AN ANALYSIS OF TRACTOR PURCHASE COSTS AND EFFICIENCIES

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Tractors are the source of mobile power for the agricultural industry, and it is important to remember that power means rate of work.

In step with progress in the technology of design and production, it is pertinent to occasionally appraise the cost of power supply to farming. This may be expressed by three values. Firstly, the purchase cost: that is, the capital cost per unit of potential power. Secondly, the operating cost: in which overall efficiency (and thus fuel used per acre worked) is a major item. Thirdly, the cost per unit weight: since tractors are essentially processed raw materials and weight is a factor affecting tractive efficiency.

The data presented in this paper is the result of analyses of the relationship between cost and performance which were carried out in the 1962 and 1966 seasons for one region of this continent, namely, Southern Ontario. The three considerations enumerated above were developed as five parameters, as follows: 1. capital cost per pto horsepower, 2. capital cost per drawbar horsepower, 3. relative engine efficiency, 4. tractor conversion efficiency, and 5. capital cost per unit weight. In each year, calculations were made for all the tractors offered in the region for which University of Nebraska Test data were available; that is, 61 tractors in 1962 and 79 tractors in 1966.

TABLE I. RANGE OF VALUES

	1962		1966	
	Average Value	Range	Average Value	Range
Cost/lb. weight (cents)	84.4	57.7-118.5	92.0	72.0-136.0
Cost/pto hp (dollars)	85.3	64.2-109.8	95.4	75.0-133.9
Cost/db.hp (dollars)	101.6	73.9-133.1	113.3	91.0-153.1
Relative engine efficiency (%)	92.8	73.7-115.0	92.9	75.3-116.0
Conversion efficiency (%)	88.7	77.7- 95.0	87.8	82.2- 94.1

TABLE II. INFLUENCE OF TRACTOR SIZE

	1962		1966	
	Tractors over 50 pto hp	Tractors under 50 pto hp	Tractors over 50 pto hp	Tractors under 50 pto hp
Number of tractors	30	31	47	32
Cost/lb.weight (cents):				
average	81.1	87.6	92.0	95.0
range	58-118	65-114	72-136	72-120
Cost/pto hp (dollars):				
average	83.9	86.6	94.9	98.1
range	64-105	73-110	75-120	82-134
Cost/db.hp (dollars):				
average	99.5	103.7	111.0	117.6
range	74-124	85-133	91-144	96-153
Relative engine efficiency (%):				
average	93.2	92.4	93.3	92.5
range	78-115	74-110	75-109	77-116
Conversion efficiency (%):				
average	88.8	88.6	88.0	87.7
range	83-94	78-95	83-94	82-92

Although the results of this survey relate quantitatively to Southern Ontario, the relative values obtained should be indicative of the situation in similar areas and modified only by differences in transportation costs from the point of manufacture. Southern Ontario is a highly mechanized area of diversified agricultural production, and the results of this analysis may be regarded as representative of fully mechanized regions into which the required supply of power units is imported from manufacturing plants elsewhere.

LIMITATIONS OF THE AVAILABLE DATA

The performance data used was that provided by the Nebraska Tractor Test Reports. These values are directly comparative; but they also represent maxima and thus the analysis was necessarily made on the basis of "academic" performance. It may be considered that this introduces a source of error, since the relationship between drawbar performance in the test and on a farm in Southern Ontario is not only an unknown but also a variable between different tractors. However, no other comparative performance data is available.

It must nevertheless be emphasized that the values of cost per unit drawbar power which are given in this

paper are therefore of cost per academic horsepower, and not of the cost per potential horsepower actually purchased by the farm operator and available for use.

There is also a further point of some importance in this connection. The rate of work and the operating efficiency under variable field conditions can be affected by the facility with which gear changes can be made, and with which the engine can be loaded to give minimum specific fuel consumption. Thus, in comparing any two tractor designs, it is possible for the one developing the lower drawbar power in academic tests to achieve, in practice, the higher rate of work under variable conditions of soil, crop, or topography – by virtue of a difference in transmission system design. The influence of this factor on the effective power which can be developed, i.e. on the potential rate of work which is purchased, cannot be demonstrated from the comparative performance data available.

