Animal-Drawn Wheeled Tool Carrier: An Appropriate Mechanization for Improved Farming Systems

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Abstract

The animal-drawn wheeled tool carriers were developed to carry out transportation and other agricultural operations by one single frame thus reducing the cost of machinery systems. They have not gained the expected popularity among a large majority of farmers because until recently they tried as alternative to traditional single-purpose machinery system which did not present sufficient time saving advantage to justify heavy investments. The recent experiences at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India and the Centre of Agricultural Research for the Semi-Arid Tropics, Petrolina (PE) Brazil (CPATSA) in the adoption of this type machinery system as an integrated component of improved farming systems has shown the possibility of increasing crop production and better time saving advantage even for small land holdings.

Note: This paper is based on author's own experience and available literature and need not represent the thoughts of ICRISAT or CPATSA.

Introduction

The animal-drawn wheeled tool carrier is a multipurpose machine based on the idea of a linked sequence of operations. It is possible to use this machine for numerous agricultural operations using one single frame to which various implements can be attached. It can perform virtually all the operations that a tractor can, thus providing to many farmers the versatility and precision previously available to only a few. The other type of multipurpose animal-drawn machine commonly used are called tool bars. The basic distinction between tool bars and tool carriers are, whereas the former are used solely for field work, the later can also be fitted out as carts for transport work.

The concept of animal-drawn wheeled tool carrier is not new. Approximately 25 years ago such machines could be found in East Africa, India and Senegal. This type of machine has been defined by various authors (ICRISAT, 1983, Bansal and Thierstein, 1982, Mexico, 1977, and Lal and Nunes, 1980, 81 and 82) as a machine designed to perform various agricultural operations and transportation; consisting of rigid frame (chassis) supported by two wheels (often pneumatic tyres) with a provision of attaching implements behind the chassis and a lifting mechanism to raise and lower them, and a beam connecting the frame to the yoke of the animals.

Basically the animal-drawn tool carrier is a frame with a built-in versatility to provide a link between the power source (animals), and soil working and other tools used with it, keeping the latter in a definite orientation with respect to the soil.

This concept of agricultural mechanization for small and medium farmers has been tried with varing success in many countries. In most cases it has not received the popularity among a large majority of farmers even with the numerous advantages in terms of low cost of operation, comforts for the operator(s) and animals, and quality of operations.

The objective of the paper is to analyse the reasons for its limited adoption rate, the basic aim of developing this type of machine, the research experiences in terms of its economic and technical viability and identification of special cases (if applicable) under which they should be recommended for use.

Traditional Animal-Drawn Implements

The traditional implements for animal traction commonly used can be divided into following two categories:

(a) *Implements developed by farmers themselves:* These type of implements are generally found in places where the use of draught animals has a long tradition, such as India, in countries of north of the Sahara and in Ethiopia (Africa). The lengthy history of these implements has resulted in a variety of designs. Although these type of implements **(Fig. 1)** look crude at first sight, they have been evolved by centuries of experience of the farmers and have stood the test of working in particular regions endowed with their specific agro-climatic conditions. The size and shape of these implements often vary from region to region depending upon soil type, cultural practices, and size and type of animal used, etc. But there are no radical differences among the implements meant for similar operations. These implements are generally made and repaired by local artisans (blacksmiths and carpenters). In India, particularly, the mode of payment for these implement is through goods-exchange.

(b) *Implements developed by specialized institutions or industries:* These type of implements, generally made of steel and are manufactured on commercial scale by specialized industries. The basic design feature of these implements do not vary much. It gives the impression that the know-how of these implements has been diffused from a single point of its origin. The typical example of such implements, a mouldboard plow, is shown in **Fig. 2**.

Fig. 1 Traditional wooden plow commonly used in India.

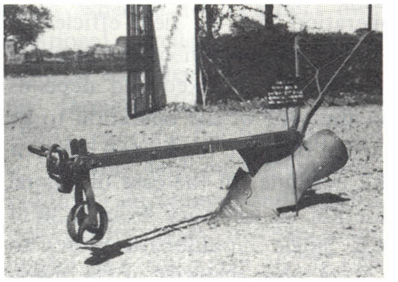

Fig. 2 Animal-drawn steel moldboard plow.

