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A Single-board Computer-based Data Acquisition System for Agricultural Machinery Evaluation

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Abstract

A portable, single-board computer-based field data acquisition system to measure pull force, time and other parameters of animal-drawn machines and implements was developed in 1985-86. The system is compact, lightweight, and rugged. Software is in Basic and assembly language. Data can be collected automatically under program control using the on board real time clock, or manually by using the status of the push-button switches as a condition in the program. The real time clock can be used to log time and data for data. This system improves the quantity and quality of data collected in the evaluation of agricultural implements and machinery.

Introduction

Large quantities of accurately collected data are needed to assess performance of soil-engaging implements and machines. In conventional data collection, the pull force is usually measured with a spring dynamometer **(Fig. 1)**, time observations of various operations are made with stop watches, and the observations are noted manually. These techniques may not achieve good resolution of data, and often lead to erroneous results, because of the fluctuations of the pointer of the dynamometers and more than one stop watch is used for different time intervals, along with other human related factors. It is necessary to have better instrumentation and computerized data acquisition, to sense and record different parameters affected by the design of the implements and machines under field operating conditions. A portable-computer based data acqusition system can collect large amounts of data accurately in the field (Clark and Adsit 1985), and this data can be reduced, analyzed, and printed in the field directly or transferred to a mainframe computer for analysis and permanent storage.

A portable single-board computer based data acquisition system was developed at ICRISAT for use with animal-drawn machines and implements to record the pull force, and time references in the field in 1985-86. This system allows the use of up to eight different input channels.

For one year the output data was collected using a 24-character wide portable printer **(Fig. 2.)**. Printed data required careful handling until it was fed in to a mainframe computer, and manual feeding of large amounts of data requires killed operators and careful rechecking. The system was, therefore, modified using a hand-held data terminal in place of the printer.

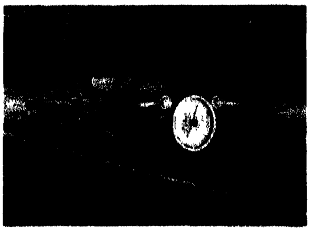

Fig. 1 Spring dynamometer fixed on a telescopic beam.

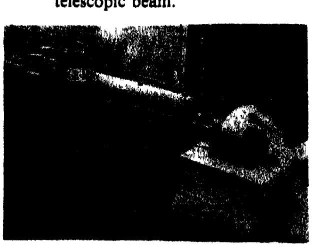

Fig. 2 Data acquisition system with printer. 1—System, 2—Pull force transducer.

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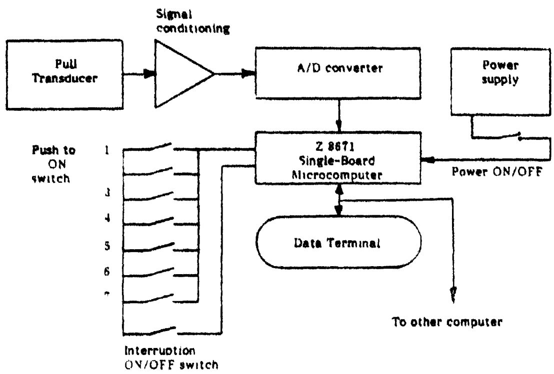

Fig. 3 Block diagram of data acquisition system

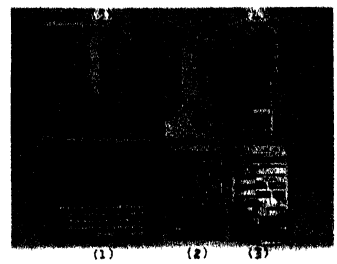

Fig 4 Data acquisition system hardware 1—Data terminal, 2—ADC board, 3—Z 8671 single-board computer, 4—Power supply and signal conditioner, 5—Switch box

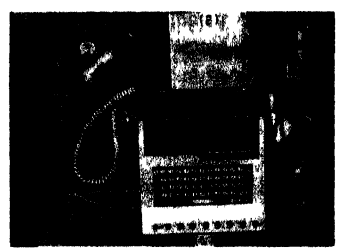
Fig. 5 Data acquisition system components 1—Data acquisition system, 2—Battery, 3—Pull force transducer

