PROPER SIZE OF TRACTOR IN LOCAL GREENHOUSE

BY

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CONTENTS

I. INTRODUCTION

Protected cultivation has been wide spreed in Egypt during the last ten years as in many other countries all over the world which have resorted to the protected cultivation as a modern method to produce vegetables and fruits. This resortation in ordr to get advantages which are well known for protected culture such as:

a. The yield per unit area from vegetables is doubled many times in the protected cultivation compared with the production of opened field.

b. The possibility of producing vegetables and fruits out of season.

c. It has also a high quality and suitable for exportation.

There are over 20,000 plastic tunnels in Egypt of about 500 m^2 each. They are spreed mostly in Nobaria, Giza, Sharqia and Kafr Eldawar.

There are many types of greenhouses but the most common types are the single plastic greenhouse which is called the Quonset house (Hassan, 1988). This type is considered as the most common in the plastic tunnels.

Once, these greenhouses became very important and wide spreeded all over Egyptian country, therefore, mechanization system should be applied inside these greenhouses.

The tractor is considered as the main source of mechanical power and is used for heavy draught operation which is mostly consumed during primary tillage.

Conditions inside the greenhouse are different from that of the opened field because the maximum height of machinery is a limiting factor for operation such machine under greenhouse. This height should be less than 2 m beside the two curved sides of greenhouse which can not be prepared well if unsuitable tractor is used. Therefore, the main aim of the present research is to determine the optimum and most suitable tractor size to operate under local greenhouse.

The objectives of the present study were:

1. The field performance characteristics of different powered tractors during ploughing operation under local greenhouse conditions.
2. Comparison between two- and four wheel drive tractor.
3. Effect of greenhouse size on the performance of tractor.

2. REVIEW OF LITERATURE

2.1. Greenhouse:

2.1.1. Definition of Greenhouse:

Mastalerz (1977) defined the greenhouse as a structure covered with transparent material that utilizes solar radiation energy to grow plants. Greenhouse may be covered with glass or glass substitutes. It is called plastic-house or plastic greenhouse when covered with plastic film.

2.1.2. Greenhouse areas in Egypt:

Hosny, (1984) reported that the area of greenhouses in Egypt estimated 126 ha (in 1984) used for vegetable crops.

El-Aidy (1991) reported that in Egypt, plastic tunnel greenhouses are used increasingly as a newly developed technique for vegetable or ornamental production (about 1,000 ha in 1991).

He also added that the majority are semi-circular profile structures with a framework of galvanised steel pipe having a diameter from 30 to 50 mm. Their dimensions are ranged from 8 to 9m wide by 60 m long and 3.5 m hight.

2.1.3. Type of plastic tunnel constructions:

Mastalerz (1977) reported that there are three basic types of greenhouses as shown in Fig. (1):

1. The lean-two greenhouse (Fig. 1-a).
2. The detached or single-span greenhouse, (Fig. 1-b).
3. The curved arch ridge and furrow houses, (Fig. 1-c).

Sirjacobs *et al.* (1988) reported that a survey of the greenhouse structures currently used for vegetable crops in the Mediterranean countries which Egypt being one of them. The shapes that appear most frequently are: Saddle-roof (a), Shed-roof (b), round arch (c), round arch with vertical side-wall (d), pointed arch with sloping side-walls (e) and pointed arch with vertical side walls (F). Possible shapes of greenhouses are shown in Fig. (2).

2.2. Classification of tractors:

Hanna (1976) mentioned that the agricultural tractors can be classified according to the following criteria:

a. Traction devices:

1. Wheal type tractor (steel type and pneumatic tire tractors).
2. Track type tractor or crawlers.

He also showed that the use of the track type tractor in Egypt has been limited to either heavy earth-moving operation or deep ploughing for sugarcane lands.

b. Type of fuel:

1. Gasoline engine tractor.

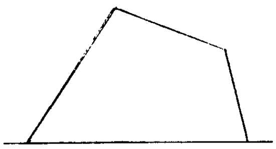

Fig. (1-a)

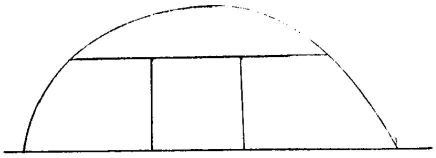

Fig. (1-b)

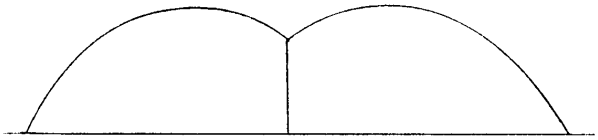

Fig. (1-c)

Fig. (1): Different types of greenhouse construction according to Mastalerz (1977).

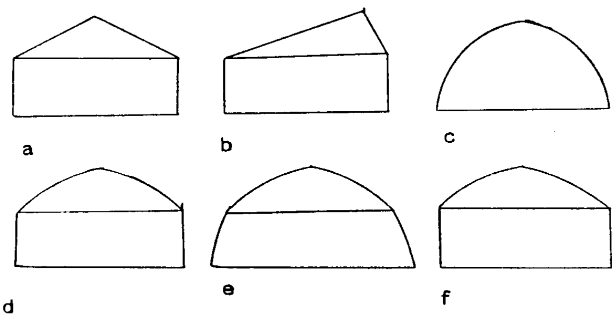

Fig. (2): Different types of greenhouse construction according to Zabeltitz (1988).