Wheeled Tool Carrier, its Reason for Development

A common package of implements for farmers using animal traction consists of plow and harrow for land preparation, planter or seeder for planting and animal-drawn transport carts. Most of these traditional implements do not make the best use of available energy from their power source because of their low draft utilization (Goe and McDowell, 1980). At the same time the work done is inefficient and involves considerable strain and drudgery for the operator(s) and the animal(s). Another major drawback is that each implement has its own frame and beam in addition to its principal functional component. The main idea behind developing wheeled tool carrier type of mechanization has been to enable to carry out transportation and other agricultural operations by one single frame, thus reducing the cost of machinery system. This type of mechanization makes things easier for the person operating the machine since he can ride on its frame. Experience has shown that with the driver seated, greater speeds are attained as compared to walking along or behind the implement, with the tractive resistance remaining the same. The stable support given to the tool carrier by its two wheels and the fixed tool bar results in precise depth control during the operation with the attached implement. This guarantees a better quality work. The various models of wheeled tool carrier developed in different parts of world has been listed by Lal and Nunes (1980 and 1981), Bansal and Thierstein (1982). The list and addresses of manufacturers of wheeled tool carriers have been published by ICRISAT, 1983. The basic components of wheeled tool carrier could be grouped into the following:

(a) Frame and support wheels: basic structure to mount other components.

(b) Implements attaching and lifting mechanism: a set of well designed linkages for fixing the attachment(s) and for raising and lowering them as desired; controlled by its driver through a well positioned handle.

(c) Animal hitching and power transmission mechanism: a solid beam made of steel or wood to connect the frame to the animal(s) yoke.

(d) Implements and attachments: the real working components that depend upon the type of operations to be carried out.

Working Capacity, Economics and Draft Utilization Efficiency

The area that can be covered in a day using animal traction with traditional implement or wheeled tool carrier depends on many factors such as the effective working width of the machine, speed of operation and the field efficiency. The working width of the machine is generally prefixed and depends on the type of the operation to be carried out, the model and make of the machine. In the case of animal traction it can vary from 0.20 m (e.g. single mouldboard plow) to 1.50 m when majority of the operations are carried out using wheeled tool carrier.

The speed of operation depends upon the draft or load of the implement, soil conditions, size of animal, climatic conditions and accumulated working hours. The working speed of oxen is about 2.5 to 3.5 km/h; and that of horses and mules, a little higher. Animals can generally pull 7.5 to 20% of their body weight depending on the type of loading and type of animals, their breed, physical condition, and type of loading.

The field efficiency or operational field efficiency is the percentage of useful working time to the total registered time of the machine in operation. It depends on many factors such as the skill of operator, size and configuration of field, its condition at the time of operation and type of operation itself. If the field is long, less time is wasted in turning than if turning has to be done frequently in a short field. Lal (1983), based on the conventional field efficiency equation (i) developed a simpler equation; (ii) which facilitates estimating field efficiency based on the parameters which can be measured on a sample basis.

$$Ef = \frac{To}{Te + Ta + Th} \times 100 \qquad \text{(i)}$$

where

Ef = Field efficiency or operational efficiency

To = Theoretical time per ha of the operation depending on the theoretical working width and speed to operation

Te = Effective time per ha of the operation depending on the effective working width and speed of operation

Ta = Time lost per ha due to interruptions that are proportional to area

Th = Time lost per ha due to interruption that are not proportional to area.

$$Ef = \frac{\frac{1}{V}}{(\frac{1}{V} + \frac{T}{L})\frac{1}{Eff}} \qquad \text{(ii)}$$

where

V = Speed of operation, T = Turning time, L = Length of the field, and Eff = Time efficiency.

All the terms in equation (ii) are self-explanatory except time efficiency (Eff) which is defined as a percentage of operative time which includes turning time and transport time from farmstead to field and back in relation to the total time registered for the operation. It could vary between 60-90% as listed by Lal (1983) for various operations with wheeled tool carrier.

The comparison of the economics of mechanization by wheeled tool carrier with traditional implement package is not straight forward. The traditional single-purpose implements are designed for individual specific operation whereas the wheeled tool carrier, as mentioned earlier, can carry out various operations by changing the attachment only. The other differences such as higher command area, precision, accuracy and comforts for the operator(s) and animals achieved during the operation with wheeled tool carrier need to be taken into account when comparing its economic performance with traditional implements.

Lal and Freire (1982) elaborated on various steps to estimate and compare the cost of individual operation separately and that of complete crop cycle with and without transport activity with animal power using wheeled tool carrier and traditional implement package when used on different sizes of land holdings. In the first case the analysis has been made for two types, the traditional and the modified cultivation systems. In the traditional system, the complete plowing of the field with one unit of mouldboard plow is done every year. And in the case of modified system the plowing is done only on the cropped rows using a set of right and left hand plows to increase the field capacity of the operation. The analysis of traditional implements, due to its operational limitations, is carried out only for the traditional system of cultivation.