Hardware

The block diagram of the system in **Fig. 3** shows the pull transducer, signal conditioning circuit, analog to digital converter, single-board computer, and a hand-held portable data terminal

The pull force was measured using a strain gauge-based tension load transducer with a load capacity of 0 to 500 kg

Figure 4 shows the hardware of the data acquisition system The signal conditioning circuit interfaces the transducer to the analog to digital converter This is constructed using a strain gauge amplifier module consisting of three sections, a high quality instrumentation amplifier, adjustable transducer exitation, and gain control over a wide range The selection of different gains for a linear calibration could be done by the selection of different hardware components

The analog to digital converter (ADC) and the single-board computer (ARC 41) were chosen from Arcom Control Systems* These parts were chosen because of the cost, availability and capability Commercial packages for such kind of application were about $15 000 (Clark and Adsit 1985), the present system was developed at a cost of about $1 000 only The ADC board is of eight bit, eight channel, and this was configured to accept +10 V full scale input signal. The single-board computer is based on Z 8671 single-chip microcomputer with built-in Basic interpreter (1983) A 4k EPROM, 4k RAM (expandable up to 16k), two IO (input/output) ports, and an RS 232 serial port for interfacing to a printer or another computer are provided Port 2 is wired to 7 push-to-on switches and one toggle switch, which can be called into the program when manual control is required

The data terminal has two lines of 40-character wide liquid crystal display (LCD), a 50-key miniature ASCII keyboard in standard Qwerty style, and 10k of battery backed memory that can be organized into files An RS 232 port is provided for communication with other computers The data terminal comes with rechargeable batteries and consumes 65 mA

The power supply board is supplied with DC voltage from a 6 V, 10 Ah rechargeable alkaline battery, from which ±5 and ±12 V were derived The total current requirement of the system is about 600 to 800 mA The battery requires recharging after 6 to 8 h of total operation

All of these components of the data acquisition system are fixed inside a compact box weighing 3 1 kg, and 90 x 180 x 200 mm in size are shown in **Fig 5** The battery and the system were either carried in hand or placed on the machine according to convenience The transducer **(Fig 2)** was fixed to a telescopic beam with chain links such that the entire pulling force transmitted through this link A person carrying the system is able to walk along with the machine in collecting the data, hence, portable

Software

The program is written in BASIC and assembly language (1981) for measuring the pull force only The flow chart **(Fig 6)** of the program for pull force measurement was developed to achieve a procedure of data acquisition as shown in **Fig 7** using the push-to-on switches to control data acquisition These switches are repeatedly used in the program to control the start-stop operations, e.g , run, data collection and any interruptions At the end of each run this program prints a summary of the number of data points and average pull force in kgf The retrieved sample data shown in **Fig 8** corresponds to the scheme of data acquisition **(Fig 7)** The data collection status is displayed on the terminal throughout the