2. Kerosene engine tractor.

3. Diesel engine tractor.

He also showed that the Diesel engine tractor is commonly used in Egypt for technical and economical reasons.

c. <u>Variation in wheat drive:</u>

1. Single axle wheel type.

2. Two-wheel drive (2WD).

3. Four-wheel drive (4WD).

Hanna also showed that the single axle wheel type tractors are generally used for gardening, small farming and practically known as walking tractors. The two wheel drive tractors have their rear wheels as driving devices, and the front wheels are smaller in size for both stability and steering.

The four wheel drive tractors have all the four wheels engaged through the transmission system, as traction devices and connected to the tractor. They might have the two front wheels either equally or smaller in size than the rear wheels.

Liljedahl *et al.* (1979) mentioned that the tractors classification based on steering method, the arrangement of the frame and traction members as follows:

1. Crawler
2. Standard row-crop
3. High clearance
4. Utility

5. Orchard
6. Universal
7. Lawn and garden
8. Power tiller
9. Tree skidder
10. Skid steer loader
11. Four-wheel drive with smaller front steering wheels
12. Four-wheel drive with equal-sized front and rear steering wheels.
13. Four-wheel drive with equal sized wheels and articulated frame steering.

He also showed that the lawn and garden tractors have a power output of less than 15 kW and are primarily designed for the care of large lawns. They can tow or carry a lawn mower, a sweeper, a snow blower, a bulldozer blade, and many other attachments.

He also showed that the power tiller is the common name for a hand tractor, that is, a two-wheeled tractor guided and supported by hand. In the rice-growing regions of Japan and Southeast of Asia, the hand tractor is equipped with a rotary tiller, hence, the name "power tiller". The usual power of this tractor is from 2 to 12 kW.

He also stated that the simply four wheel drive tractors have been developed so as to be able to produce more drawbar power. In Europe, four wheel drive may be as small as 15 kW and are used especially in vineyards. Four-wheel drive tractors can be steered by pivoting the tractor in the center.

2.3. Comparison of the performance of two and four wheel tractors:

Reddy, V.R. (1975) mentioned that the power tiller can not only be used for puddling, ploughing, cultivating and harrowing both for primary and secondary land preparations, but also it can be successfully used for transporting, pumping, spraying, threshing and other several farmer uses.

Jain (1980) mentioned that power tiller is a multi-purpose hand tractor designed primarily for rotary tilling and other farm operations. For its direction and control, an operator walks behind it. It is also known as a garden tractor, hand tractor and walking tractor. In view of its high manoeuvrability and versatility, it is ideally suited for agricultural operations in small fields and farms where larger conventional four-wheeled tractor is difficult or uneconomical to operate.

Sheikh *et al.* (1979) carried out a field study to assess and compare the performance of different types of tractors for wheat cultivation in Pakistan. They found that:

a. The cost of tillage operation per hectare of a power tiller of 12 HP is three times the cost of operation of a general purpose tractor of 47 HP.

b. The penetration resistance of soil resulting from the application of power tiller was highest.

c. The shear strength of soil determined after the tillage operations was maximum for power tiller and garden tractor.

d. Power tiller was difficult to operate and it exerted unnecessary strains on the operator's shoulders.

Wali Ullah *et al.* (1989) conducted a comparison between performance of a four wheel tractor and a two wheel tractor for small plots ranging from 0.25 ha to 4 ha. They found that the two-wheel tractor under study consumed about 41% more fuel than the four-wheel tractor for an average plot size of one ha. On the other hand, for a plot size of 0.25 ha the four-wheel tractor consumed 5% more energy than the two-wheel tractor which is expected to be higher for smaller holdings. They added that the cost analysis showed that it is not economical to work a plot smaller than 0.6 ha with a four wheel tractor in Bangladesh.

2.4. Comparison of the performance of two and four-wheel drive tractors:

Dommal and Race (1964), classified the tractors with respect to drive type into three categories of power. They proposed that the tractor under the following power of about 37.3 kW should basically be two-wheel drive. Tractors ranging between 37.3 to 89.5 kW could be either two-wheel drive or four-wheel drive and the tractors above 89.5 kW should be four wheel drive.

Domier *et al.* (1971) carried out field tests with three tractors: crawler, two wheel drive tractor, and four wheel drive tractor on three fields with estimated P.T.O. power outputs ranging from 90 to 112 kW. Comparisons were made on the basis of tractive efficiency. Tractive efficiency being defined as the ratio of drawbar power to axle power.

The two wheel drive tractor had tractive efficiencies ranging from 52 to 69.8%, while the four wheel drive tractor had tractive efficiencies ranging from 68.3 to 74.5%, with an increase of 13.1 to 19.3% over the crawler and the two wheel drive tractor respectively.