A difficulty in making the analyses was found to be the determination of truly comparative purchase costs. In each case, the value to be used in the calculations was the manufacturer's "suggested retail price" of the tractor as equipped for work in modern agriculture. This included all equipment necessary to its proper function, such as live pto, hydraulic system, and 3-point hitch; but not such items as, for instance, special seats, additional ballast weights, or power steering on small machines. Unfortunately, some essential components which are considered to be 'standard equipment' by many manufacturers are classed as 'optional equipment' by others; and also, for example, front weight may be built-in by one company but available as optional ballast with another. In addition, there are variations in transportation charges from the point of manufacture to the distribution centre and then to the dealer; variations in pre-delivery and service charges; and variations in tire sizes, etc. The result is that the determination of comparative cost data is not as straightforward as it should be and, although every effort was made in this investigation to determine truly comparative prices, it is possible that complete success may not have been achieved. It is quite

TABLE III. INFLUENCE OF ENGINE TYPE

	1962		1966	
	Gasoline Tractors	Diesel Tractors	Gasoline Tractors	Diesel Tractors
Number of tractors	27	34	34	45
Cost/lb.weight (cents):				
average	84.8	84.1	90.0	95.0
range	60-114	58-118	72-123	74-136
Cost/pto hp (dollars):				
average	80.9	88.9	91.4	99.8
range	64-101	73-110	75-108	79-134
Cost/db.hp (dollars):				
average	98.4	104.2	109.6	116.7
range	74-133	82-124	91-133	96-153
Relative engine efficiency (%):				
average	86.3	97.9	85.1	96.7
range	74-94	85-115	75-96	80-116
Conversion efficiency (%):				
average	87.2	89.8	87.0	88.5
range	78-94	83-95	83-90	83-94

TABLE IV. INFLUENCE OF MANUFACTURING COSTS

	Average of all 34 Tractors	Average of 8 Tractors manufactured overseas
Cost/lb. weight (cents)	84.1	78.3
Cost/pto hp (dollars)	88.9	88.6
Cost/db.hp (dollars)	104.2	101.4
Relative engine efficiency (%)	97.9	100.2
Conversion efficiency (%)	89.8	91.5

TABLE V. INFLUENCE OF TRANSMISSION SYSTEMS

	Sample (A)		Sample (B)	
	Conventional	High-Low	Conventional	Semi-automatic
Average values of:				
Cost/lb. weight (cents)	84.0	90.0	88.0	97.0
Cost/pto hp (dollars)	89.6	91.2	89.1	100.5
Cost/db. hp (dollars)	106.5	104.7	104.3	122.6
Relative engine efficiency (%)	81.8	89.9	92.9	89.4
Conversion efficiency (%)	86.1	89.4	89.2	85.8

TABLE IV. COMPARISON OF 2WD AND 4WD

	4WD Tractors	2WD Tractors
Number of Tractors	5	11
Average cost/lb.weight (cents)	103.0	93.0
Average cost/pto hp (dollars)	117.9	89.2
Average cost/db. hp (dollars)	140.6	102.5
Average relative engine efficiency (%)	92.7	96.9
Average conversion efficiency (%)	91.2	89.1

apparent that some rationalization of this situation by the industry on a cooperative basis is highly desirable.

DEFINITIONS

The pto horsepower used in the calculations was the quoted maximum power at rated engine speed in the Nebraska Test Report. The drawbar horsepower used was the maximum drawbar power with ballast, irrespective of the gear or speed at which this was obtained. An indication of the conversion efficiency, that is, the efficiency of the tractor as a machine for converting engine power into drawbar power, was taken to be the maximum drawbar power expressed as a percentage of the maximum pto horsepower. The relative efficiency of the engine was expressed by using a specific fuel consumption of 0.45 lb/hp-hour as a datum; thus engine efficiency was calculated as 0.45 divided by the specific fuel consumption at maximum pto horsepower at rated speed.

The cost per pto horsepower was calculated from the suggested retail price of the tractor as shipped without additional ballast. The cost per drawbar horsepower was calculated using the suggested retail price plus the value of the ballast which was added in the test to derive the quoted drawbar performance. The cost per pound weight was determined from the suggested retail price and the weight of the tractor without additional ballast, as also recorded in the Nebraska Test Report.