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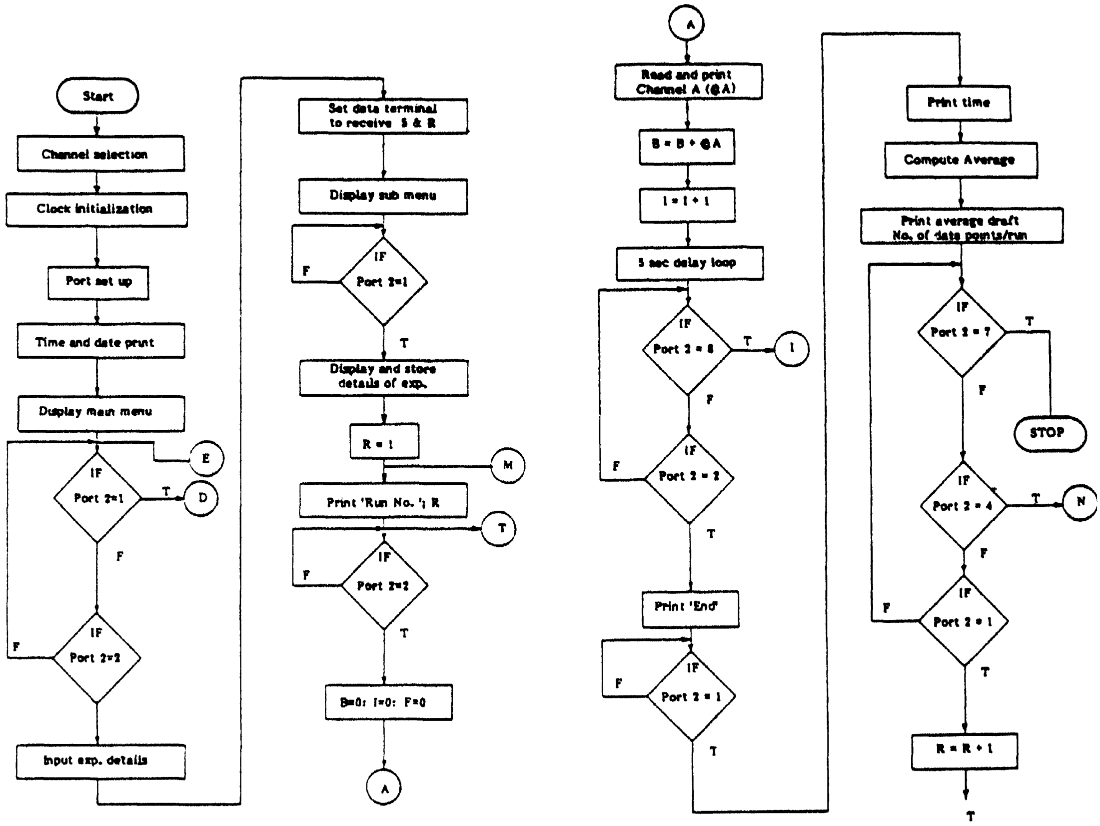

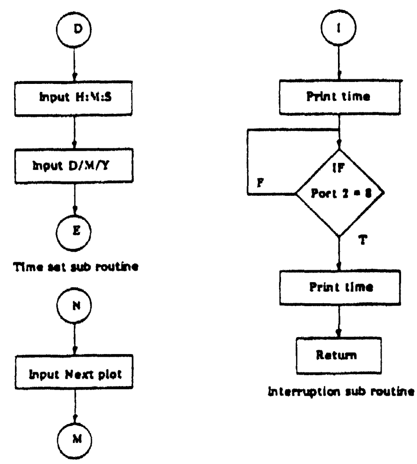

Fig. 6 Flow chart of the program.

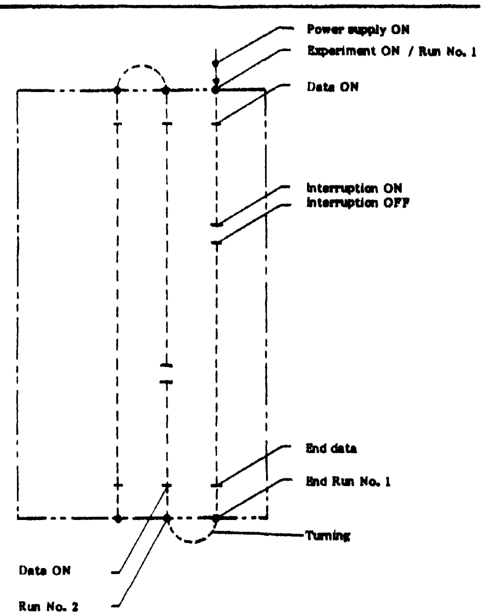

Fig. 7 Procedure of data acquisition in the field.

operation. The data terminal handles the storage of data in the form of files that can be transferred later to another computer. After transferring the data to a mainframe computer timing details such as running time, turning time, and interruption time can be separated, along with average draft and number of data points for each run.

Results

The complete setup of the data acquisition system was used in the farmer's fields **(Fig. 9)** in the evaluation of different sowing machines. The data was collected for pull force and time for each sowing machine using the data acquisition system for the 1986 rainy season.

The collected raw data (**Fig. 7**) was transfered to a mainframe computer and run time, turning time, interruption time and pull force for each run were analyzed separately. The results were used in the evaluation of different sowing machines.

