FINAL TECHNICAL REPORT

Improving the Productivity of Draught Animals in Sub-Saharan Africa

R5926

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PROJECT TITLE: R5926: Improving the Productivity of Draught Animals in sub-Saharan Africa

PRODUCTION PROGRAMME Livestock Production Programme

PROGRAMME PURPOSE: Performance of livestock (including draught animals) in semi-arid crop/livestock production systems improved.

Principal INVESTIGATORS
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Zimbabwe: Professor Lindela Ndlovu University of Zimbabwe (UZ);
Forbes Muvirimi, Livestock Development Trust and formerly Department of Agricultural, Technical & Extension Services (AGRITEX)
Edward Nengomasha, Department of Research and Specialist Services (DRSS).
Ephraim Mbanje, AGRITEX-Institute of Agricultural Engineering (IAE).

TOTAL COST OF PROJECT: £ sterling 213 775

Year	Planned	Actual
1993/94	47 470	36 937
1994/95	78 630	79 988
1995/96	77 783	57 620
1996/97	-	39 230
TOTAL	211 298	213 775

DURATION OF PROJECT: January 1994 to March 1997 (three years, three months)

EXECUTIVE SUMMARY

Purpose

The purpose of the project was to provide basic information and practical techniques for use by researchers and extension workers on alleviating constraints limiting the use of draught animals of reduced capability in semi-arid areas.

Work was carried out by a multi-disciplinary team including socio-economists, animal scientists and agricultural engineers together with farmers and implement manufacturers. Annual reviews by stakeholders played a key role in achieving the following outputs:

Outputs

- The identification and characterisation of specific target groups of farmers (recommendation domains) relating to the management and output of draught animals in Zimbabwe.

  A multi-disciplinary systems approach has been successfully used in this project. This has provided a methodology for improving planning and appraisal of research and extension activities, relevant to DAP, for use in Southern Africa.

- The provision of basic information for improved management (nutrition and working practices) of donkeys in smallholder mixed farming systems.

  The development and modification of tillage implement designs and practices suitable for donkeys and cattle of limited draught capability, through:

  Compiling a detailed database of animal drawn tillage implements
  An evaluation of potentially low draught implements on station and on farm.
  The development of a light weight plough, now in commercial production and a light cultivator presently being tested.

  An increase in the Zimbabwe DAP research capacity has resulted from undertaking a PhD, MPhil and two MSc thesis during the project

Contribution of outputs

The project has contributed towards increasing the productive potential of semi-arid production systems through improving the performance of draught animals in crop/livestock systems by provision of information for improved management of donkeys and development of light weight implements. The use of a multi-disciplinary team with socio-economic, animal science and agricultural engineering skills working closely with farmers and implement manufacturers has shown that a systems approach involving stakeholders results in an integrated project which can achieve immediate impact.

Promotion pathways have included other scientists involved with research into DAP, extension organisations (Government and NGO), machinery manufacturers and small scale farmers. Involvement of all stakeholders in the project has facilitated dissemination of outputs to date.

BACKGROUND:

A shortage of draught animal power (DAP) is recognised as one of the principal constraints to increased crop production in communal areas in Zimbabwe. A similar problem exists on many smallholder farms in other parts of sub-Saharan Africa. The situation in Southern Africa further deteriorated as a result of the serious droughts in 1992/93 and 1993/94 in which many cattle and donkeys died. The scope for intervention to alleviate DAP constraints is either through increased supply (more animals, improved nutrition, health, management and use of alternative animals) or reduced demand (improved implements and reduced tillage practices).

This project resulted from a mission to Zimbabwe in 1992 (Barrett, O'Neill and Pearson, 1992). A project proposal (SRI, 1993), developed from this, was approved by the Livestock Programme Manager at the Natural Resources Institute (NRI). The proposal provided for ownership and involvement of Zimbabwe institutions and individuals in undertaking project activities. This included three integrated components: socio-economics, animal science, and implement testing and development.

Silsoe Research Institute was appointed as the main contractor for NRI (manager of DFID Livestock Production Programme). In terms of this agreement UZ was appointed the main collaborator in Zimbabwe with close links to AGRITEX and DRSS. A further agreement between SRI and the University of Edinburgh (UE) facilitated the role of CTVM in support of the animal component of the study.