Dwyer and Pearson (1976) studied the tractive performance of a two-wheel drive tractor, a four-wheel drive tractor with front wheels smaller than rear, and a four-wheel drive tractor with equal sized wheels, each with the same 63 PTO kW engine. The tractive performance was measured in 13 different field conditions. They indicated that the average maximum drawbar power of the four-wheel drive tractor with equal sized in all fields was 14% higher than that of the two wheel drive tractor. The average maximum drawbar power of the four-wheel drive tractor with unequal sized wheels was 7% higher than that of the two-wheel drive tractor.

Liljedahl *et al.* (1979) mentioned that through the decade of 1970-1980 the number of manufactured four wheel drive tractors has considerably increased in USA. They also added that the four wheel drive tractors have been developed so as to be able to produce more drawbar pull. The size of four wheel drive tractors varies in USA and Canada from 100 kW to over 300 kW. However, in Europe, the four wheel drive tractors may be manufactured as small as 16 kW.

Ohrmann *et al.* (1980) mentioned that many farmers do not utilize the full power potential of their tractors. Field data reveals that observed drawbar power often was less than half the rated engine power. Four-wheel drive tractors can increase efficiency and reduce costs but only if the tractor's power is used efficiently.

Clark (1984) found in his field of study on the tractor performance with both two and four-wheels drive tractors of 16.7 PTO kW, that when ploughing with the four wheel drive tractors, the drawbar power and ground speed increased significantly, while fuel consumption per hectare decreased significantly as compared to the two wheel drive.

A cost analysis to plough 10 ha/yr with either two or four-wheel drive with a 16.7 PTO kW tractor showed that costs were approximately equal. However, the four wheel drive model did provide a significant increase in field speed, providing a timeliness advantage.

A second cost analysis compared the use of 16.7 PTO kW four-wheel drive tractor with a 24.9 PTO kW two-wheel drive tractor. It was found that the operation costs to plough 10 ha/yr are about 25% less for the four-wheel drive tractor.

Depeng *et al.* (1983), found that in China, small four-wheel drive tractors are suitable to agricultural conditions and farming requirement in most areas. They are suitable to the economic conditions and management scale in most areas. They are conforming to the level of mechanical knowledge and management in rural areas. They requires less investment and produce quick returns. Small four wheel drive tractors are an intermediate product between walking tractors and ordinary tractors in use in China's agricultural mechanization.

The same authors estimated that up to 1985, in the period of readjusting the nation's economy, walking tractors, small four-wheel drive tractors and boat type tractors will continuously play an important role in China's agricultural mechanization.

2.5. <u>Field capacity and efficiency:</u>

Bateman (1943) noted that percentage of total field time lost due to minor repairs, adjustments, and crop unloading without time lost in turning and in idle travel acrose the ends of the field ranged from 1 to 10 percent for disking, plowing, harrowing, or cultivating corn (two row) and from 10 to 16 percent when operating an 8 ft grain drill or a 7 ft mower.

Abou-sabe (1958) showed that the field efficiency for most of the machines noticeably drops when used in small land holdings, due to frequent turning at the headlands.

Awady (1974) derived the service time per hectare in the form of a second order polynomial, including the effects of operation, turnings, and transportation between fields. Cost was consequently derived and found to decrease with the increase of holding size. Small machinery, at any rate, were found to suit large holdings as much as big ones, but were superior in the case of small holdings.

Barger *et al.* (1963) define field capacities and efficiency of an implement as:

- Theoretical field capacity of an implement is the rate of field coverage that would be obtained if the machine was performing its function 100 percent of the time at the rated forward speed and always covered 100 percent of its rated width.
- Effective field capacity is the actual average rate of coverage by the machine, based upon the total field time.
- Field efficiency is the ratio of effective field capacity to theoretical field capacity, expressed as percent. It includes the effects of time lost in the field and of failure to utilize the full width of the machine.

Richey *et al.* (1961), reported factors affecting the capacity of field machines as:

- Operating width as affected by:
  a. Measured width of machine.
  b. Percentage of width actually used.
- Speed of travel as affected by:
  a. Draft of machine.
  b. Drawbar power available
  c. Traction of power source.
  d. Variations in grade and rolling resistance.
  e. Operating limitations on speed such as quality of work, rough ground, obstacles, etc.
- Percentage of non-operating time due to idle travel, such as travelling to field, turning at ends, etc.

Kepner *et al.* (1982) reported that the effective field capacity of a machine is a function of the rated width of the machine, the percentage of the rated width actually utilized, the speed of travel, and the amount of field time lost during the operation. The required amount of the over-lap is largely a function of speed, ground condition, and skill of the operator. The effective field capacity of a machine may be expressed as follows:

$$C = (SW/10) \times (E_f/100)$$

Where:

C = Effective field capacity, in hectare per hour.

S = Speed of travel, in kilometres per hour.

W = Rated width of the implement, in meters.

E_f = Field efficiency, in percent.

The field efficiency of a machine may be expressed as follows:

$$E_f = \frac{To}{Te + Th + Ta} \times 100$$

Where:

To = Theoretical time per hectare.

Te = Effective operating time To x 100/K.

K = Percentage of implement width actually utilized.