Calibration

A rectangular frame was constructed to hold a spring dynamometer and the transducer (**Fig. 10**) linearly by tying one end of the dynamometer at one end of the rectangular frame. The other end of the transducer was attached to a threaded shaft, on which a nut could be moved to attain the required tension on the transducer and dynamometer. Initially, the transducer was balanced at no-load for zero output from the computer. As the tensile load on the transducer increased in steps of 50 kg using the above described setup, the gain of the signal conditioning circuit and the ADC converter were adjusted until the output showed the corresponding values for the pull force. The resolution of the system for pull force was 2 kg with a total range of 0 to 500 kg.

Conclusion

The single-board computer based data acquisition system is compact, relatively low cost, lightweight and easy to operate. It is very helpful in recording large amounts of data accurately in the field. The present system is programmed to record only one parameter and other parameters such as depth of working of an implement, speed of the machine, temperature and other conditions could also be included for simultaneous recording.

```
Planter evaluation
at Chevela planting
Plot no:1
Date 30-6-86
Run no:1
Time 15:2:20
Data:
148
128
124
152
146
148
*
Time 15:2:49
interuption
Time 15:8:55
*
116
110
126
126
128
128
140
148
142
end
Time 15:9:37
Av.Draft:134 Kgs
Data bits:15

*
Time 15:11:23
interuption
Time 15:14:18
*

Run no:2
Time 15:14:20
110
116
124
124
126
138
138
122
150
146
end
Time 15:15:12
Av.Draft:129 Kgs
Data bits:10

*
Time 15:15:47
interuption
Time 15:22:06
*

Run no:3
Time 15:22:10
Data:
164
162
170
156
162
154
end
Time 15:22:30
Av.Draft:161 Kgs
Data bits:6

Run no:4
Time 15:23:25
Data:
132
120
146
148
140
134
158
118
end
Time 15:24:9
Av.Draft:137 Kgs
Data bits:8

Run no:5
Time 15:24:44
Data:
122
154
134
116
142
116
116
124
112
end
Time 15:25:27
Av.Draft:126 Kgs
Data bits:9

Run no:6
Time 15:25:59
Data:
130
148
156
128
158
156
156
138
136
132
140
end
Time 15:26:55
Av.Draft:143 Kgs
Data bits:11

Run no:7
Time 15:27:28
Data:
140
134
130
112
132
110
168
160
148
142
110
122
end
Time 15:28:23
Av.Draft:134 Kgs
Data bits:12

(Run nos. 8-12 follow)
```

Fig. 8 Sample data.

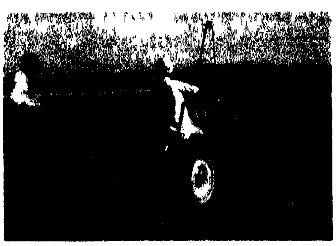

Fig. 9 Using data acquisition system in fields.

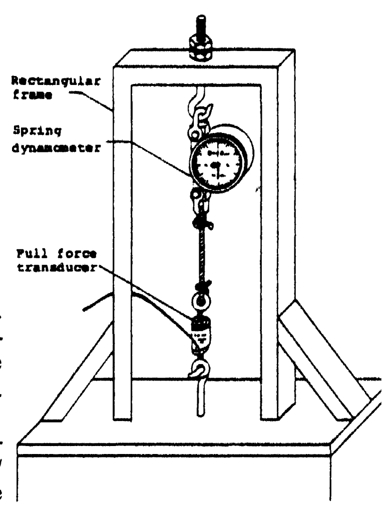

Fig. 10 Calibration setup.

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ARC 41 Z8-BASIC computer with real-time clock. 1983. User's Manual. Arcom Control Systems Ltd, Unit 8, Clifton Road, Cambridge CB1 4WH UK. ■■

Table 5 Effect of Ethrel (2000 ppm) application at late boot on plant growth on two cultivars of pearl millet under field conditions

Cultivar		Plant height (cm)[a]	Panicle length (cm)[a]	Panicle exsertion
ICMPE 13-6 30	Treated	70	21	partial
	Control	99	22	complete
	SE	± 2 0	± 0 4	
BJ 104	Treated	45	13	partial
	Control	64	14	complete
	SE	± 1 5	± 0 3	