The variation in prices which occurs at the dealer level was not included in the study.

OVERALL RANGE OF VALUES

In 1962, the suggested retail prices of the tractors in the survey ranged from 2330 to 7020 Canadian dollars; the shipping weights were from 2850 to 9725 lb.; and the maximum pto horsepower at rated speed ranged from 23 to 84. In 1966, however, the price range was from 2900 to 11300 Canadian dollars; the weight range was from 2850 to 11750 lb.; and the pto power ranged from 27 to 127 hp. These changes were partly due to a demand for increased power supply, and hence the introduction of larger models into the market region together with some discontinuation of smaller designs.

The major point demonstrated by the analysis is, however, the very wide variation in cost per unit power and per unit weight. This is summarized in Table 1 and the frequency distributions are shown on Figures 1 and 2. It will be noted that both the average and the range of the efficiencies remained almost constant, but that costs increased by the order of 10% between 1962 and 1966.

The range of costs is shown to be appreciable. For instance, power for farm operations in Southern Ontario could be purchased at a cost in terms

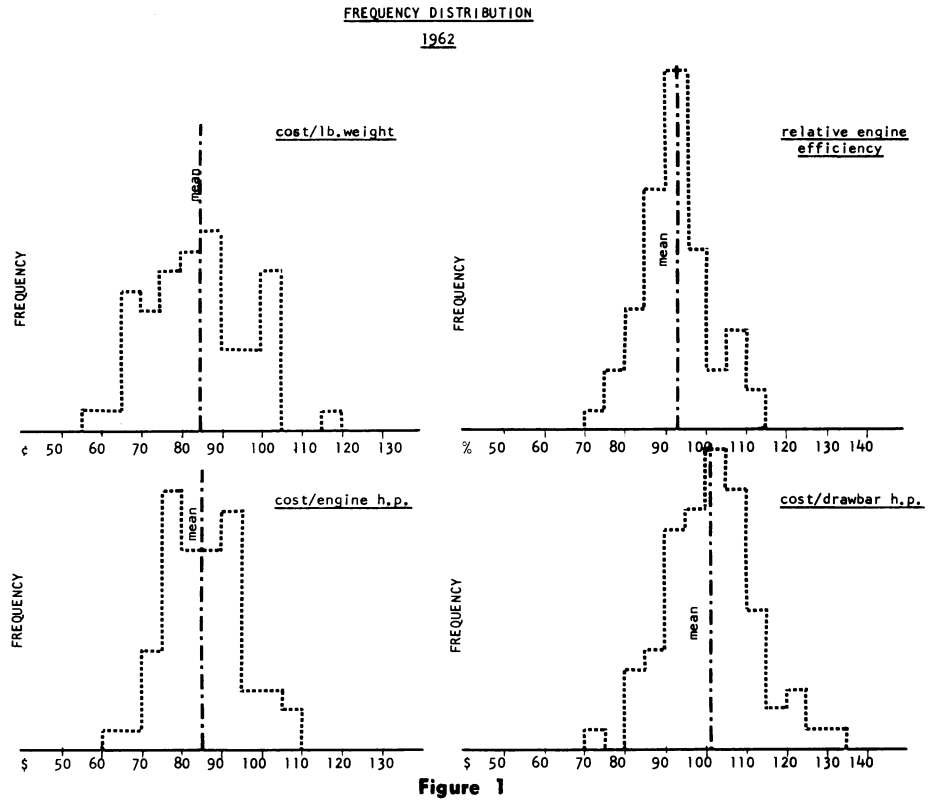

Figure 1

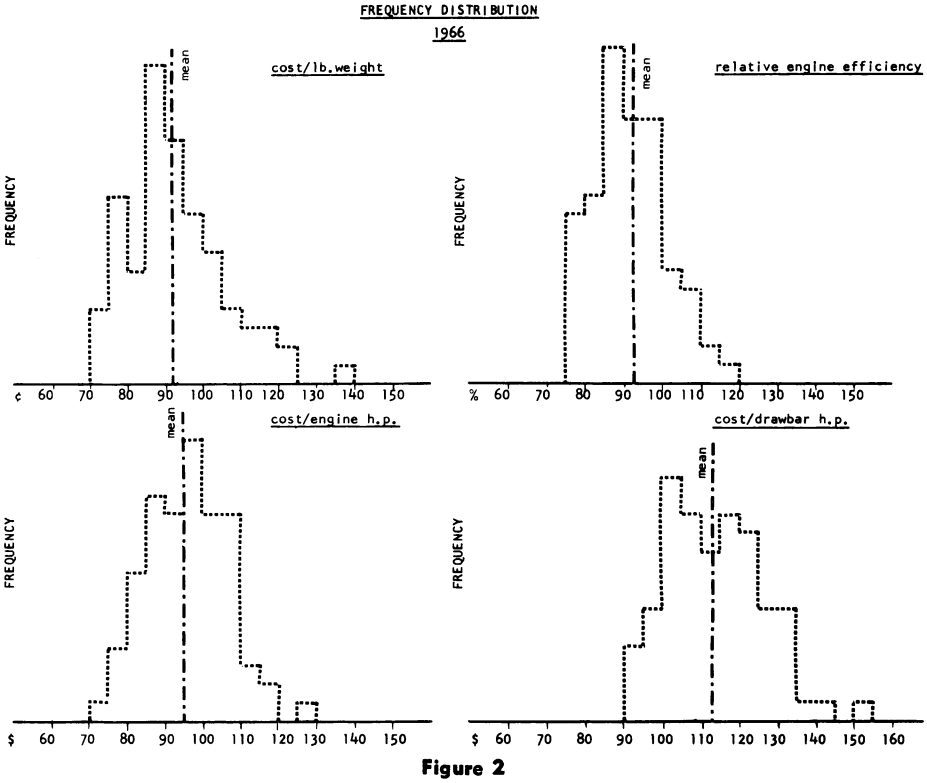

Figure 2

of dollars per pto hp as low as 64 or as high as 110 in 1962, and as low as 75 or as high as 134 in 1966. Yet a horsepower is, by definition, a horsepower. (Similar variability can be determined in other regions. For example, in the Province of Saskatchewan in 1964, the range in cost per drawbar horsepower for the 75 tractors on the market was from 85 to 160 dollars).