Th = Time lost per hectare due to interruptions that are not proportional to area. At least part of Th usually tends to be proportional to Te.

Ta = Time lost per hectare due to interruptions that tend to be proportional to area.

Kaul and Egbo (1985) stated that the field capacity of a farm machine is influenced by many factors, some of which are within the control of farm manager to obtain maximum field capacity. In this connection the following definitions are of significance.

Theoretical field capacity is the rate of field coverage possible if the machine works all the time at the recommended speed and utilizes its entire width of operation.

Effective field capacity is the actual rate of field coverage by the machine. Ideally, the effective field capacity should be the same, or as close as possible to the theoretical capacity. However, in practice, this is not possible because:

a. It is generally impossible to utilize the full width of operation of a machine without any over-lap.

b. It is not always possible to work at the rated speed because of the condition of the field, the judgement and efficiency of the operator, and the amount of power available. Considerable time is lost during turning at the ends of rows, in minor breakdowns, and the lubrication. Thus, it is impossible for the machine to work effectively all the time.

Field efficiency is the ratio of effective field capacity to theoretical field capacity. They added that in Nigeria and most of African countries the field efficiency is low because of breakdowns, small field and lack of organised services.

2.6. Traction performance characteristics of agricultural tractor:

Abou Sabe and Henein (1964) reported that tested performance is only one of the factors to be considered before making a selection of the most suitable type for local calculation of the optimum quantity of conditions. Other factors which must be taken into consideration, include easy operation of the tractor, easy service and repair, availability of spare parts and the initial and maintenance costs. The maximum pull that can be obtained does not depend only on the maximum power of the engine but depends mainly on the load on the rear axle, the type of soil and the height of hitch point.

Al-Katary (1976) studied some specifications of suitable tractor for Egyptian conditions. He found that:

a. Rolling resistance power is higher on stubble field than on asphalt and increases by the increase in tractor speed.
b. Unit draft increases by the increase in tractor speed.
c. Drawbar power increases by the increase in tractor speed but the maximum drawbar power at higher gears occurs at lower drawbar pull.
d. Tractive power efficiency is lower at higher gear ratios.

Grevis and Bloome (1982) reported that a tractor power monitor to measure ground speed, wheel slip, drawbar pull and drawbar power was developed and tested. The power monitor provided the tractor operator with information on several variables relevant to tractor performance. This information can be used when making decisions on both operation and selection of tractors and implements.

2.6.1. <u>Drawbar pull:</u>

The drawbar pull is the force acted in the direction of travel produced by the vehicle at the drawbar (ASAE, 1984).

2.6.2. Rolling resistance:

Hunt (1983) stated that the rolling resistance is the force required to keep the equipment moving at a constant speed and is proportional to equipment weight.

2.6.3. Slip:

Richey *et al.* (1959) showed that the increased weight per tire reduces travel reduction (slip) for a given pull. They also indicated that for a given soil and percent travel reduction, pull is approximately proportional to weight of the vehicle.

Raghavan *et al.* (1978) found that it is necessary to operate machinery in agricultural fields with as little wheel slip as possible in order to reduce losses in terms of fuel cost, tire wear and possible reductions in soil fertility and crop yields associated with higher soil compaction. The programming of traffic in fields to minimize compaction must take into account the type of soil, the moisture content and the tractive energy required for field work.

Shebi *et al.* (1988) reported that increasing tractor power from 19 to 47 kW decreased the travel reduction from 11.2 to 3.5%, while the estimated drawbar pull increased from 0.72 to 1.42 kN. As tractor speed was increased from 4 to 11 km/h, travel reduction reducted from 15 to 5.8% while the estimated drawbar pull increased from 1.1 to 1.25 KN for a given size of tractor. They also added that the measured drawbar pull was consistently higher than the estimated drawbar pull. This disparity was probably due to in adequacies of soil parameters used, changes in soil properties from point to point and excessive vibration of dynamometer pointer.

2.6.4. Tractive efficiency:

Sheets (1967) reported that to obtain the maximum drawbar horsepower should be added rear-axle ballast in the correct quantity to cause the maximum horsepower to be obtained at a slip rate of as near 5.7 percent as possible and at some travel speed between 4.0 and 5.5 M.P.H.* He also mentioned that, many considerations must be investigated before the calculation of optimum quantity of ballast which must be added to obtain desired vehicle weight. This calculation requires selection of the proper location and type of the used ballast. For example physical dimensions and characteristics of the basic tractor under consideration must be known. Also the operating speed at which maximum drawbar horsepower is obtained must be determined. He also added that maximum drawbar horsepower divided by maximum power take off horsepower gives an average ratio of 0.884 with 0.814 the lowest and 0.933 the highest.

Zoz (1972), outlined a method of predicting a tractor's drawbar performance under various field conditions. A graphical solution based on tire performance criteria may be used to

* Mill/hour

determine the expected drawbar pull, drawbar horsepower, travel speed, and travel reduction of any tractor under various soil conditions. He also reported that the tractive efficiency is determined as a ratio of the power out put (drawbar horsepower) to power input (axle horsepower).