[a] = Mean of 20 plants/treatment

ment, when Ethrel-treated panicles (at early protogyny) were inoculated with ergot (at full protogyny), high levels of ergot developed in two susceptible genotypes (82—87% severity), but the resistant genotypes had only ≤ 1% ergot, although they showed 75% male sterility (Table 4)

Effect on plant growth

Ethrel-treated panicles (at late boot) of ICMPE 13-6-30 and BJ 104 showed significant reduction in plant height, panicle length, and panicle exsertion from the boot-leaf sheath compared to the untreated plants In both genotypes there were reductions of about 30% in plant height, and 5% in panicle length, with partial panicle exsertion (Table 5)

Discussion

The results have clearly demonstrated the potential of Ethrel as a male gametocide in pearl millet, although complete sterility could not be achieved The chemical behaved as a true male gametocide and did not affect female fertility The minimum effective concentration of Ethrel was 2000 ppm and the critical flowering stage of application was late boot or early protogyny Since Ethrel application at late boot resulted in partial panicle exsertion, the early protogyny stage (which succeeds the late boot stage) seems to be the most appropriate time for Ethrel application to induce maximum male sterility in pearl millet The inconsistency in the levels of induced male sterility in different genotypes in different experiments (Tables 1, 2, and 4) may be attributed to several factors, including differential genotypic responses to Ethrel and variations in the age of the florets in different parts of the same panicle at the time of Ethrel application Incomplete sterility from Ethrel application was also reported in wheat (*Triticum aestivum* L) (LUCAS 1972) and barley (*Hordeum vulgare* L) (NICHOLLS and MAY 1963), and this effect was attributed to the differences in the age of the florets in the spikelets and among the tillers of the same plant To obtain maximum male gametocidal response, Ethrel should be sprayed before meiosis is initiated in the oldest florets of the panicles (BENNETT and HUGHES 1972, HUGHES et al 1974) In our study application of Ethrel at late boot had negative effects on plant growth in terms of height, panicle exsertion and its length Similar results were reported on corn (*Zea mays* L) (EARLEY and SLIFE 1969) and soybean (*Glycine max* L) (SLIFE and EARLEY 1970)

Ethrel application in both ergot resistant and susceptible genotypes induced male sterility by affecting pollen viability, but did not influence the ergot severity levels This result was confirmed by *in vitro* experiments on germination of pollen and conidia, wherein pollen germination was completely inhibited but conidial germination was not affected In an ergot-susceptible genotype wherein anthesis occurs much after inoculation, self-pollination does not interfere with ergot infection In an ergot-resistant genotype, on the other hand, where rapid self-pollination induces stigmatic constriction and prevents ergot infection (WILLINGALE and MANTLE 1985, WILLINGALE et al 1986), Ethrel treatment would be expected to prevent self-pollination completely (by rendering pollen nonviable) and subsequently to increase ergot severity, but these results were not obtained In ergot-resistant lines where maximum sterility was 75—84% (Table 4), 16—25% florets were still fertile and there were sufficient pollen grains from these fertile florets to self-pollinate the florets and reduce ergot severity In this case, therefore, it was not possible to eliminate completely the effect of self-pollination on imparting ergot resistance in the test lines Two recently developed ergot-resistant male sterile lines, however, show complete sterility (no evidence of fertile pollen) and have given consistently high levels of ergot resistance (RAI and THAKUR, unpublished data)

Although Ethrel could not induce complete male sterility in pearl millet lines tested in this study, its potential of inducing male sterility could be realized in the production of pearl millet hybrid seed One of the major problems in hybrid seed production in pearl millet is pollen-shedding, which impairs the purity of male sterile lines A few fertile sectors in some panicles of male sterile lines produce pollen, the amount of which varies in different environments This variability causes a serious problem in producing true hybrid seed where a few promising, high yielding F_1 hybrids can be produced on male sterile lines that have marginally more pollen shedders Application of Ethrel at 2000 ppm at early protogyny could help overcome this problem, and complete male sterility could be obtained by affecting the fertile sectors in the male sterile lines The potential and economic viability of this method, however, remains to be determined

Zusammenfassung

Die Wirkung von Ethrel als Gametozid bei der Perlhirse und sein Einfluß auf die Mutterkornbildung