Figures 1 and 2 also show that the deviation from the mean values was even greater in the case of cost per unit weight than in the case of cost per unit power. Some of the variation in cost per unit weight was due to the differences between large and small tractors in this respect.

INFLUENCE OF TRACTOR SIZE

Although efficiencies were substantially independent of size, there were differences in cost per unit weight and in cost per unit power, as shown by Table II. The lower specific costs of tractors developing more than 50 pto hp are presumably because the design and production costs of precise components are not a direct function of dimensions.

It is evident that the utilization of larger agricultural power units does not incur a cost penalty.

Conversion efficiencies were shown to be unrelated to tractor size, and lower by approximately 1% in the 1966 analysis. It is also of interest that the range of conversion efficiency values is remarkably wide. This is a factor influencing the range of costs per drawbar horsepower.

INFLUENCE OF ENGINE TYPE

The type of engine is, of course, a major influence on the relative engine efficiency and the cost per pto horsepower, as well as affecting the cost of drawbar power. This is demonstrated by Table III. Relative engine efficiencies were shown to have declined slightly in 1966 as compared to 1962, and to be about 13% higher with diesel engines. The cost per pto horsepower was approximately 10% higher with diesel-engined tractors; but the capital cost per drawbar horsepower was only of the order of 6% greater. The higher conversion efficiencies of the diesel tractors may be noted in this connection. However, Table III also shows that the costs per unit weight of the diesel-engined tractors were greater than with the gasoline-engined models in 1966 and this is opposite to the influence of tractor size.

