range may also be commissioned by various projects such as PROINPA and CIMMYT. This may involve extensive design and development work on prototype machines prior to manufacture of a production batch."*

The visit reported here differed from three previous visits in that no implements were brought to Bolivia from the UK: the intention was to respond to current detailed requirements of PROMETA as identified in discussion with the Project Director and staff upon arrival. It was expected that the requirements would be focused on horse-pulled implements at various stages of development, *viz* weeders, ridgers, seeders and reversible ploughs.

3 PROCEDURES

On arrival

Monday 12th February was the first working day, spent in discussing the work programme and reviewing progress with implement development since the previous visit one year previously. Implements under development were examined in the workshop. Relevant student theses dealing with aspects of the research programme were introduced and taken away for reading .

During the visit

Time was devoted mostly to design work, discussions with project staff and guiding and helping staff in the experimental workshop to modify existing designs and construct new ones. Three on-farm visits were made to assess implements in work, by direct observation and by discussion with

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[1] The meaning of all abbreviations used is given on page ii for reference as necessary.

farmers, at the following locations:

Wednesday 12th February. To Capinota: farmer assisted trials with ridgers in a freshly ploughed field.

Friday 14th February. To Chuchulcani: demonstration/farmer evaluation of weeders and ridgers at work in a potato field. Visit to nearby weed research plots.

Thursday 22nd February. To maize field on the University farm: trials of weeders and ridgers.

Work undertaken on these visits is outlined in more detail in section 4 that deals with the various types of implement and make references to associated background matters. Additional matters that arose are discussed in sections 5 and 6.

Departure

The last working day was Friday 23rd February. Monday 21st February was a general holiday for the Cochabamba carnival. The return journey to UK was started on Tuesday 27th.

4 IMPLEMENT DEVELOPMENT AND EVALUATION

4.1 Weeders

Previous work

Remmy Crespo, a student at the University, had just completed his thesis project on the development and evaluation of weeders for pulling by either a donkey or a horse - a draft copy of his thesis was consulted. He had investigated three different tine arrangements for a three-tined weeder:

PROM 101 One leading tine fitted with duckfoot point plus two trailing tines fitted with left hand and right hand angled half-hoes.
PROM 102 All three tines fitted with duckfoot points.
PROM 103 All three tines fitted with chisel points.

Investigations had been conducted using the two-pole harness with a PROMETA triangular frame for attaching the weeders.

Crespo's work showed that the PROM 101 weeder was as effective as the traditional manual weeder (*lampa*) in terms of weeds remaining after work (c. 180 g/m^2), with a very considerably greater rate of work (4 day/ha compared with 22 day/ha). The other two weeders had a similar rate of work as the PROM 101 but weeds left untouched were rather more than twice as many (by weight). Farmers had a strong preference for the PROM 101.

Work done during the visit

The PROM 101 and 102 weeders were demonstrated in a potato field at Chuchulcani on 14th February, pulled by one or other of two donkeys available. The field had a moderate slope with the crop growing on ridges at a between-row spacing which varied from about 50 cm to 70 cm, leaving a width of about 30 cm to 50 cm between the foliage (and roots) of the potatoes. Weed growth was strong. It had rained overnight and the clay-loam soil was quite wet initially, drying to a more workable state by mid-day. The weeders were operated by male and female farmers whose opinions were sought and recorded by University staff (not available in English at the time of returning to the UK).

Problems observed with the PROM 101 weeder included:

- it was difficult to steer the weeder accurately enough to avoid damage to the growing plants (foliage and roots).
- frequent stops were necessary to clear the build-up of severed weeds and soil between the two rear hoes.
- the upright wings of the rear hoes tended to damage crop's roots.

Additionally, farmers had previously asked for the under-frame clearance to be increased by 5 cm, from 35 cm to 40 cm to reduce the risk of crop damage.

The PROM 102 weeder was also tried and worked reasonably well but farmers preferred the PROM 101 for use in the potato field. Any conclusions drawn from these trials must be viewed with caution as soil conditions were unfavourable and the weeder had to be set to a very narrow width because of the narrow between-row spacing of the crop. Weeders must be effective in a wide range of crops, weeds and soil conditions and the relative effectiveness of different configurations will depend on specific circumstances. Farmers will want to choose a versatile weeder capable of giving an acceptable level of performance in the range of crops, soils and other conditions which are most important to them.

In the light of observations made, the PROM 1 weeder was modified to reduce the problem of weed clogging by staggering the two rear tines by 12 cm to improve soil flow, as shown in Figure 1. An alternative solution suggested by Porfirio Gamez was to build a single tine weeder and this was done using a 32 cm wide sweep, as shown in Figure 2.

Figure 1: PROM 1 weeder modified by staggering the fore-and-aft setting of the two rear angle-hoes by 12 cm.

Figure 2: Single-tine weeder with 32 cm sweep.

Preliminary evaluations of the two weeders were made on Thursday 22nd February in a university field planted with maize at a spacing of about 60 cm between rows. Maize height was about 50 cm and inter-row weed growth was strong: soil conditions were good. The PROM 101 weeder was set to a working width of 40 cm. Soil flow was much improved by the stagger of the tines with infrequent clogging which was considered acceptable. Stability and control of the implement were not considered to be as good as when the rear tines were set level with each other – the weeder tended to pull on the side with the leading rear tine. The single wide sweep performed effectively and was more controllable.