PROJECT PURPOSE:

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RESEARCH ACTIVITIES:

Identification of post graduate students

Applications were invited and suitable candidates selected by AGRITEX, DRSS and UZ to undertake the following:

> A socio-economic (or Farmer Recommendation Domain (FRD)) study, as an MPhil through UZ.
>
> An animal study, as a PhD through CTVM. In addition two further M.Sc students were appointed by UZ to provide input to the Animal study.

Forbes Muvirimi, from AGRITEX, was selected to undertake the FRD study being provided with study leave for a 18 month period. The initial 12 months were on full pay, with the remaining period on half pay. At the end of the 18-month period, Muvirimi resigned from AGRITEX, repaying his study leave costs, to take up a new post with the Livestock Development Trust. Notwithstanding these events, Muvirimi elected to continue working with the project for his MPhil albeit on a part time basis.

Edward Nengomasha from Matopos Research Station, DRSS was selected to undertake the PhD and Messrs Bwakura and Dube were selected to undertake MScs as integral components of the animal study

AGRITEX-IAE initially appointed Philip Msara to undertake the implements component of the

project. After some 12 months, Ephraim Mbanje assumed this role.

Rapid exploratory survey

A rapid exploratory survey and evaluation of existing relevant data in three areas was carried out as a multi-disciplinary team (Ellis-Jones et al, 1994) in order to provide:

An initial characterisation of DAP farmers in order to delineate preliminary FRDs.
Farmer perceptions of the value of donkeys, their uses feeding and management.
Farmer views on existing implements

This survey assisted in the identification of the major constraints for increasing DAP, and from this, the detailed design of the component parts of the research was undertaken. These were discussed at a workshop held at Matopos Research Station in October 1994 (Ellis-Jones, 1994). Papers were also presented on ongoing work activities. A further workshop was held in September 1995 (Ellis-Jones *et al.*, 1995) providing opportunity for a further review of research activities and discussion by stakeholders.

Formal survey and detailed monitoring studies

A formal survey at sample locations in the same areas as the initial exploratory survey quantified the preliminary farmer recommendation domains. Detailed monitoring studies with a number of collaborating farmers from each of the eight recommendation domain were also undertaken. (Muvirimi, 1995, 1997a and 1997b) to provide detailed case studies. Much of the on-farm research was undertaken with these participating farmers.

This component of the project, undertaken as an M.Phil through the University of Zimbabwe was intended to be completed during 1996/97. However, due to the resignation of the AGRITEX staff member, his re-employment by the Livestock Development Trust and part time commitment to the project, delays have been experienced in completion of the MPhil. It is now expected to be submitted early in 1998.

Animal studies

PhD study

After initial participation with the exploratory survey which identified farmer perceptions of the value of donkeys, their uses, feeding, management and problems in animal management, the following activities were undertaken.

An investigation of the morphological characteristics of donkeys in lower rainfall areas (NRs III, IV and V) in south western Zimbabwe, including seasonal variations in live weight, body condition and health status. Comparison were also made with donkeys in other countries.

Development of a practical method of estimating the live weight from body dimensions of donkeys in Zimbabwe, and testing of methods developed elsewhere in North Africa and Western Europe.

Measurement of the ploughing capacity of different sizes and teams of donkeys in different soil conditions on-station and on-farm, and comparison with outputs from pairs of oxen.

Studies on the effects of work on intake, digestion and mean retention time of local roughage diets by donkeys.

A study of the effects of frequency of watering on intake, digestion and mean retention time of local roughage diets by donkeys.

This work was submitted for a PhD degree (Nengomasha, 1997b) through CTVM. The PhD thesis has been completed and is awaiting final examination in December 1997.

M.Sc studies
The two M.Sc studies (Bwakura, 1995 and Dube, 1996) were undertaken concurrently to provide:

Further characterisation of Zimbabwean donkeys, giving attention to management, foraging behaviour and body characteristics.

Measurement of the performance of single donkeys undertaking a variety of secondary tillage operations using a light toolbar with single ripper tine (ripping), single cultivation tine (weeding) and single ridger (ridging/weeding). Harrowing was carried out using a light zigzag harrow.

Both studies were completed and MScs awarded by UZ.