The cost per ha of the operations of the crop cycle varies by system of mechanization. The variation depends on the size of land holding, cultivation system, inclusion of transport activity or not in the analysis and the command area of the machinery system. With the assumption of equality of command area (15 ha) for the both type of mechanization systems, the cost per ha of using single-purpose implement set is always inferior to that of the wheeled tool carrier for traditional system of cultivation with or without inclusion of transport activity. In the modified system of cultivation the cost of using wheeled tool carrier becomes cheaper for land holding more than 8 or 10 ha depending upon the integration of transport activity in the analysis. However, with the limit of command area of 5 ha for traditional equipment and 15 ha for wheeled tool carrier type of mechanization, the operational cost of traditional equipment becomes higher than that of other type from 5 ha onward for both the systems analyzed. For large holdings, the traditional equipments need to be supplemented by second or even third set of implement along with their power source (animals) to meet the operational requirements during critical periods.

The cost of the wheeled tool carrier type of mechanization can be considerably reduced by maximizing the annual use of the machine. The cost of wheeled tool carrier was estimated to be Rs. 166/ha on a 14 ha farm with broad-bed and furrow system of cultivation (Bansal and Thierstein, 1982). The cost was reduced to Rs. 155/ha when 400 h/year of transportation was added.

The large price difference between traditional implement package and the wheeled tool carrier type of machinery system does not imply equally large difference in their cost of operation and rental rates. In the cost analysis of an integrated machinery package (power source: animal, machinery and the operator(s)) the cost of bullocks and the operator(s) contribute a large percentage in its operational cost. Therefore, a 50% reduction in machinery cost generally reduces rental rate of the entire package by approximately 27% only. (Binswanger *et al*, 1979).

Apart from the advantages of higher operational capacities and low cost of operation, the tool carrier type of mechanization system has demonstrated the added advantage of improving the draft utilization efficiency of power source. The pull to drag the machine without any implement varies between 10-20 kg and to carry out different operations the variation has been observed in the range of 90-220 kg (Lal, 1979). In general, it is higher for plowing, ridging and bedforming. The pull recorded for these operations seems rather high as compared to the general belief that animals (especially bullocks) can pull loads equivalent to 10-12% of their body weight. Bansal *et al* (1980) also reported that draft observed for plowing and ridging with tool carrier is high and appear beyond the capacity of animals to sustain a full work day. That bullocks could still perform these operations on consecutive working days without any sustained visual fatigue needs a detailed study about animal performance with this type of mechanization. Klaij (1983) stated that at ICRISAT, using wheeled tool carrier, bullock pairs were able to exert a force of 225.0 kg while plowing during a 6-h work day. At first sight this would correspond to a very high power level of 1.9 kW, assuming a walking speed of 3 km/h sustained over a period of a 6-h working day. However, it must be realized that with wheeled tool carrier the bullocks are intermittently loaded, as turning time at each and of the field may be as high as 1 min resulting in a net working period with observed draft to less than 50% of total registered operating time. It could be one of the reasons for the ability of animals to sustain higher drafts specially when used with wheeled tool carrier.

*U$ 1 = approximately Rs. 10.00

Utilization of Wheeled Tool Carriers

The wheeled tool carrier type of mechanization has been under trials for more than 2 decades, but until recently it has been tried as an alternative to traditional equipment packages with little effort to look at farming systems as a whole. Under such circumstances the wheeled tool carrier type of mechanization really did not present sufficient time-saving advantages over single-purpose implements to convince farmers to undertake heavy investment for this new type of mechanization system. Bansal and Thierstein (1982) showed a saving of only 6% in the case of rainy season castor bean crop and that of 27% for rainy season pearl millet/pigeonpea intercrop by using tropicultor (a well-tested wheeled tool carrier) over traditional single-purpose implement on a conventional method of flat farming. Baron and Anjos (1983) reporting the time required for plowing and cultivation with traditional implements and wheeled tool carrier type mechanization showed the advantage of 29.15% for plowing and that of 31.23% for two passage of cultivation. They also showed an increase in specific pull for plowing with wheeled tool carrier (Policultor 1500) when compared with the other light weight tool frames called Policultor 600 and Policultor 300. They also showed that time required for cultivation with a traditional cultivator when pushed by a mule is minimum in the two passages separately or summed together.