Suggested further development and trials

Work by Crespo has compared the PROM 101 weeder with the PROM 102 and PROM 103, concluding that it is the favoured type for weeding in potatoes and, possibly, in maize. It has not, it seems, been evaluated against the multi-purpose ridger/weeder now widely used in the Capinota area for furrowing prior to planting potatoes, then converted to a weeder by the addition of a pair of tines (Figure 3) and finally reinstated as a ridger for earthing up - a sequence of operations which could equally well be used for maize growing on ridges. It would be unwise to put the PROM 101, or a derivative of it, into production until it has demonstrated distinct advantages over the established product which is selling well.

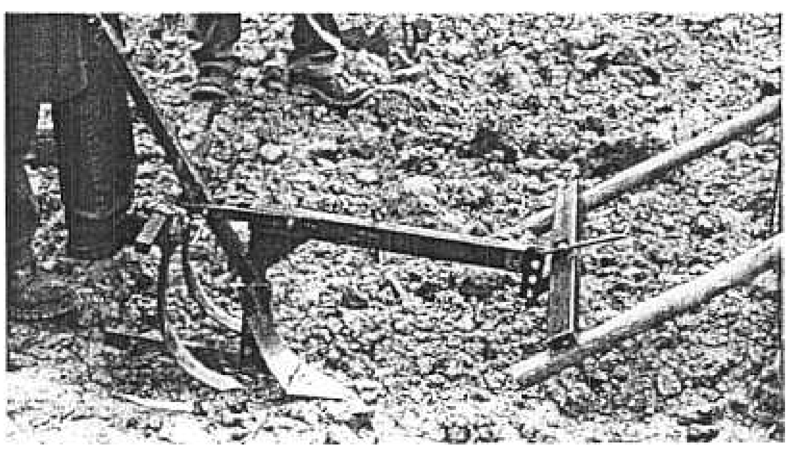

Figure 3: Ridger converted for weeding in potatoes by removing mouldboards and fitting two weeding tines.

It must be noted that the three 'PROM' weeders have only been evaluated comparatively for one crop in one set of conditions. Each of the weeder configurations is likely to show advantages and disadvantages in different circumstances. The PROM 102 is likely to be more suited to wide spaced crops grown on the flat while the PROM 103 may prove effective as a scarifier in rougher, possibly more stony soils, knocking out weeds and preparing the land immediately before sowing so as to give the crop a good start against weed regrowth.

Additionally it is necessary to examine the potential for devising crop production systems which discourage weed growth so that the need for machinery use is reduced, if not eliminated. This possibility is reviewed in more detail in Section 6.

Suggested work programme

Examine existing crop production practices with a view to identifying alternatives which discourage weed growth (Section 6).

For weeding in potatoes: run a comparative evaluation of the PROM 101 against the multi-purpose furrowed/weeder/ridger already in widespread use. Do farmers think it has any advantages?

For all four weeders: adjustment and control could be improved by attaching the weeder to the swingletree of a chain (or rope) pulled high-lift harness. This will ensure maximum flexibility of movement at the implement's point of attachment and hence permit more sensitive control compared with the two-pole harness, which restricts free movement. Precise guidance and control might also be helped by a 'handlebar' type handle. The chain-pulled harness will give better crop clearance compared with the two-pole harness which has to be attached by a triangular frame having a low set cross-member.

For the PROM 101: try the effects of each of the following:

- reducing the width (transverse measurement) of each of the rear half-sweep hoes by 3 cm to 5 cm to reduce clogging, particularly when it is to be used in narrow rows;
- making the blades of the rear sweeps narrower (longitudinal measurement);
- removing the vertical fins on the rear half-sweeps.

For the PROM 102, PROM 103 and single-sweep weeders: continue with systematic evaluation of the weeders in a representative range of crops and soil conditions in various locations.

4.2 Ridgers

Previous work

A ridger built in January 1998, suitable for pulling by a single donkey or horse, was adapted in October 1998 to act also as a weeder in ridged crops. Since then it has been sold in large numbers as a multi-purpose implement for furrowing, weeding and earthing up potatoes. Farmers in Capinota asked PROMETA to extend the mouldboards upwards and increase the under-frame clearance in order to make higher ridges which would improve soil cover over the potatoes and reduce the risk of greening. PROMETA's experimental workshop built a prototype incorporating the requested changes (Fig 4) and it was ready for trials when the adviser arrived in February 2001.

Figure 4: Prototype weeder with extended mouldboards - the extension is clearly seen. Under-frame clearance has also been increased.

Work done during the visit

The prototype ridger and one of the original type were taken to Capinota on the 12th February for comparative trials, with a dynamometer to measure their draught. Trials were run with both ridgers at their maximum width setting. The ridger with extended mouldboards made the larger ridges, as expected, but this result and the dynamometer readings were inconclusive as it was found that the share point of the original type ridger was inclined upwards making it less stable in operation, restricting the depth to which it would penetrate into work and hence the size of the ridge it could produce.