Implement development
Assessment of the use and maintenance of tillage implements
An appraisal (Chatizwa and Ellis-Jones, 1997) carried out with farmers found implements to be in poor condition with most farmers having little knowledge on their correct use. Although the sample size was relatively small, the survey clearly indicated the generally poor condition of DAP tillage implements with ploughs and cultivators often being used incorrectly and being poorly maintained. A need was identified to consider a more detailed study to:

Assess the condition of implements countrywide
Assess the knowledge of farmers and extension staff
Evaluate the impact of farmer and AGRITEX training courses in mechanisation for small scale farmers
Propose appropriate action to improve the efficiency of the use of implements.

Development/adaption of draught implements
This included a review of potentially suitable low-weight, low-draught and low-cost tillage implements To facilitate field testing an Animal Traction Logger (ATL) was commissioned for the Project and IAE staff trained in its use. This was followed by the training and measurement of the draught performance of IAE donkeys, with follow-up activities at Domboshawa and Matopos Research Station.

A database (Mbanje and O'Neill, 1997a and 1997b) of potentially suitable equipment was prepared to provide a catalogue from which potentially suitable animal-drawn primary and secondary tillage implements for donkeys and cattle of low draught capability could be selected. The database was compiled, obtaining draught requirements from manufacturers, when possible, and supported by field testing when draught specifications not otherwise available. It includes implements acquired from within Zimbabwe and imported from elsewhere.

Testing equipment under farm conditions
Preliminary on-station testing was carried out on a range of implements sourced both in and

outside Zimbabwe in conjunction with local manufacturers. This included an evaluation of equipment already developed and tested in Zimbabwe. This was followed by close collaboration with Bulawayo Steel Products (BSP) Ltd on the design and development of their lightweight draught equipment This undertook farmer testing and appraisal with farmer comments fed back to BSP together with suggestions for design modifications. These included adjusting handle height and allowing greater clearance between mouldboard and beam to avoid accumulation of trash. Modifications were made and further testing undertaken before incorporation into the final design.

Liaison was also maintained with WALCO Manufacturing Company (Private) Ltd, manufacturer of the first prototype donkey plough in Zimbabwe, regarding design and performance factors.

Technical, social and economic evaluation of suitable equipment
Economic considerations (Mbanje *et al.*, 1997), as well as factors affecting the adoption of alternative tillage implements and practices from both the farmers' and manufacturers' perspectives were assessed through formal questionnaires and informal discussion with farmers. Field trials, both on-station and on-farm, followed as closely as practicable the FAO recommended procedures[1] for the evaluation of primary and secondary tillage implements.

Collaboration with other projects
Close collaboration with the SRI Conservation Tillage Project was also maintained to share information, participate in farmers' days and assist in evaluation of equipment. Hynes and Mashavira, 1995 and Mashavira *et al.*, 1997 provided important inputs to the crop production aspects of the evaluation.

Project Workshop
A project workshop was held at completion of the project involving all stakeholders to promote the outputs of the project and obtain views on further requirements for research and development work. Proceedings of the Workshop (Ellis-Jones *et al.*, 1997) have been distributed.

OUTPUTS

The identification and characterisation of specific target groups of farmers (recommendation domains) relating to the management and output of draught animals in Zimbabwe.

Specific farmer recommendation domains identified are shown in Table 1

Table 1: Farmer recommendation domains and the distribution of work animals in the survey areas

Animal ownership	Farmer recommendation domain		Semukwe (n=80)	Chikwanda (n=82)	Sebungwe (n=87)
No animals		No access	14% (11)	4% (3)	3% (3)
	2	Some access	30% (24)	34% (28)	11% (10)
Inadequate animals	3	Inadequate donkeys	30% (24)	4% (3)	2% (2)
	4	Inadequate donkeys & cattle	5% (4)	1% (1)	6% (5)
	5	Inadequate cattle	2% (2)	7% (6)	6% (5)
Adequate animals	6	Adequate donkeys	4% (3)	2% (2)	0% (0)
	7	Adequate cattle and donkeys	11% (9)	6% (5)	25% (22)
	8	Adequate cattle	4% (3)	42% (34)	46% (40)
		TOTAL	100% (80)	100% (82)	100% (87)

Source: Muvirimi, 1997a

A detailed characterisation of each of these is given by Muvirimi 1997a and 1997b.