Domier and Willans (1977) reported that maximum tractive efficiency usually occurs at low values of travel reduction, or at a gross traction coefficient of 0.4 to 0.5. Various combinations of speed and drive wheel weight can be used for some operations and the forward speed required to utilize the power available is too high, and at te low forward speeds, the amount of added ballast is not economical. A compromise exists between tractive efficiency, field capacity and costs. A weight to power ratio of 60 kg/kW for two wheel drive tractors will result in optimum tractive efficiency.

2.7. Proper sized tractor and power requirement:

Singh and Singh (1975) mentioned that with increasing farm mechanization, both the number and the size of tractors have been increasing in India for the last two decades. There are farm size varying from 2 fraction of a hectare as family farms to a few thousand hectares of government and private farms. The tractors available on some of these farms vary from 20 HP to 75 HP range.

Crossley (1979), reported that a small tractor designed for use on direct traction in the developing countries needs to be robust and heavy, with large tires, good ground clearance and an engine power of at least 9 kW. The initial and operating costs of such a unit are likely to be high and prior to an application would require careful investigation to establish whether the economic and social environments were suitable. As with all engine powered mechanization devices, the successful introduction of a small tractor would be dependent upon the existence of or early potential for, repair and maintenance facilities, extension, credit arrangements, and marketing system. Single or twin cylinder Diesel engines of between 7.5 kW and 15 kW are usually specified for small tractors. Such engines are likely to be operated for long period at near their peak power levels at high speeds (between 2500 and 3600 RPM).

Liljedahl *et al.* (1979) stated that the power-to mass ratio is greater for Japanese tractors than for others. He added that, in North America, four wheel drive is used mostly on tractors over 100 kW, while in Japan, tractors as small as 7 kW may have four wheel drive. He also added that in Europe and the United Kingdom, four wheel drive with front wheels smaller than the rear is common, whereas in North America, almost all four wheel drives tractors have equal-sized wheels. He also showed that the hand tractors are quite population in

Japan and south east of Asia, primarily because of the small farms found there.

El-Awady *et al.* (1979) carried out a study to select the tractor power to suit the land holdings under the conditions of kingdom of Saudi Arabia and Arab Republic of Egypt. He found that the optimum tractor and implement size ranges between 14 and 17 HP. The same author also explained that the presence of the most important number of tractors layed in the range of 50-60 HP in the Arab World is explained by the fact that imported equipment are designed and manufactured to suit the countries of origin which are advanced and have large agricultural holdings.

Culpin (1981), mentioned that the best basis for choosing suitable tractors is experience, and practical trial in the conditions in which the machines are to work. In most instance the tractor will need to be an all purpose machine which can be applied to almost any kind of farm work, including ploughing, cultivations, sowing, row-crop work, harvesting, transport and stationary P.T.O. work.

He also mentioned that one of the most difficult problems in choosing tractors for general farm work is to decide whether all the tractors should be of one make and size, or whether a range of makes or sizes should be selected to suit the various jobs.

Sheikh *et al.* (1983) reported that the economic factors alone should not be considered for suggesting an optimum size of tractor. Soil, crop and machine variables are important in addition to economic factors, for determining a proper tractor size.

They also added that an integration of the knowledge of economics, engineering and agriculture is necessary in order to develop an optimal solution for the power required to perform farming operations.

Rahman *et al.* (1984), found that the drawbar pull available with a tractor is directly proportional to the weight of the tractor. Tractors in the range of 25-35 HP generally have a weight about 2/3 to 3/4 the weight of 45 HP tractors. He added that the maximum PTO horsepower is 22 and 41 for 25 and 45 HP tractors, respectively.

They concluded that the ability of a smaller tractor to carry out tillage operation with proportionally scaled down implements is lower than that of bigger tractors by about the same proportion as its weight. He also added that the medium size of tractors (25 to 35 HP) consumes less fuel and therefore more economical to operate compared to 45 HP or larger tractor.

2.8. Energy requirements for plowing operation:

Zoz (1974) reported that primary tillage is one of the larger power consuming operations in the farm. As, it is the operation which influences the size of the power unit required for the total farm operation.

Metwally *et al.* (1978) studied the effect of tractor high speeds during tillage operation, on the total operating costs under Egyptian conditions. They found that the optimum operating speed was of about 7.44 km/h by a minimum operating cost of 0.140 LE/feddan at the Faculty farm and under the experimental conditions.

they also designed a nomogram to determine the optimum ploughing speeds at optimum costs of labor, fuel and soil consumption per unit feddan for a heavy soil in three suggested cases.

Frisby and summers (1979), carried out a study on energy related data for selected implements using a John Deere 2360 Diesel tractor. Draft, fuel consumption, field speed and travel reduction for six tillage and two planting implements were measured on three soil types. They found that the mounted straight points chisel plough with 307 cm width of cut and

30.7 cm depth at speed of 6.41 km/h on loamy soil consumed 23.73 lit/h.

Sheikh *et al.* (1983), stated that tillage requires the maximum energy amongst all agricultural operations consequently, it is among the most expensive operation in agriculture. They also added that in the age of energy crisis therefore, care must be exercised in selecting and using the tillage implements with a view to minimize foreign exchange spent on fuel.