The current PROMETA ridger is fitted with near-vertical mouldboards which push the soil to the side with a high-draught bulldozing action rather than a low-draught lifting and turning movement. The adviser believes that ridging bodies which lift and turn the soil are more efficient and versatile. Ox-pulled ridgers with such bodies have been developed in Pakistan – where they are widely used in sugar beet production. They have a relatively long inclined point to give good penetration together with mouldboards which rise at a shallow angle for efficient soil movement. Figure 5 shows three of the bodies built by a small workshop specialising in animal draught implements, attached to a simple but strong frame to make a tractor-pulled ridger. The configuration of these ridger bodies does not lend itself to hinged mouldboards for adjusting their working width but this can be done using pivoting wings as shown in Figure 6. A three-dimensional model of a 'pivot-wing' ridger was made in clay (Figure 7) to provide a tangible demonstration of the shape and layout of this type of body. The memories of PROMETA staff were stirred and a similar body, made some years previously, was retrieved from the depths of the implement store. The body was refurbished and made slightly smaller in the experimental workshop. It was used briefly in a field on the University farm on 22nd February, but it was still too large and too heavy for use by a single horse and results were inconclusive.

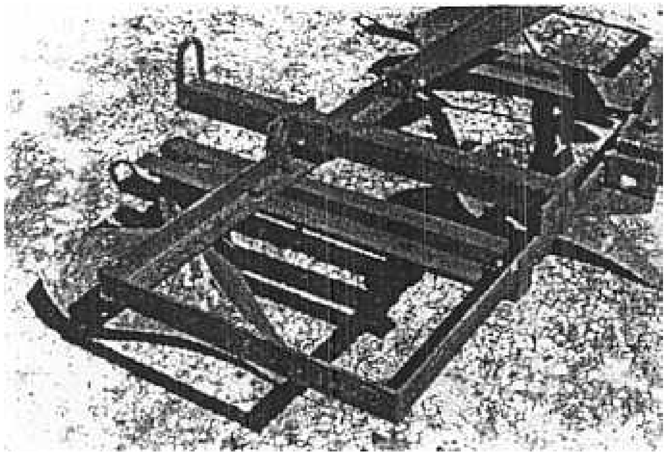

Figure 5: Pakistani ridger fitted with bodies developed for animal-pulled use in close cooperation with local farmers. The bodies are shaped to lift and turn the soil efficiently rather than pushing it aside with a bulldozing action.

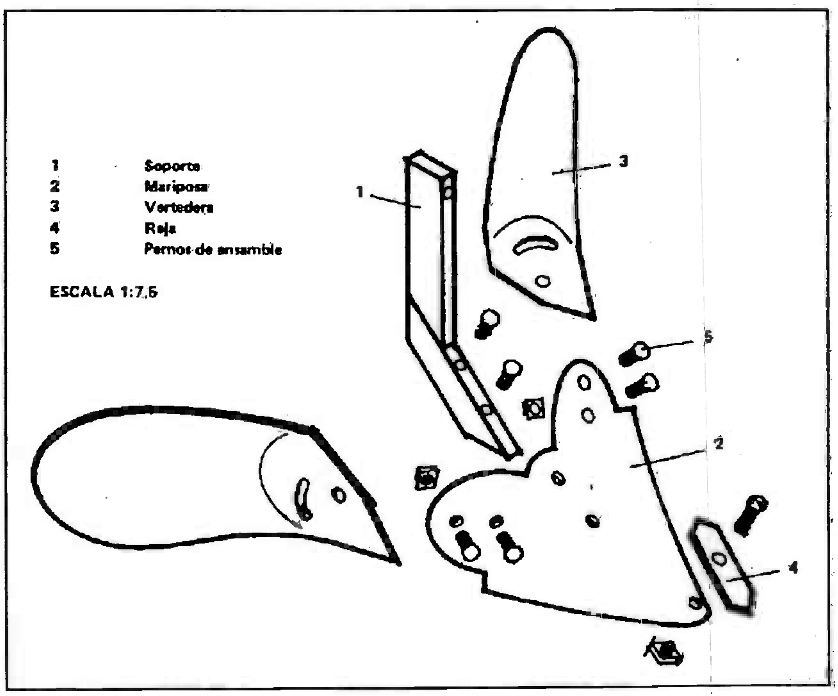

Figure 6: Pivot-wing ridger. For guidance only – improvements are possible, *e.g.* the point is one item which could be improved considerably.

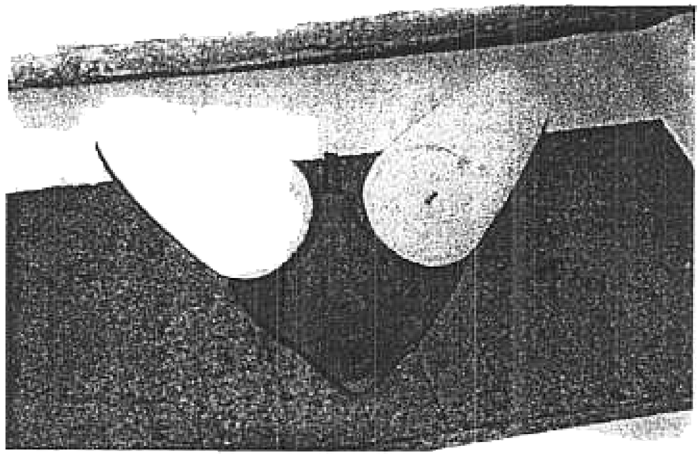

Figure 7: Clay model of pivot-wing weeder – a model (not necessarily in clay) is often helpful in implement design/development.