A tested methodology for improving planning and appraisal of research and extension activities relevant to DAP for use in Southern Africa

Systems approach

A systems approach was used to identify opportunities for increasing the productivity of DAP (Muvirimi and Ellis-Jones, 1995, Ellis-Jones, 1996 and 1997). This identified the factors associated with the wider adoption of draught animal power technologies. Although primarily based on work undertaken in Zimbabwe's semi-arid areas, examples from other regions have been used to demonstrate the important role draught animals do and can play in sub-Saharan Africa. Initial investment, profitability, animal availability, competing demands for livestock products, nutrition, health, availability of suitable implements and a poor image of DAP continue to limit the wider adoption and improvements to DAP technologies.

It was concluded that draught animal power technology is appropriate and affordable for many small scale farmers. Research and extension needs to ensure that:

- Problems are approached in an multi-disciplinary manner considering the socio-economic circumstances of farmers, the existing use and management of draught animals and implements, based on a sound understanding of the farming system.

- Research, training and extension needs to be targeted at specific farmer recommendation domains with technology options available for each.

- Farmers, researchers, extension workers and manufacturers (large and small) should be involved in problem identification, research project design and evaluation.

This project operated within this framework.

The provision of basic information on the work capacity, feed requirements and responses to management inputs (nutrition and working practices) of donkeys in smallholder mixed farming.

Basic considerations in developing feeding strategies for working animals (Pearson 1997).
More information is available on the nutrition of working ruminants than on working donkeys in the tropics. Most food eaten is used to provide energy, requirements for protein, minerals and vitamins for work are usually low. The amount of extra energy needed to maintain live-weight on a working day depends on the work done. Working animals can expend from 1.2-2.5 times maintenance energy requirement daily on a working day of more than four hours. As food intake does not show a significant increase on working days then the extra energy needed has often to be supplied by improving the quality of the diet fed. This is because the staple diets of most draught animals are poor in quality and therefore hardly supply enough nutrients for maintenance let alone work. . Unless the quality of the diet is above about 9 MJ ME/kg DM and energy used on a working day is less than 1.8 times maintenance, then ruminants will generally lose weight when working. Effects of live-weight and body condition on work output are discussed. There is little evidence to suggest animals in good body condition do more work than those in lean body condition, provided the critical weight required to pull the implement in the local conditions is not compromised. It is suggested that dry season feeding may not be economic in some cases, where working seasons are short. Practical considerations in planning feeding strategies such as number of days worked, on and off-farm income and labour available are also discussed.

An investigation of the morphological characteristics of donkeys in lower rainfall areas (Nengomasha, 1997a)
Measurements of heart and umbilical girth, height, length, cannon bone circumference, live weight, sex and age were taken in 335 working donkeys in south west Zimbabwe. Body measurements were similar in the two sexes and were not significantly different from those measurements taken from donkeys in Morocco and Kenya. Age of working donkeys ranged from less than one to over 25 years with the average eight years old. Heart girth was the best single predictor of live weight - Live weight (kg) = Heart girth $(cm)^{2.83}/4786$. Accuracy of prediction was improved by the inclusion of an extra variable such as length, or umbilical girth. Seasonal fluctuations in live weight of 38 donkeys were monitored on farms. Changes in live weight mirrored the seasonal availability of grazing. Weight was lowest in October/November at the end of the dry season and highest in July/ August. No seasonal fluctuations related to disease incidence were evident.

Measurement of the ploughing capacity of different sizes and teams of donkeys (Nengomasha, 1997b)
The work output, speed and time spent working were measured in teams of donkeys and cattle and mixed teams of cattle and donkeys ploughing fields on-station (Matopos Research Station) on different soil types and on-farm in Nkayi and Matobo districts. Heavier donkeys (676 kg four-animal team weight) did more work than lighter teams (484 kg four-animal team weight), but the ox teams (608 kg two-animal team weight), outperformed the donkeys on-station. Field efficiency in ploughing was best using four oxen in a team (10.4 h/ha), mixed ox/donkey teams (two of each) were 12-19 h/ha, with 4-donkey at 15.2 h/ha when ploughing sandy clay soils. Results on farm confirmed the on-station results. Donkeys were capable of ploughing a number of different soil types, provided that they were combined in sufficient numbers (usually four) to have sufficient combined live weight to meet draught requirement. Draught forces of 13-16% live weight seemed workable with donkeys. Results showed that it was practical for farmers with insufficient ox-power to use mixed teams of cattle and donkeys for ploughing.