In Feld- und Gewachshausversuchen wurde die gametozide Wirkung von Ethrel (2-Ethylchlorid-Phosphonsaure) auf die Perlhirse (*Pennisetum americanum*) und sein Einfluß auf die Entwicklung von Mutterkorn gepruft Bei Anwendung von 2000 ppm Ethrel zu einem Zeitpunkt, wenn sich die Rispen noch in den Blattscheiden befinden oder die Narben beginnen, empfangnisbereit zu sein, konnte bei der Hybride BJ 104 ein Hochstmaß an mannlicher Sterilitat erzeugt werden Durch die Behandlung mit Ethrel wurde die weibliche Fertilitat in einer mannlich sterilen Linie nicht beruhrt Die Anwendung von 2000 ppm Ethrel zum Zeitpunkt des Rispenschiebens hatte zur Folge, daß sich die Rispen nur zu einem Teil entfalteten und die Lange der Pflanzen und Rispen verringert wurde *In vitro* angewendet verhinderte Ethrel (2000 ppm) die Keimung der Pollen vollstandig, aber es vermochte nicht, das Auskeimen der Konidien von *Claviceps fusiformis*, der die Mutterkornbildung bei Perlhirse verursacht, zu beeintrachtigen Durch die Anwendung von Ethrel konnte weder die Resistenz noch die Anfalligkeit gegenuber Mutterkorn verandert werden, was wahrscheinlich darauf zuruckzufuhren ist, daß mit Ethrel keine vollstandige mannliche Sterilitat erreicht werden kann

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spillway. Of the 1108 mm total seasonal rainfall in 1981, 228 mm was recorded as excess surface water which could have escaped as runoff from the field. In the conventional system, 98 mm, or an additional 9%, of the seasonal rainfall was stored within the upstream zone of the bunded field. Most of this water (81%) had infiltrated, and only 19% was lost by evaporation. In the gated-outlet system, 140 mm, or an additional 13% of the seasonal rainfall, remained behind the bund. However, most of this water was stored for only short periods and then slowly released by opening the gated outlet. The water balance near two bunds (one for each system) during the period 27 July to 12 August is shown in Fig. 5. Water stagnation near the bund was visible for 16 days (27 July to 12 August; solid lines) in the conventional system. In the gated-outlet system the periods of water stagnation near the bund were short (27 to 28 July, 2 to 4 August) because excess water was released through the outlets. The various water-balance components for conventional and gated-outlet contour bunded watersheds over 3 years (1981/82–1983/84) is shown in Table 3. In the low-rainfall year 1982/83 the runoff from conventional and gated-outlet systems was similar. However, in high-rainfall years 1981/82 and 1983/84 the runoff values were higher in the gated-outlet system, mainly because the excess water (undesirable for crop growth) was allowed to flow as runoff.

CONCLUSION

Well-designed and maintained conventional contour bunds on SAT Alfisols undoubtedly conserve soil and for this purpose contour bunds are perhaps efficient. However, it appears that the associated disadvantages – mainly water stagnation and the absence of crop drainage (particularly during the rainy season) causing reduction in crop yields – outweigh any advantage from the viewpoint of soil conservation. Water stagnation in conventional contour bunds increases over the years as more fine particles are deposited around the bunds. In most years crop yields are greatly reduced in the areas around the bund. On SAT Alfisols, the contour bunds with gated outlets appear to have good promise. Some of its advantages over the conventional contour bunds are:

(1) The problem of prolonged water stagnation around the contour bund is reduced in the gated-outlet contour bund system. This results in higher crop yields particularly in areas near the bunds.

(2) The chances of bund breaching are less in the gated-outlet contour bund system because of less prolonged water-ponding. In conventional contour bunds the occasional breaching of a bund is quite common mainly because of prolonged water-ponding (as many as 40–50 days of continuous water-ponding).

(3) The peak runoff rates are generally less in gated-outlet contour bunds when compared to conventional contour bunds.

(4) Relatively more timely tillage and other cultural operations are possible in

the gated-outlet contour bund system because of better control on ponded runoff water In conventional contour bunds, timely operations are often not possible because of the prolonged water-ponding situation.

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