Meanwhile the prototype ridger with extended, hinged, mouldboards had been used for earthing up potatoes in demonstrations at Chuchulcani, pulled by a single donkey, with good results. No draught measurements were made.

Suggested further development and trials

There are two major directions which might be taken. First: to continue with modifications to the existing hinged-mouldboard ridger. Second: to initiate development of a pivot-wing alternative. The first direction has a short-term appeal but the adviser believes that the second is likely to lead to a more efficient and versatile machine.

Factors to be considered include:
Efficiency. The hinged-mouldboard ridger has a nearly vertical mouldboard which acts as a bulldozer pushing the soil to one side: the pivot-wing ridger can be designed for a more efficient soil-moving action which lifts and turns the soil.
Versatile soil placement. The pivot-wing ridger can be adjusted to move the soil upwards or to one side, or some direction in between.
Harness implications. The request for greater under-frame clearance does not arise from the design of the implement but from its method of attachment to the two-pole harness, using a triangular steel frame with a cross-member which interferes with the crop. If a chain-pulled harnessing system were used the height of the swingletree could be raised to give the necessary additional clearance to avoid damaging the crop (See section 5).

Suggested work programme

a pivot-wing ridger should be made, based on a combination of the designs shown in figures 5 and 6, with a body width of about 20 cm (excluding wings).
on-farm comparative trials should be made to determine the relative versatility of the two types of ridging body in furrow-making and earthing-up modes and to measure their draught requirements.
on-farm comparative trials should be made of the two-pole harness and the chain-pulled harness for each of the two ridgers.

4.3 Seeders

Porfirio Gamez outlined the work which was being undertaken on development of a cell-plate seeder similar to that used in Brazilian made machines. Interim results were satisfactory for a wide range of seeds and work should continue as planned, including use for direct seeding in conjunction with the PROMETA winged tine cultivator.

4.4 Reversible Plough

Previous work

On the occasion of the author's previous visit to CIFEMA, in February 2000, trials were undertaken of two reversible ploughs intended for use by a single horse, *viz*:
- the ARA (Arado Reversible Andalus) designed and built in the UK;
- the ARC (Arado Reversible CIFEMA) designed and built by PROMETA.

Both ploughs were typified by conjoined right and left hand mouldboards pivoted to turn through 180° to reverse the direction of ploughing: in the case of the ARA the bodies turned under the pivot pin and for the ARC over the pivot pin. Reversal under the pivot pin, as on the ARA, permits the design of a smoother mouldboard with more effective turning of the soil and greater under-beam clearance while reversal over the pivot pin makes it easier to design the changeover mechanism.

The trials showed that:
- the draught of the ploughs was rather too much for the relatively lightweight horses available on the hillside farms visited, but was well matched to the capabilities of two oxen using a head yoke with a single long beam to pull the plough.
- the ARA turned the soil and resisted clogging by vegetation notably better than the ARC.
- farmers preferred the cable operated changeover mechanism of the ARC rather than the lever operated mechanism of the ARA.

Comparative draught measurements have not been made.

PROMETA responded by developing a revised version of the ARC, which is shown in figure 8. Careful attention was given to improving the mouldboard shape in order to promote more effective soil movement than on the original model and to eliminating the small gap between the landside and share point where surface vegetation had tended to collect, causing clogging.

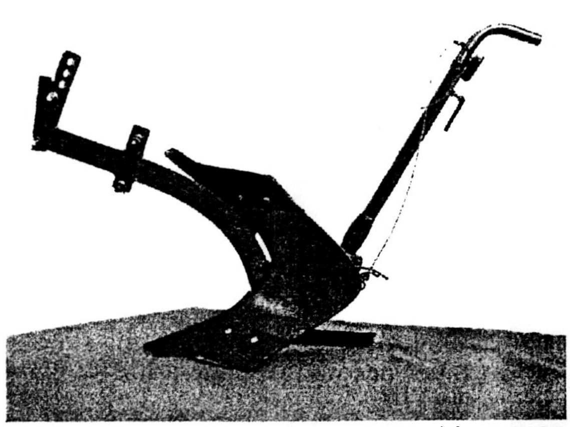

Figure 8: Reversible mouldboard plough developed by PROMETA in year 2000.

A trial batch of about 30 of the revised ploughs was made and distributed to farmers in the Capinota area for extended on-farm trials. Farmers reported continuing problems with clogging arising from insufficient clearance under the plough beam accentuated by the shape of the leading edge of the mouldboard, which had to be cut away in order to provide clearance for the leg of the plough frame - an unavoidable consequence of the over-the-pivot-pin layout. The plough was redesigned to overcome these problems, necessitating the use of an under-the-pivot-pin changeover system. Work was proceeding on devising a cable operated changeover mechanism, for which farmers had expressed a preference, but a satisfactory arrangement was proving elusive.

Work done during the visit

Work was concentrated on developing a suitable changeover mechanism to be:
- effective when working in field conditions;
- robust and reliable, with long life;
- simple, easy to manufacture;
- user-friendly, acceptable to farmers (*e.g.* they prefer a cable-operated mechanism).