The wheeled tool carrier type of mechanization system can be utilized most profitably by integrating it into an improved system of farming. This has been clearly demonstrated at ICRISAT and CPATSA where the wheeled tool carrier has been adopted as an integral component of improved farming systems. At ICRISAT the system evolved is based on the construction of broad beds separated by furrows at a regular interval of 150 cm. **Fig. 3** shows the cross-section of such broad beds with several cropping patterns at 75, 45 and 30 cm spacing. The furrows serve as drainage channels for carrying excess water into grassed waterways, as a pathway for animals and the tool carrier wheels and also as channels for supplemental irrigation. The use of wheeled tool carrier with various attachments for this system of cultivation has been explained in Bansal and Srivastava (1981), ICRISAT (1978) and Lal (1981).

A net profit of 43% in time saving has been shown by Bansal and Thierstein (1982) when wheeled tool carrier is used on this system as compared to traditional imple-

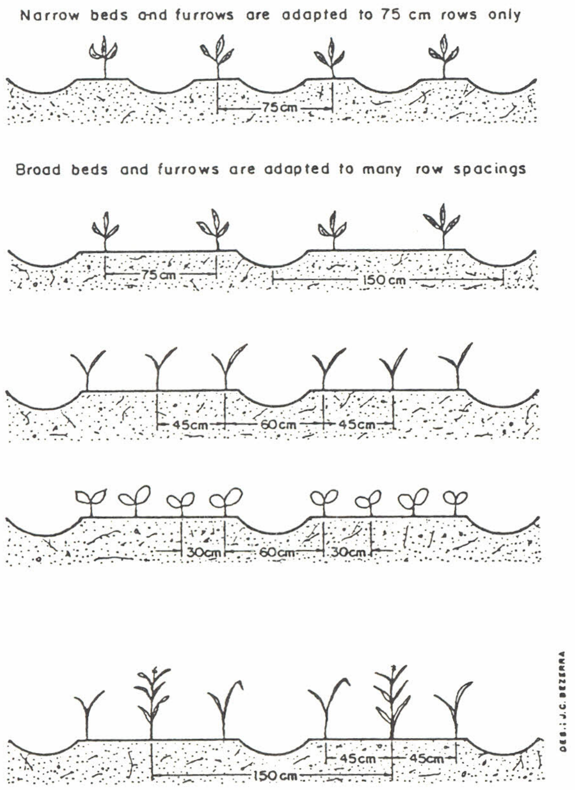

Fig. 3 Crop combinations and row arrangements of 75 cm ridges and 150 cm broad beds.

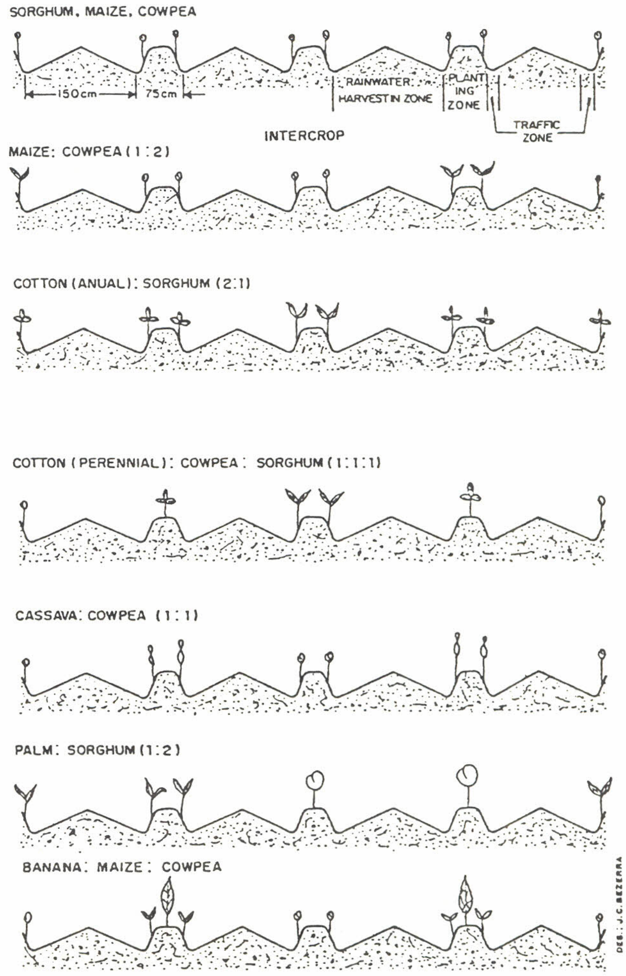

Fig. 4 Crop combinations on a new type *in situ* rainwater harvesting technique.

ments when used for flat cultivation.