Walker (1984) measured the performance of a Diesel tractor engine under various loads, speed control settings, and alcohol fumigation rates. He also determined the performance in terms of torque, power, alcohol and Diesel consumption, thermal efficiency, smoke and carbon monoxide emission, and fuel cost. The fumigation of alcohol was proved to be of value if Diesel fuel substitution or increased power and torque were the goals. Increased smoke production was recorded for heavy load conditions, especially at maximum speed control settings. Carbon monoxide production increased with alcohol input at heavy loads. The fuel cost for alcohol fumigation was greater than for Diesel only operation.

Saleque, and Jangiev (1990) mentioned that energy is more expensive, its efficient utilization in agricultural production systems has become a major concern to agricultural engineers and tractor owners. The reduction of energy waste in tillage operation depends upon the matching of tractor-implements and their operating characteristics. This can be determined only by experiment. They calculated the optimal operational parameters for the tractor during field work. These parameters included wheel slip, travel speed, tractive efficiency and area tilled per unit energy.

2.9. Tractor size and ploughing costs:

Chancellor (1968) reported that the very small tractors are frequently given consideration by individual farmers because the tractor represents the replacement of animal power. Manageable amounts of animal power are rather small, and so only a small tractor is required for replacement. Perhaps, even more important is the fact that the amount of land tilled by one farmer has been limited by animal power and thus a farmer's need for power may appear to him to remain limited by the land area he manages. The small fields manageable with animal power are also more adaptable to small tractors than to medium or large sized tractors. However, the main feature of small tractors which brings them into consideration is their lower total initial cost, which makes them compatible with the resources of the large number of individual farmers. He noted also that, very large tractors are considered by governmental and large agricultural organizations because of such ideas as economy of scale, savings in operator wages and ease administration of fewer units. Larger tractors also are capable of certain heavy duty jobs, such as land clearing, which are not possible with smaller units.

Chancellor (1969) found that the elements of decision on tractor size concerned with the adaptability of large equipment to small fields or row crops, alternate uses in earth moving and other noneconomic factors concerned with the physical size of the tractor will not be considered here. Only the economic advantage and disadvantage of small and large size tractors will be quantitively compared to provide a basis for economic optimization of tractor selection.

Zoz (1974) determined the implement and tractor costs in general terms, particularly in terms of the performance parameters of width, travel speed, power and weight. Optimization is really the process of determining the trade-off between fixed and operating costs to determine the best combination of width and speed for the least total cost per unit of area plowed. The higher investment costs of slow speed operations are balanced against the higher energy cost at increased speeds.

Hanna *et al.* (1979), found from their study on the field capacity and operating cost in relation to field shape and area that the cost of ploughing per feddan is greatly affected by the plot area and its length to width ratio. Using a regular 60 HP (44.76 kW) four wheel tractor, the cost of ploughing/feddan sharply increased when the plot area becomes smaller than one feddan. On the other hand, the ploughing cost per feddan when using two motor cultivator has been found not to be greatly affected by the field size.

They also added that the motor cultivators might be more economical than the regular 65-HP (44.76 kW) tractors if the type of tillage offered by the rotary plough at a depth not exceeding 10 cm is acceptable to the farmers. Otherwise the regular chisel plough with two passes, executed by the four wheel 65 HP (44.76 kW) tractor is clearly more economical especially when ploughed plots exceeds the size of one feddan.

Rahmoo *et al.* (1979) mentioned that the tractor, being the most important single item of machinery for selective farm mechanization in developing countries, requires a high basic investment. Full considerations of farm size and annual use are required to be made in purchasing a tractor of a certain horsepower along with necessary implements. The economic benefits from a tractor depend upon the efficient manner of its use. Tractors are used mainly for those farm operations in which animal and human power are uneconomical.

He also reported that the total cost per hour and custom-hire rates per hour showed that the owners of both old and new tractors were making reasonable profits from their tractors.

The annual use of 1600 hours was found most economical as the lowest cost per hour occurred at the level. The repair cost increased with the age of the tractors.

Metwally (1980) estimated the economical use of new agricultural implements. Mathematical analysis related to the costs from labor, energy, machine and the maximum utility obtained from improving the quality of the product was carried out.

Bukhari (1982), mentioned that the tractor is the most important source of farm power for mechanizing the farm, requiring a high initial capital investment. The selection of the right tractor means the difference between profit and loss of the investment. The knowledge of power costs for tractor operation has a prime importance in making management plans and decisions. It is also useful in comparing different types of tractors.

Kepner *et al.* (1982) mentioned that the total cost is generally desired on either operation unit area or production unit-basis. Determination of the total cost per unit of work involves the following factors:

a. Annual use of the implement, in hours or hectares.

b. Effective field capacity of implement, in hectares per hour.

c. Total annual fixed cost per hour for implement.

d. Total operating cost per hour (repairs, fuel and Lubricants), for implement.

e. Cost per hour or per hectare for tractor power required by implements that are not self-propelled.

f. Labour cost per hour.