Latching mechanism

The latching mechanism, already designed, holds the plough body assembly in either of its two working positions by a spring-loaded latch which is self-engaging, holding the uppermost (non-working) landside against the plough leg. When the latch is released the plough body swings down through 90 under its own weight to take up the position shown in Figure 9a.

A user-friendly hand-operated changeover mechanism, preferably cable operated and automatic in operation, is needed to complete the 180° movement to bring the alternative mouldboard into its working position. Work at PROMETA was concentrated on designing a cable-operated mechanism in accordance with farmers' expressed wishes. This had proved difficult but, during the consultant's visit a 'swinging arm' mechanism was designed, made and fitted to the plough as shown in Figures 9b and 10. This enabled the method of operation to be checked and demonstrated. In this design an arm pivoting on the backplate of the frog is locked at one of its two extreme positions by a spring-loaded locking pin, incorporated in the arm, which engages with one or other of two holes in the back plate. A cable is used to pull up on the arm, bringing the plough body into its new working position where it is held in place by the latching mechanism. Just before reaching this position a disengaging pin fixed to the plough frame forces the locking pin in the pivoting arm out of engagement so that the arm can fall under its own weight, with assistance if necessary, to engage with the alternative hole at the bottom of the backing place. The arm is now locked in place ready to be used for the next reversal of ploughing direction.

No fundamental problems were apparent although detail design could be significantly improved. Subsequent to his departure the author realised that there would be difficulty in achieving the necessary accuracy of manufacture and assembly and that the design could not be recommended as it was not likely to be sufficiently robust and reliable for the intended operating environment. This was confirmed by Porfirio who wrote that:

> "Based on the idea that we had during your visit, we tried, with Edgar, to perfect it but without much success".

The following 'postscript' outlines further analysis of the changeover system in order to arrive at a more robust design, even if not automatic in operation.

Postscript

The following part of the report takes account of ongoing ideas and dialogue with Porfirio Gamez following the author's return to the UK.

Analysis of the functioning of the changeover mechanism

When the latch is released there is insufficient energy to carry the plough body through to full reversal and the body will quickly reach a position of stable equilibrium in the 'horizontal' position shown in Figure 9a. The changeover system has to perform two functions – first to provide an energy input to raise the body to its new position and second to ensure that the plough body reversal is correctly executed, *i.e.* the body does not revert to its old position but does in fact take up its reversed position for the opposite direction of work.

It is possible to derive the required energy input from the draught animal, *e.g.* by means of a ground wheel drive, but this would add weight and considerable complication, which is not a realistic proposition in this case. So the additional energy must be found from a human source, almost certainly the operator, either directly or indirectly. Porfirio suggests one indirect method:

> ".... The idea (which works well) is that at the end of the furrow, the latch is lifted, the turn-over is initiated by dragging the plow for a few moments so that this impulse permits the change of position of the mouldboard which remains latched again by means of a spring-loaded latch".
>
> "This new intent was more simple and does not require a manual action except to release the latch by means of a cable".
>
> "We ran a few trials around CIFEMA with good results for this change-over system. We are starting a stage of field trials in other places to glean the opinion of farmers".

In reality the energy for this type of turnover comes indirectly from the operator, who must manipulate the plough by applying a force to it in order to obtain the necessary reaction from the soil.

Energy may be applied directly by the operator, for example by pulling on a cable or by manipulating the plough by hand. Operators will no doubt choose a mechanism according to their assessment of the force needed and the ease with which it can be applied, *i.e.* the 'ergonomics' of its operation.

With regard to the second function of the changeover mechanism – control of the position taken up by the plough body – this may be done consciously by the operator or automatically by the mechanism.

Based on the alternatives discussed above, Figure 9 shows a variety of feasible solutions, all of which are human-powered. An automatic changeover mechanism is shown in Figure 9b, Figure 9c shows a system whereby the operator selects the direction of changeover by selecting one from a pair of cables to transmit his pull to the appropriate side of the plough, while Figure 9d shows a simple system controlled directly by the operator.

End of Postscript

Suggested further development and trials

Based on work done in Bolivia and the further analysis made in the postscript, it is recommended that:

1. The changeover methods suggested in Figures 9c and 9d should be built and evaluated alongside the soil reaction method described in Porfirio's memo (first of the comments from him as quoted in the postscript).
2. The swinging handle method as first fitted to the ACA (January 2000 model) should be reexamined with a view to designing a simpler and more robust method for locking the handle in position. This system locks the plough body to the frame in a very positive and robust manner compared with the spring-loaded latch used on the three mechanisms mentioned in recommendation 1 above.