At CPATSA, located in a very arid zone of northeast Brazil (Hargreaves, 1974) the wheeled tool carrier has been used for a new type of *in-situ* rainwater harvesting technique (Lal *et al*, 1983).

This system consists of broad and narrow ridges alternatively spaced on contour. The broad ridges serve as rainwater harvesting zone, the narrow ridges as planting zone and furrow between the two as waterstorage and pathway for the animals and tool carrier wheels and also as drainage or irrigation channel when the system is laid out on some slope. **Fig. 4** shows the schematic diagram of this system with the crop configurations under test at research centre and on farmers' field. The sequence of operations required to implant the system consist of ridging the field with three ridgers spaced at 75 cm followed by an operation with a ridger-blade, (Lal *et al*, 1983) specially developed for the purpose and attachable to the wheeled tool carrier **(Fig. 5)**. This represents a net saving 69.6% of time required for pre-planting land preparation operations (when it is possible to implant the system with one passage of each operation) as compared to traditional system of one plowing and one cultivation even when tool carrier is used. The number of passage required for each of these operation to achieve the required shape depends upon the soil condition at the time of its implantation and size of bullocks. The experience so far has shown that under good soil condition it is

Fig. 5 Implantation of new type of *in situ* rain water harvesting technique with ridger-blade.

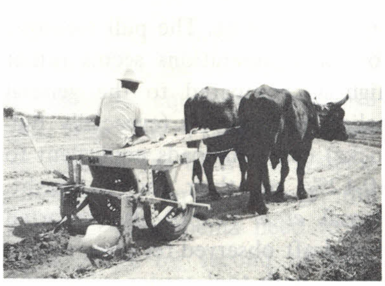

Fig. 6 A pair of sugarcane ridgers reforming planting zone in a new type of *in situ* rain wate technique.

possible to implant the system without initial land preparation operations of plowing and harrowing. As the new system is semi-permanent, in the consecutive years the operations required for its reformation consist of re-ridging the planting zone with a set of sugarcane ridgers **(Fig. 6)** and reforming the water harvesting zone with the ridger-blade leading to the net saving of 73.9% and 78.6% as compared to conventional land preparation using wheeled tool carrier and traditional equipment, respectively. **Table 1** shows the sequence of operations and estimated time required for pre-sowing field preparation using wheeled tool carrier and traditional equipment under conventional flat cultivation and for *in-situ* rainwater harvesting technique.

Table 1 Estimated Time Required for Pre-sowing Field Operations.

Machinery system	1st year		Consecutive year	
	Operations	Time required BPH/ha	Operation	Time required BPH/ha
Traditional implement for flat cultivation	Plowing	20	Plowing	20
	Cultivation	8	Cultivation	8
	Total	28	Total	28
Wheeled tool carrier for flat cultivation	Plowing	20	Plowing	20
	Cultivation	3	Cultivation	3
	Total	23	Total	23
Wheeled tool carrier for *in situ* rainwater harvesting system	Ridging	3	Re-ridging Planting zone	2
	Ridger-blade Utilization	4	Ridger-blade Utilization	4
	Total	7	Total	6

Conclusions

The animal-drawn wheeled tool carrier type of mechanization system developed to integrate field operation and transportation through one single frame (chassis) has not reached many farmers. Until recently it has been mainly looked upon as an alternative to single-purpose implements. Under such situation this type of mechanization system did not provide sufficient time-saving advantages to justify the higher initial investments. The ICRISAT and CPATSA have been successful in integrating this type of machinery into the package of improved farming systems. In both cases the use of traditional implements to carry out different operation was questionable. It leads to thinking that these type of implements should be compared with tractor rather than the traditional equipment packages.

Under traditional system of farming the wheeled tool carrier type of mechanization is economical for a command area of about 5 ha.

For an improved farming system, the limit of land holding to make heavy investment for wheeled tool carrier type of machinery package depends upon the net time saving advantages for various operations coupled with the added yield advantages of the new farming system. Under such conditions it could be estimated that even the land holding of 2-3 ha could give sufficient return to justify heavy investment on wheeled tool carrier.