Measurement of the performance of single donkeys undertaking a variety of secondary tillage operations (Ndlovu *et al.*, 1997)
Use of single donkeys for the tillage operations of ridging, harrowing, cultivating and ripping on two different soil types required the donkeys to pull with average draught forces equivalent to 20 to 37 % of live-weight. The effective working times are short which suggests that although the single donkeys could sustain this effort for a short period, the length of time over which they could maintain the work was low and therefore single animals are unlikely to be as useful to a farmer as two donkeys for these activities. Heavier animals outperformed lighter animals, irrespective of sex or physiological status.

Effects of frequency of watering on intake, digestion and mean retention time of local roughage diets by donkeys. (Nengomasha, 1997c)
Eighteen donkeys (nine male, nine female) were individually housed and fed natural pasture hay (crude protein 60g/ kg DM). The animals were allocated to one of three treatment groups: Water offered *ad libitum*, water offered every 48 h or water offered every 72 h. Daily feed intakes were monitored and water consumption for 35 days. Water intake was significantly higher for donkeys receiving water *ad libitum* than those offered water every 48 h and 72 h (averaging 8.5, 4.9 and 5.1 l/d respectively over the experiment). Food intake of the animals receiving the less frequent watering (2.8 and 2.7 kg DM/d) was about 13% that of the food intake of donkey with *ad libitum* access to water (3.1 kg DM/d). The results of the present study showed that the Zimbabwean donkey was able to maintain relatively high levels of voluntary feed intake of conserved forage despite being deprived access to water for periods up to 72 h in moderate ambient temperature conditions (maximum about 26◦C).

The development and modification of tillage implement designs and practices suitable for donkeys and cattle of limited draught capability.

Database
A database (Mbanje and O'Neill, 1997) is available, holding design and performance data of 36 tillage implements, comprising all the Zimbabwean mass-produced implements plus selected foreign implements, designated as "low-draught" and imported by the Project for testing.

Implement evaluation
Detailed data have been obtained on the draught demand and performance of 7 (animal-drawn) primary tillage implements, which were tested both on-farm in the Semukwe and Kezi communal lands and on-station at IAE, Domboshawa and Matopos. Preliminary data on the performance of donkey-drawn carting systems were also provided.

Implement development

Ploughs
The development of the BSP light-weight plough provides an example of stakeholders working together to develop an implement for which a need was identified by farmers with a large potential market. As a result, within the lifespan of this project, it is now being commercially produced for use as a dual purpose implement for ploughing and cultivating by donkeys and light weight cattle.

The WALCO and IAE ploughs have given promising results in on-station trials. Both are considered suitable for small scale manufacture but at present are not being actively marketed. Other imported ploughs have also performed adequately under some conditions. Manufacturers

have not yet shown an interest in pursuing these simpler designs. Potential still exists but they will need to compete with the BSP light plough and there may be some difficulty in making them strong enough for dual purpose use.

BSP light cultivator
The BSP light cultivator is also ready for commercial production. It is likely to have a smaller niche market for those farmers owning donkeys with adequate financial resources to purchase both a plough and cultivator.

CONTIL ripper, toolframe and attachments
Considerable scepticism by farmers exists on their potential role and until problems of weed control and minimum tillage techniques are overcome, the ripper is unlikely to be widely adopted. The toolframe offers considerable versatility, but is not highly regarded by farmers at present. Under such circumstances manufacturers are unlikely to consider production. Where rural artisans are able and wish to respond to individual farmer requests, these implements have the potential to increase productivity. The toolframe is particularly well suited for those with inadequate draught.

Increase in DAP research capacity in Zimbabwe
An integrated systems approach to DAP research has been successfully developed. This integrates socio-economic, animal and engineering disciplines, bringing farmers and manufacturers into the development process.

Zimbabwean researchers have received two MScs from UZ, a PhD degree from UE is expected shortly and a MPhil from UZ should be completed early in 1998.