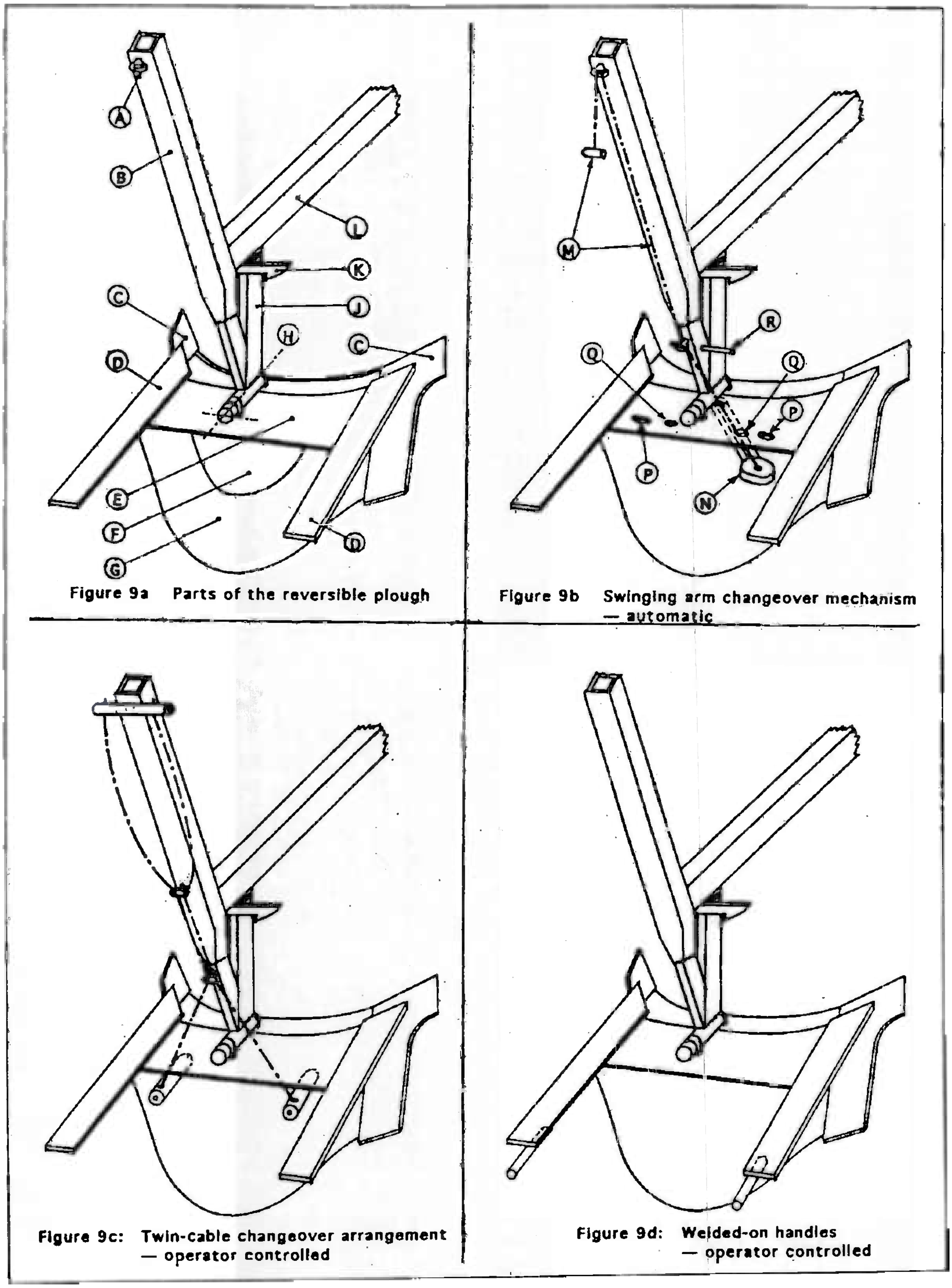

Figure 9a Parts of the reversible plough

Figure 9b Swinging arm changeover mechanism — automatic

Figure 9c: Twin-cable changeover arrangement — operator controlled

Figure 9d: Welded-on handles — operator controlled

Figure 9 Various change-over mechanisms for a PROMETA reversible plough
Please refer to commentary for explanations

COMMENTARY ON FIGURE 9

Figure 9a: parts of the reversible plough

Figure 9a shows the plough in its equilibrium position after unlatching. The problem is to raise one side of the plough so that the latch engages to hold it in its working position.

Plough parts are annotated as follows:

A	Cable guide	B	lower part of the plough handle
C,C	Shares	D,D	Landsides
E	Backplate, part of the frog	F	Mouldboard support plate, part of the frog
G	Cojoined left and right hand mouldboards	H	Axis of rotation
J	Leg (aka stem) of the plough frame	K	Latch
L	Beam of the plough		

Figure 9b: automatic swinging arm changeover mechanism

Figure 9b shows an automatic, swinging arm, changeover mechanism, such as the one described in the text. It is shown in position to raise the right hand side of the plough so that the left hand body (in the view as shown) is latched into its working position. At this stage the swinging arm is released to fall into its alternative position with its locking pin engaged in the hole on the left side of the backplate. This mechanism has been found to be too sophisticated for acceptance into CIFEMA's product programme.

Parts are annotated as follows:

M	Pull handle and cable	N	Swinging arm
P	Clearance hole for disengaging pin	Q	Hole for locking pin on swinging arm
R	Disengaging pin (each side)		

Figure 9c: operator controlled twin-cable changeover arrangement

In this arrangement two cable clamps are welded to the inside face of the backplate as shown. Each clamp is made from suitable rod, as available, with a transverse hole near one end to take the cable and an axial threaded hole for a clamping screw to hold the cable in place. Cables from the two rods are fed through guide rings to terminate at a third rod with cable clamps at each end, welded to the handle. This serves to separate the cables so that the correct one may be selected easily by the operator and pulled by hand to raise the appropriate side of the plough body until latched in position.