3. MATERIALS AND METHODS

The importance of determining the optimum tractor size under local greenhouse conditions is quite evident from the previous review of literatures. To achive this goal five different tractors were used. Their engine-power ranging from 14 to 33 HP (10.44 - 24.63 kW). Each tractor was equiped with the proper size of chisel plough to execute the ploughing operation in two different sizes of plastic tunnels.

3.1. Materials:

The materials used in the present study are indicated as follows:

3.1.1. Agricultural tractors:

Five different types of tractors were used as shown in the following figures (3-1, 3-2, 3-3, 3-4 and 3-5). The technical data and specifications of these tractors are indicated in Table (3-1).

3.1.2. Primary tillage equipment:

Three different models of chisel ploughs were used as shown in Fig. (3-6, 3-7 and 3-8). Table (3-2) indicates some specifications of the used chisel ploughs.

Table (3-1): Technical data and specifications of the used tractors in the present work.

No.	Specifications	Tractors model				
		Pasquali 988	Kubota L245DTP	Kubota L245 FP	Shibaura SP 2040	Grill 113
1	Source of manufacture	Italy	Japan	Japan	Japan	Italy
2	Type	Standard	Standard	Standard	Standard	Standard
3	Source of drive	4WD	4WD	2WD	4WD	2 wheels walking tractor
4	Engine	Diesel, 2 cylinders	Diesel, 3 cylinders	Diesel, 3 cylinders	Diesel, 3 cylinders	Diesel, one cylinder
5	Engine HP at R.P.M. (KW)	33 at 3000 (24.63)	25 at 2800 (18.66)	25 at 2800 (18.66)	20 at 2800 (14.93)	14 at 3000 (10.44)
6	Total weight (kg)	920	910	830	530	350
7	Dimension, (cm)					
	overall length	245	257.5	257.5	216.3	150.0
	overall width	87-122	131.0	131.0	101.0	65.0
	Wheel base	117.5	155.5	160.0	128.0	-
	height	112.0	138.0	136.5	120.0	90.0
8	Tire size					
	rear	7.5-16	11.2-24	11.2-24	8.3-20	6.0-12
	front	7.5-16	7-6	5-15	6.00-12	-

Table (3-2): Specifications of chisel ploughs used in the experiments.

No.	Specifications	Plough model		
		No. 1	No. 2	No. 3
1	Sources of manufacture	Local	Italy	Italy
2	Type	Mounted	Mounted	Trailed
3	No. of tines	5	5	3
4	Category	II	II	I
5	Blades arrangement	2 front, 3 rear	2 front, 3 rear	2 front 1 rear
6	Working width (cm)	120	100	60
7	Total weight, kg	180	120	80
8	Type of tine	Pointed	Ducks foot point	Ducks foot point

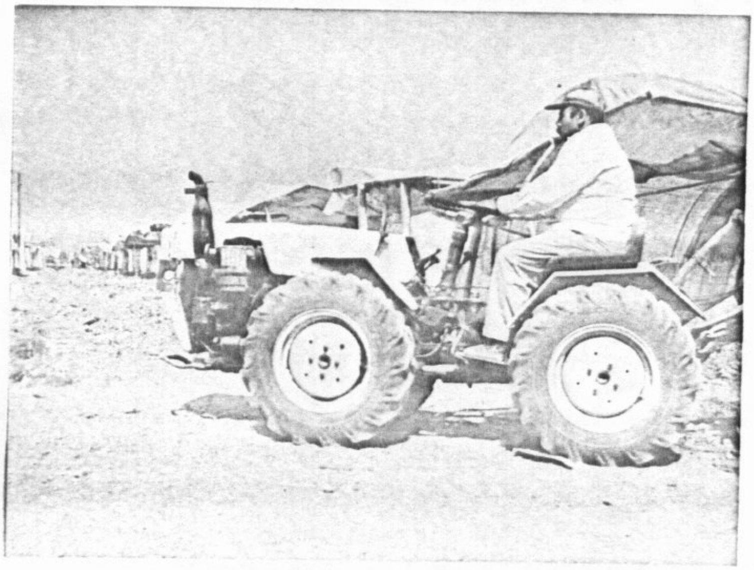

Fig. (3-1): Pasquali 988 (4WD) tractor.

Fig. (3-2): Kubota L.245 DTP (4WD) tractor.

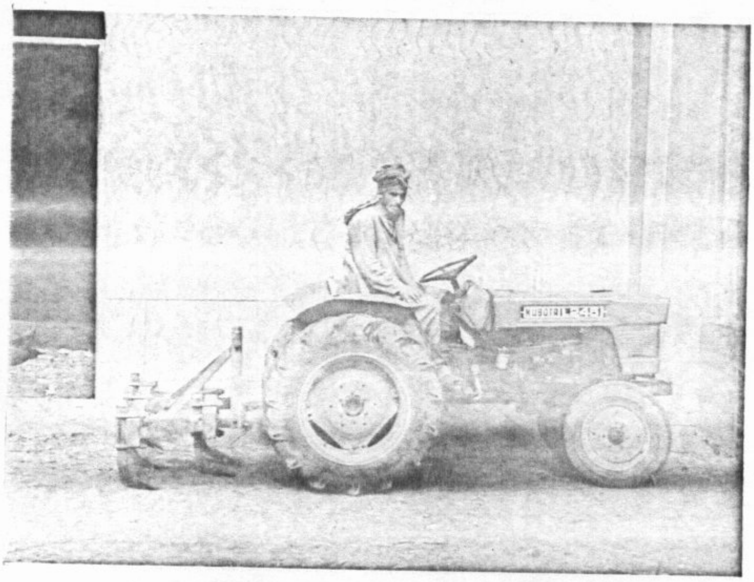

Fig. (3-3): Kubota L245 FP (2WD) tractor.