The machinery should be looked upon as a requirement to support the farming system that has been formulated (Inn, 1979). It is specially true in case of wheeled tool carrier which are heavier, more expensive and less manoeuvrable than light weight traditional single-purpose implements. Otherwise their fate could be similar to what has been stated by Munzinger (1982) that in some cases, specially in Africa, it has been discovered that the technically attractive but also elaborate and expensive wheeled tool carriers are simply used as carts for transportation.

REFERENCES

Bansal, R.K. and Thierstein, G.E., 1982. Animal drawn multi-purpose tool carrier, Agricultural Mechanization in Asia, Africa and Latin America, XIII (4): 27-36.

Bansal, R.K. and Srivastva, K.L., 1981. Improved animal drawn implements for farming in semi-arid tropics, Agricultural Mechanization in Asia, Africa and Latin America, XII (2): 33-38.

Baron, V. & Anjos, J.B. dos., 1983. Mecaniização agrícola com tração animal. Informe Agropecuàrio, 9 (103): 30-5.

Binswanger, H.P.; Ghodake, R.D. and Thierstein, G.E., 1979. Observations on the economics of trators, bullocks and wheeled tool carriers in the semi-arid tropics of India, Workshop on Socio-Economic Constraints to Development of Semi-Arid Tropical Agriculture, Hyderabad. India.

Goe, R.M. and McDowell, R.W., 1980. Animal traction: guidelines for utilizations. Cornell International Agriculture. Mimeo. Ithaca, New York, Cornell University.

Hargreaves, G.H., 1974. Precipitation dependability and potentials for agricultural production in Northeast Brazil, Utah State University, 123p.

Inn, M., 1980. Animal power in agricultural production, with special reference to Tanzania, World Anim. Rev. (34): 2-10.

ICRISAT, 1978. Farm Power & Equipment Sub-Program Report of Work 1977/78, Patancheru, A.P., India.

Inn M. 1979 ?

International Crops Research Institute for the Semi-Arid Tropics, 1983. Animal-Drawn Wheeled Tool Carrier, Patancheru, A.P. n.p. il. (Information Bulletin No. 8).

Klaij, M.C., 1983. Analyse and Evaluation of Tillage on an Alfisol in a Semi-Arid Tropical Region of India, PhD. Thesis, Wageningen, p. 34-35.

Lal, H., 1979. Machinery evaluation and management, Report submitted to FPE sub program, ICRISAT, Hyderabad, India.

Lal, H., 1981. Operational performance of wheeled tool carrier in the broadbeds and furrow system of cultivation, Presented XI Brazilian Congress of Agricultural Engineering, Brasília.

Lal, H., 1983. Simple mathematical model of field efficiency and quantification of its components for animal drawn wheeled tool carrier, Pesq. Agropec. bras. Brasília, 18 (6): 649-656.

Lal, H. & Freire, L.C., 1982. Operational cost of animal drawn agricultural machines for different farm sizes. I Symposium of Semi-Arid Tropics, Olinda (PE). Aug. 1982. pp. 21.

Lal, H. & Nunes, P.F., 1980. Como construir o "Multicultor CPATSA" numa oficina local. Petrolina-PE. EMBRAPA/CPATSA, 22p. (EMBRAPA-CPATSA. Comunicado Técnico, 6).

Lal, H. & Nunes, P.F., 1981. Multicultor CPATSA. Fabricação e Uso. Petrolina-PE. EMBRAPA/CPATSA. 96p. (EMBRAPA-CPATSA. Circular Técnica, 6).

Lal, H. & Nunes, P.F., 1982. Operational performance of wheeled tool carriers for plowing and ridging. Pesq. Agropec. bras. Brasília, 17 (8): 1199-212.

Lal, H.; Silva, A.S.; Porto, E.R. & Nunes, P.F., 1983. A new "in-situ" rainwater harvesting technique to improve the crop production in dryland farming in the region of semi-arid tropics, XIII Brazilian Congress of Agricultural Engineering, Rio de Janeiro.

Lal, H.; Silva, A.S.; Porto, E.R. & Costa, da A.E.M. Animal drawn ridger-blade and its use in a new type of "in-situ" rain water harvesting system. Pesq. Agropec. Bras. Brasília. (in press).

Munzinger, P., 1982. Animal Traction in Africa: Policultivators. German Agency for Technical Cooperation, West Germany, p. 196-8.

Mexico, 1977. Barra-porta-implementos de tiro animal, Universidad Autonoma Metropolitana – Xochimilco. Division de Ciencias y Artes para el Diseño. Mexico, p. 24.

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