This arrangement should be relatively simple to make and operate and should be reasonably robust. Maintenance might be a problem in remote areas (spare cable and cable clamping screws may not be available).

Figure 9d: welded-on handles to assist with manual changeover

Two rods are welded to the landsides as shown. These may be used as handles as and when needed to assist in raising and latching the required side of the plough. It is likely that a simple technique for their use, possibly complementing the soil impulse method described by Porfirio, will be arrived at quickly by the operator after a little experience and experiment.

This arrangement is probably the simplest, most reliable and effective of the three arrangements illustrated.

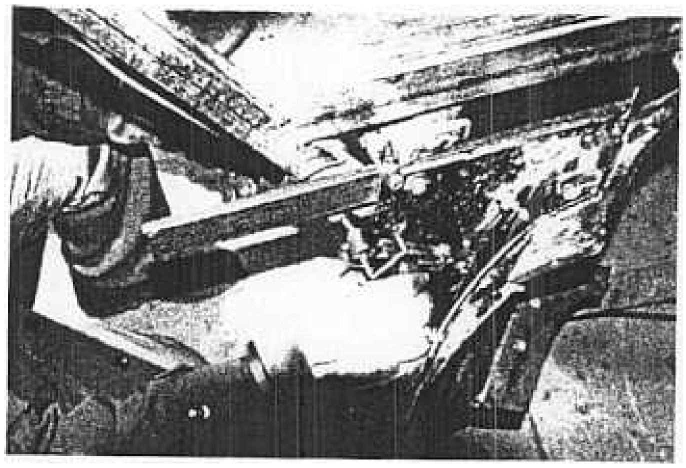

Figure 10: Showing the latching mechanism and original version of the changeover mechanism

5 HARNESSES

5.1 Preferred single-animal harness - two-pole or chain-pulled?

Until now CIFEMA/PROMETA has concentrated on promoting its donkey- and horse-pulled implements for use with a two-pole harness derived directly from that used in Capinota. This harness contrasts with the favoured harnesses in worldwide use which are, in fundamental terms:

- for equines and camelids, singly or in teams, or for a single bovine: collar or breastband pulling the implement through flexible traces (chain, rope, leather strap, *etc*) and swingletree(s);

and

for a pair of bovines: head or neck yoke pulling the implement through a single flexible trace (usually a chain) or through a rigid beam.

The two-pole harness is apparently specific to the Capinota locality - it has not been possible to find reference to a similar harness in the literature. For Capinota farmers wishing to progress from their traditional wooden-framed ard-type plough the main advantage of the two-pole harness seems to be that it may give them a sense of security by clinging to their familiar arrangement, even though it is probable that they would be much better served by the well proven and very widely used flexible trace system. Farmers taking up single-animal cultivation for the first time should have the freedom to choose the implement/harness system which suits them best.

The advantages and disadvantages of the two-pole system and of the harness using flexible traces are listed below for comparison.

Two-pole harness - advantages:

1. Farmers in Capinota (but not anywhere else?) are used to it

Two-pole harness - disadvantages:

1. Inflexible – optimum adjustment and control may not be possible. Attachment of the implement to the triangular frame allows adjustment in pitch only with no provision for adjustment in roll or yaw. 'On-the-go' adjustment is not possible so that manoeuvrability of the implement and precision of control in work is more difficult, particularly with regard to directional control.
2. Relatively expensive due to cost of the steel frame needed to attach the implement (and possibly cost of poles if not readily available).
3. The transverse cross-member of the triangular frame used to attach the implement is set low (of necessity) and can cause damage to the growing crop, particularly when used with a ridger or weeder.
4. Awkward to carry to and from the field, particularly in hilly areas.
5. Restricted market for the system, nationally and internationally.

Harness with flexible traces - advantages:

1. Relatively cheap - suitable material for traces are usually available and the harness can be made using skills which are locally available.
2. Light and easy to carry to and from the field.
3. Flexible attachment of the implement allows optimum adjustment and control in work because it is easy to make momentary changes in pitch, roll or yaw to deal with irregularities of crop, terrain or soil.
4. Height of the swingletree can easily be varied sufficiently to avoid damaging the crop in ridging and weeding operations.
5. Greater flexibility of the system provides opportunity to design a wider range of efficient implements.
6. The basic system is used worldwide, hence there is greater market potential in the home market and for export.

Harnesses with flexible traces - disadvantages

1. Implement designers need a superior level of expertise and understanding of interactions between implement, soil and harness - such designers are not readily available (PROMETA is an exception).

The list above is intended to outline the main advantages and disadvantages of the two types of harness as viewed by the author, who is convinced that CIFEMA's interests will be served best by concentrating on the demonstration, promotion and sale of implements for use with the widely used flexible harness - chain or rope pulled. This view was expressed in the report IDG/00/10 of the visit made in January/February 2000 as follows:

> *"The consultant strongly recommends the 'back to basics' approach - the chain-pulled alto levante harness should be retained for hillside farms because of its adaptability, flexibility, low cost and ease of transport on hillside tracks and should be the preferred harness for all areas except those where the use of a two-pole harness is requested. The chain-pulled alto levante system should, in the long run, provide for a more rational and versatile range of implements."*

This remains the considered judgment of the author.