CONTRIBUTION OF OUTPUTS

Contribution towards DFID's developmental goals
The project has contributed towards increasing the productive potential of semi-arid production systems through improving the performance of draught animals in crop/livestock systems by provision of information for improved management of donkeys and development of light weight implements. The use of a multi-disciplinary team with socio-economic, animal science and agricultural engineering skills working closely with farmers and implement manufacturers has shown that a systems approach involving stakeholders results in an integrated project which can achieve immediate impact.

Promotion pathways
Promotion pathways include other scientists involved with research into DAP, extension organisations (Government and NGO), machinery manufacturers and small scale farmers. Involvement of all stakeholders in the project have facilitated dissemination of outputs to date.

List of publications
Publications are detailed in Annexure I

Plans for further dissemination
Final workshop proceedings will be circulated to national draught animal power institutions, libraries in Agricultural Faculties in Africa, NARS and the Animal Traction Network for Southern and Eastern Africa (ATNESA) member countries as well as availability being advertised in Draught Animal News.

An edited version of the workshop proceedings will be published as a book by the University of Zimbabwe.

Conference papers have been provided to ATNESA.

Articles have been published in the popular press in Zimbabwe(e.g. Sunday Mail), in Draught Animal News, African Farmer, and Zimbabwean Farming.

A number of scientific publications are currently in preparation for refereed journals News of the donkey plough has been included in several international agricultural engineering publications

Findings on donkey management have been incorporated in Curricula of University of Zimbabwe and University of Edinburgh and other University and Agricultural training establishments will receive the information (e.g. Universities of Fort Hare and Pretoria in South Africa).

AGRITEX-IAE have maintained contact with the equipment manufacturers in the development of further DAP implements, in particular promotion of the light weight plough and further testing development of the light cultivator.

Follow up research/action

The following conclusions coming from the Project Workshop indicate problem areas that need to be addressed:

Animal nutrition

Declining condition and availability of community managed grazing areas.
Inadequate management of communal grazing.
Strategies for optimising the use of existing fodder.

Animal health

Improved low cost disease management of draught animals.
Better understanding of local/traditional disease control practices.
Improved community management (where appropriate) of livestock health.

Harnessing

The design and use of harnesses need improvement.
Affordable materials must be incorporated in the design.
Harnessing for mixed spans.
Hitching systems require improvement.
Improved training and extension.

Implements

- Major effort is required to improve the problem of the poor condition of existing implements, through confirmation of the extent of the problem, a rehabilitation programme for existing implements combined with an intensified training programme for their efficient use, maintenance and repair.
- Promoting awareness of alternative low draught tillage implements.
- Promoting links between manufacturers and rural artisans encouraging artisans to provide lower cost more durable more widely available spares.
- Encouraging the use of the plough as a toolbar for other tined implements
- Providing operating manuals for implements

Reduced tillage
Compilation and dissemination of reduced tillage/conservation techniques to farmers and extension agencies
Reviewing the work already undertaken
Agronomic evaluation of the light plough is also required

Other aspects
- The shortage of draught animals requires efforts to promote contracting and sharing arrangements, spreading the demand period for DAP.
- Marketing of donkey meat as a speciality (such as crocodile tails or ostrich steaks)
- Promoting more regional and interregional linkages.

Research proposals will be submitted to the International Foundation for Science, the Wellcome Foundation and the British Department for International Development Animal Health Programme to continue research to provide basic information on the disease tolerance, growth, reproduction, nutrition and from these improved management of African donkeys. It is hoped to maintain the expertise on African donkeys and their use, that has been developed in the current project.

Follow-up research projects need to be considered in other countries or communities where poor management of working donkeys might be a constraint on their productivity during **crop production** or **transport** tasks (eg Ethiopia). There is a clear need for research into the design of equipment and working practices to match the capability and capacity of the typical donkey in these communities.

LIST OF PUBLICATIONS

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Dube Z, 1996. *The use of single working donkeys (Equus asinus) in light tillage operations in Zimbabwe.* Thesis submitted in partial fulfilment of the requirements for a M.Sc degree. Department of Animal Science, Faculty of Agriculture, University of Zimbabwe, December 1996. 72 p.

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