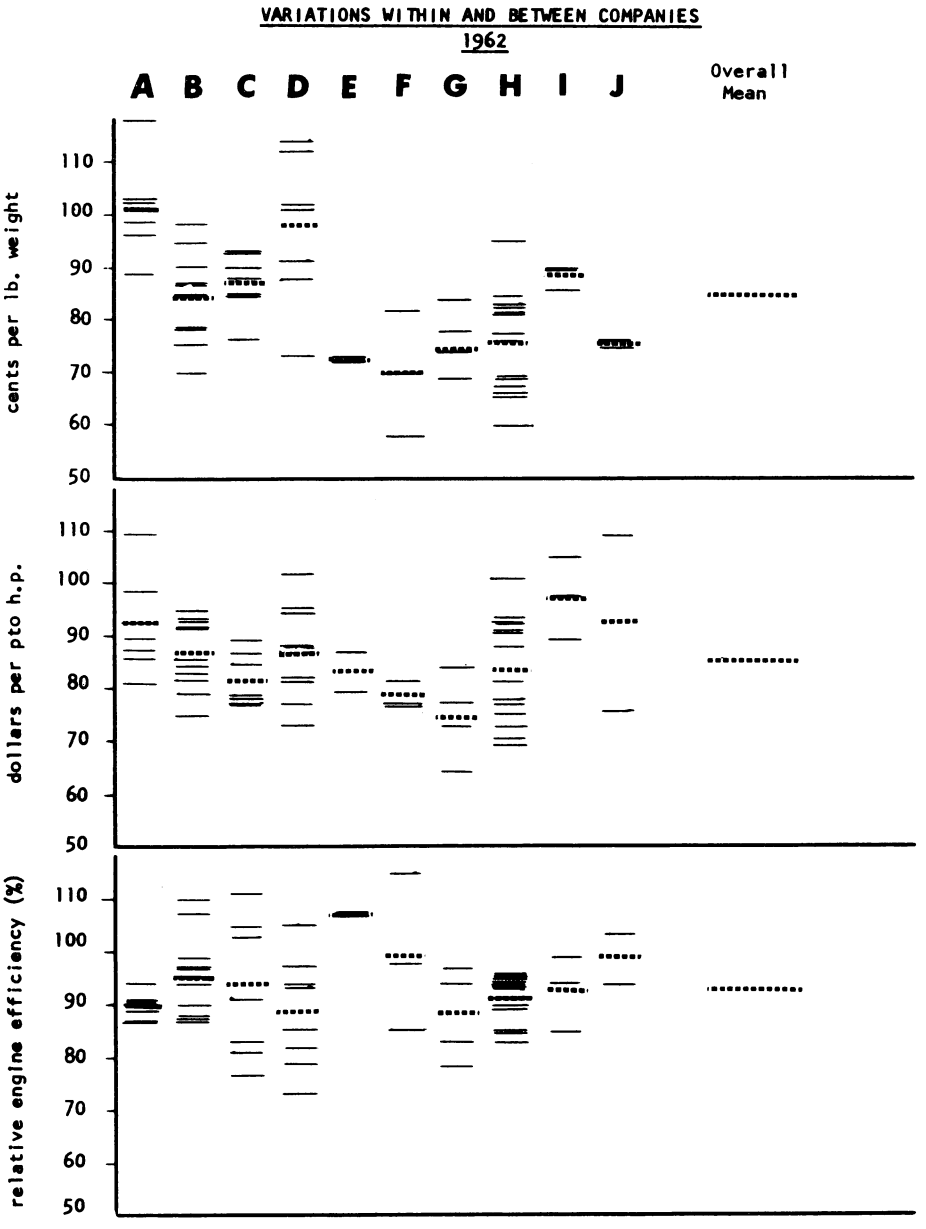

Figure 3

VARIATIONS WITHIN AND BETWEEN COMPANIES

Wide variations in the capital cost of mobile power not only occur between different manufacturers, but also between the various models marketed by any one company. This is demonstrated by Figures 3 and 4. No grouping in accordance with size, manufacturer, or engine type, for example, is apparent. The values are highly diversified, and this applies to the efficiency values as well as to the cost values.

Figures 3 and 4 illustrate the cost per unit weight, cost per pto horsepower, and relative engine efficiency for each of the tractors marketed by the ten companies denoted as A to J; and also the average value for each company. It is shown, for instance, that within the models offered by a single company in 1966 the cost per unit weight varied from 72 to 119 cents per pound, and the cost per unit power varied from 75 to 109 dollars per pto horsepower. In the case of another example, the variation was from 97 to 136 cents and from 88 to 134 dollars, respectively.

Hence, the average values per company were significantly different. They were dispersed within a range of the order of ± 10% of the overall mean in the case of both cost per unit

power and relative efficiency, and ± 20% of the overall mean for cost per unit weight.