5.2 Single-Ox Harness

The draught of the reversible mouldboard ploughs ARA and ARC referred to in section 4.4 of this report was found to be too high for the horses available in hillside areas, but when used as a beam-pulled implement it was pulled quite easily by a pair of oxen. If used with the more efficient high-lift harness the draught should be reduced to about half that of the beam-pulled implement system, making it possible for a single ox in good condition to pull it. Thus it should be possible for the same implement to be used with either a single ox or by a pair of oxen. The greater efficiency of the high-lift harness should result in similar working depth for the same pull per animal. This is an attractive proposition, particularly for poorer farmers who may only own one ox.

The potential for single-ox working has already been recognised by PROMETA which has been conducting field experiments with a single ox using a wooden collar-type two-pole harness[2]. The harness appears to be effective but relatively difficult and costly to make - it is recommended that trials should be made of a cheaper flexible trace harness using webbing or leather straps and rope traces. A possible design, derived from designs listed by Barwell and Ayre[3] is shown in Figure 11.

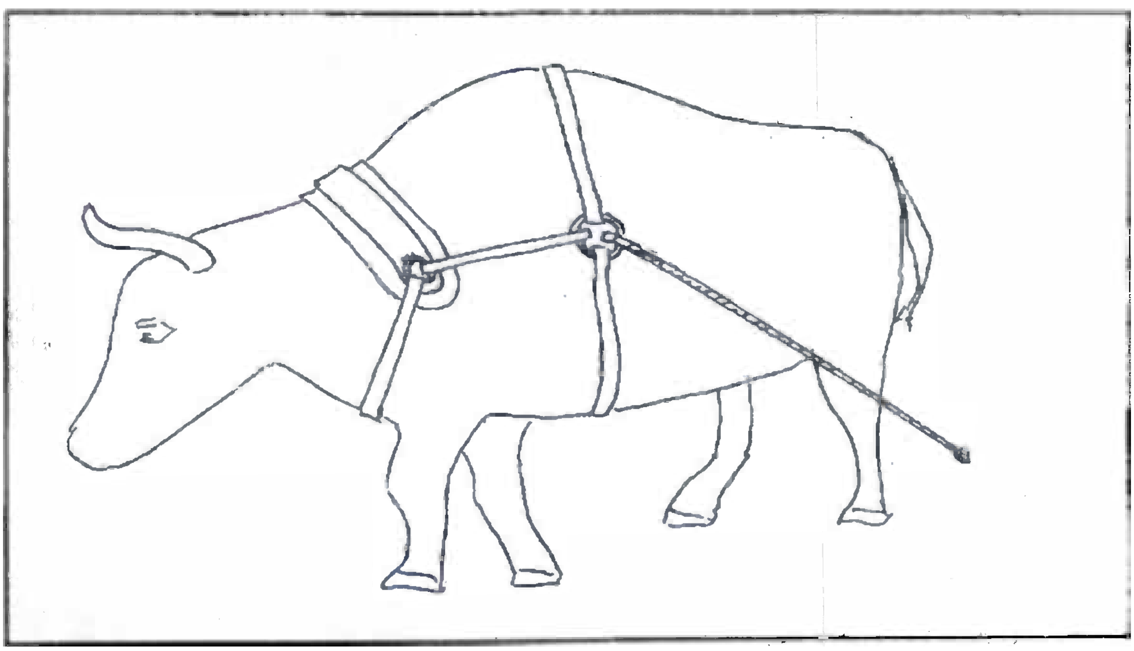

Figure 11: Suggestion for a chain or rope-pulled high-lift harness for a single ox.

[2] R. Flores E. 2000. Labranza Complementaria y Cultural con el Empleo de un Solo Animal (Equino, Bovino). II Seminario Taller Nacional Sobre Tracción Animal, Cochabamba, 9-11 Agosto 2000, pp178-181.
[3] I. Barwell and M. Ayre, 1982. The Harnessing of Draught Animals. Intermediate Technology Publications. The design shown is based on the Swiss Withers Yoke (pp32-33) and the European Flexible Harness (pp34-35), both of which have been used in Europe.

6 WEED CONTROL - REDUCTION OF MACHINERY OPERATIONS

It was suggested in Section 4.1 that the need for weed control by machinery might be reduced by modifying the crop production system. Current systems have often been developed specifically to suit tractor-powered production and are not necessarily the best when animals power is used. Maize, for example, is customarily grown with a row spacing of about 60 cm which encourages weed growth between the rows so that two weeding operations are usually recommended, when the crop has reached a height of about 10 cm and 25 cm, after which weed growth is largely inhibited by the growing crop. The 60 cm row was probably adopted to allow the large rear wheels of a tractor to pass between the rows – an even wider row spacing of about 1 m is often used if a self-propelled harvester, with even wider wheels, is to be used.

In animal-powered systems the row spacing could be reduced to 30 cm, while maintaining plant population by compensatory reduction of between-plant spacing along the row. It should then be possible to achieve effective weed control with not more than one inter-row weeding, at a crop height of 15 cm to 25 cm, after which weed growth would be seriously inhibited by the growing crop.

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