Analysis of the data showed no correlation between efficiency and cost. It can, in fact, be seen on Figures 3 and 4 that companies having higher than the average costs did not have proportionately higher than average efficiencies, and vice-versa. The variation in relative engine efficiencies, both within and between companies, is particularly noteworthy.

A number of the diesel tractors included in the investigation were manufactured outside North America and a comparison of this sub-group with the whole sample of diesel-engined tractors in 1962 yielded the values given in Table IV. The higher than average efficiencies of this sub-group and the lower than average costs per unit weight and per drawbar horsepower (in spite of transportation charges) are of interest.

Another factor contributing to the wide variation in costs is the different types of transmission systems available. A comparison was therefore made of the average values in 1966 for two small samples in which the same tractor models were available with: (A) either a conventional transmission or a design permitting high-low changing on the move; (B) either a conventional transmission or a semi-automatic design permitting changes between gear ratios without stopping. The inability to determine from available performance data the actual value of the more sophisticated transmission designs has previously been referred to and is also illustrated by Table V.

COMPARISON OF 2WD AND 4WD

No four-wheel-drive tractors were marketed in Southern Ontario in 1962, but data was available for five machines in 1966. An ancillary comparison was therefore made between the costs and academic performances of these 4WD tractors and 2WD tractors of comparable power, that is, more than 90 pto horsepower. The results are summarized in Table VI.

Thus the specific costs of the 4WD tractors were shown to be appreciably greater than those of 2WD tractors of comparable engine power, for a small gain in conversion efficiency

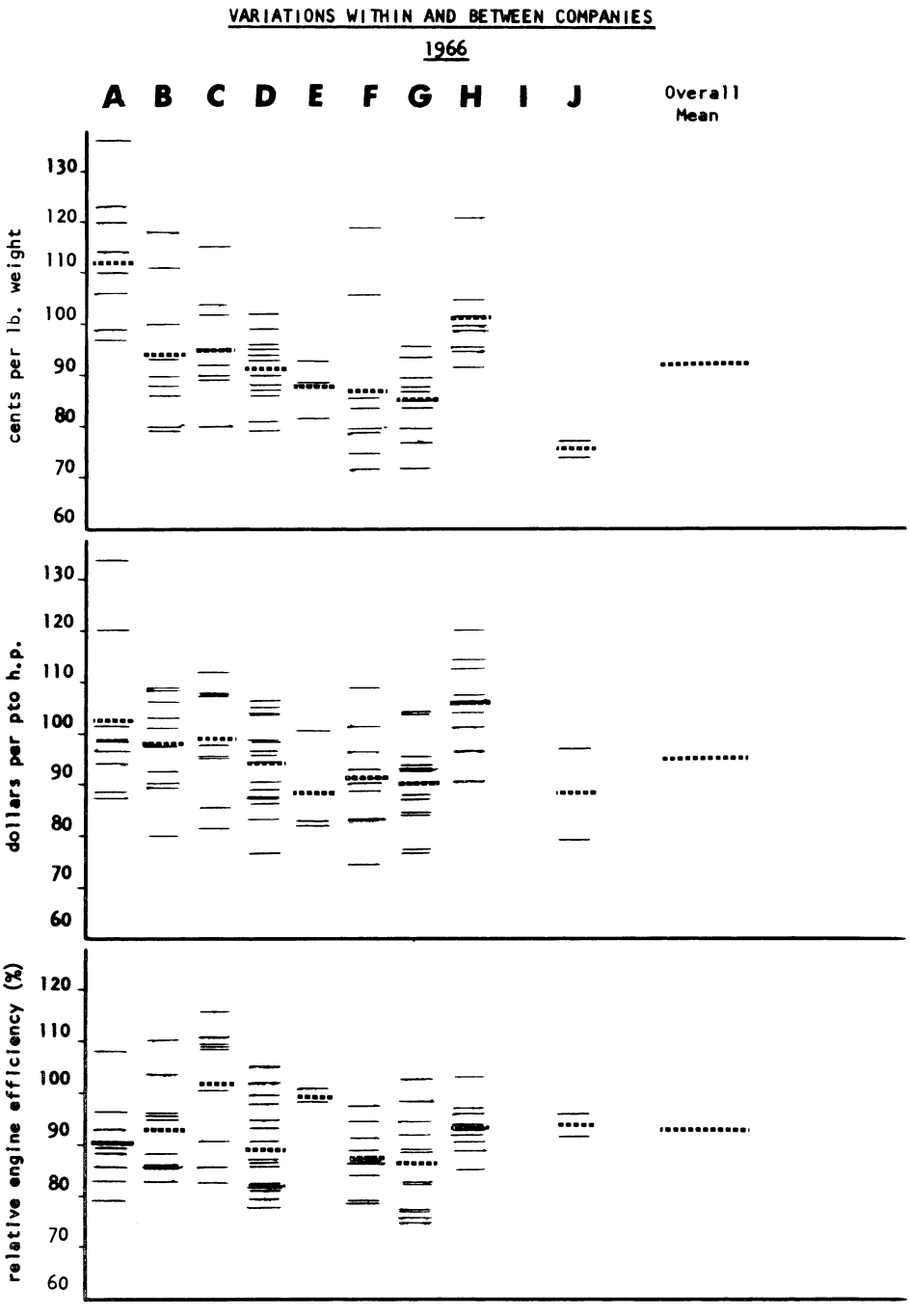

Figure 4

in academic tests. However, the 4WD values are still within the range which is given in Table II for all 2WD tractors of more than 50 pto hp. Reference to Table II will also show that the tandem connection of two average 2WD tractors so as to produce, in effect, a 4WD machine can result in lower costs per unit drawbar power than are given above.

CONCLUSIONS

1. The comparative performance data currently available may not be an accurate guide to the potential rates of work.
2. A cooperative definition of 'standard' equipment and procedures should be effected: perhaps on a regional basis.
3. Average capital costs per unit power supply have increased by approximately 10% between 1962 and 1966, without gain in efficiency.

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"Food and Peace," and the speakers will be:

Dr. Norman Z. Alcock (President, Canadian Peace Research Institute), speaking on "The Nature of Modern Conflict," and Dr. Ralph W. Cummings (Associate Director, Agricultural, Sciences, The Rockefeller Foundation), speaking on "Rural Development and Food Production in Developing Countries."

C.S.A.E. Program Coordinator, Walt. Bilanski, reports that, in addition to the general sessions, there will be several technical sessions featuring some 24 papers covering a wide range of subjects of interest to C.S.A.E. members. Walt. extends an invitation to all members to visit Hamilton, in the "Centre of Ontario's Golden Horseshoe," June 23 through June 27.

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of weathering after a period of one year and the plate steel cone base was corroded severely by the fertilizer. The authors suggest that the cone be made from a plastic material whereas the metal base could be covered with a thin layer of polyester body filler and then sanded to a smooth surface.

The costs of parts and materials used in this seeder and fertilizer applicator, exclusive of the tractor, was $1100.00. Approximately 200 man-hours were required for construction.

Detailed plans for the plot seeder and fertilizer applicator are available from the Research Station, Swift Current, Saskatchewan.

REFERENCES

1. Futral, J. G., Reid, J. T. and Butler, J. L. Precision metering device for fertilizers and other materials used in field plot work. Mimeo. Series N.S. 34. Georgia Agr. Expt. Sta., Univ. of Georgia, College of Agr. March 1967.
2. Jackson, T. L. and Cushman, H. E. Oregon fertilizer spreader. National Joint Committee on Fertilizer Application, National Food Institute, Washington, D.C. p. 52. 1956.

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4. The investigation showed wide variations in cost per unit power, in cost per unit weight, and in efficiencies.
5. The investigation showed wide variations in cost and efficiency between different models marketed by each manufacturing company, as well as between companies.
6. There was no correlation between cost and efficiency.
7. The utilization of larger conventional power units reduces capital expenditure per unit of performance by 3-4%, without influence on the efficiencies.
8. Diesel-engined tractors required approximately 10% more capital per pto horsepower, as compared to gasoline models, but the average engine efficiency was 13% higher and the difference in cost per drawbar horsepower was shown to be only 6%.
9. The tandem arrangement of 2WD tractors having average cost/performance values can effect comparable tractive power supply with less expenditure than in the case of the 4WD sample.