Fig. (3-4): Shibaura SP2040 (4WD) tractor.

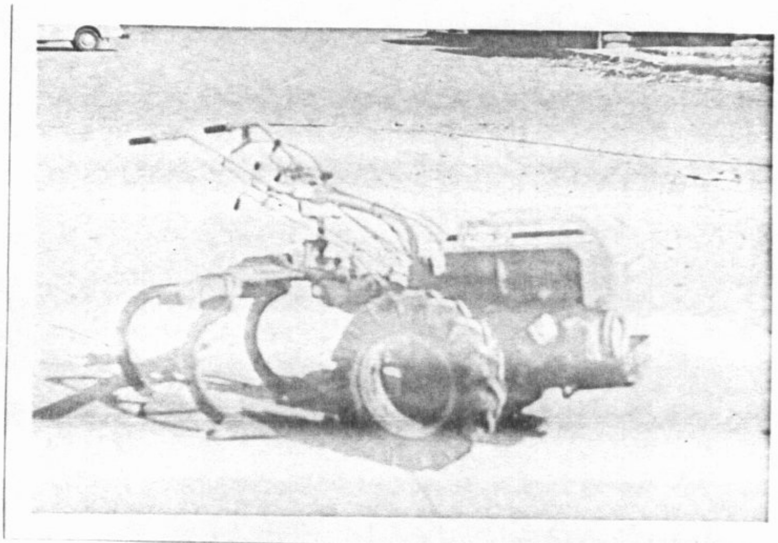

Fig. (3-5): Walking tractor grill 113 with two rubber wheels.

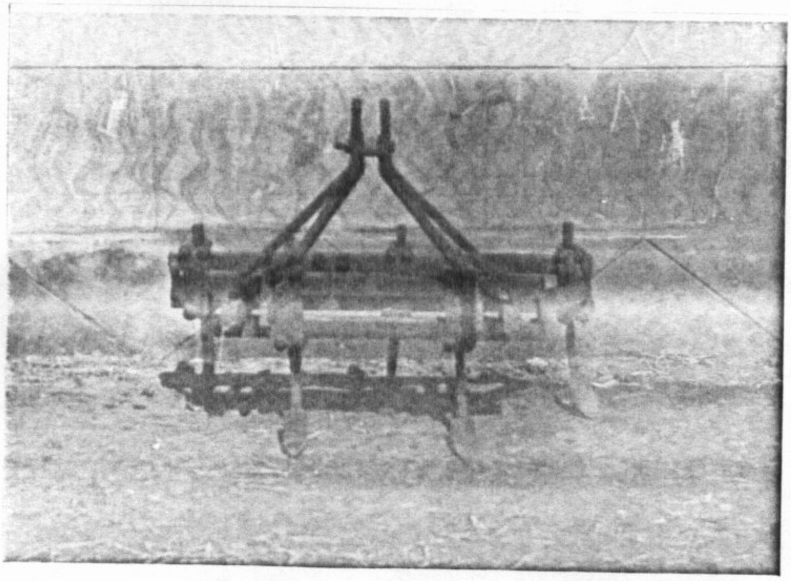

Fig. (3-6): The five shares chisel plough of 1.25 m, width.

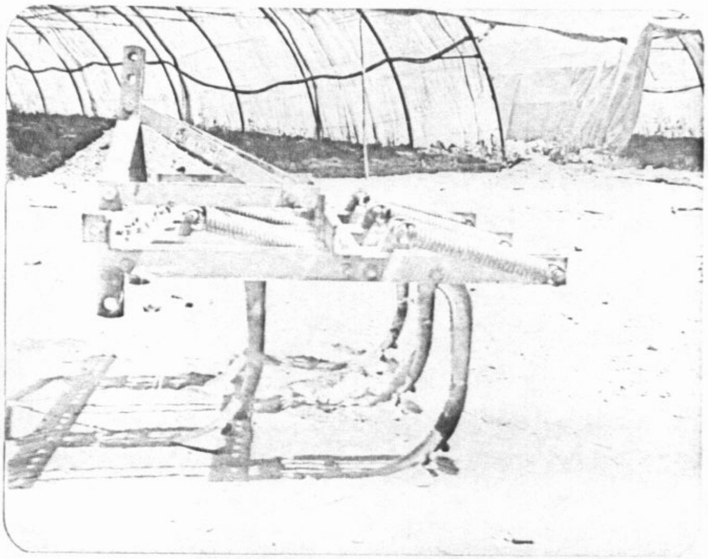

Fig. (3-7): The five shares chisel plough of 1.0 m width.

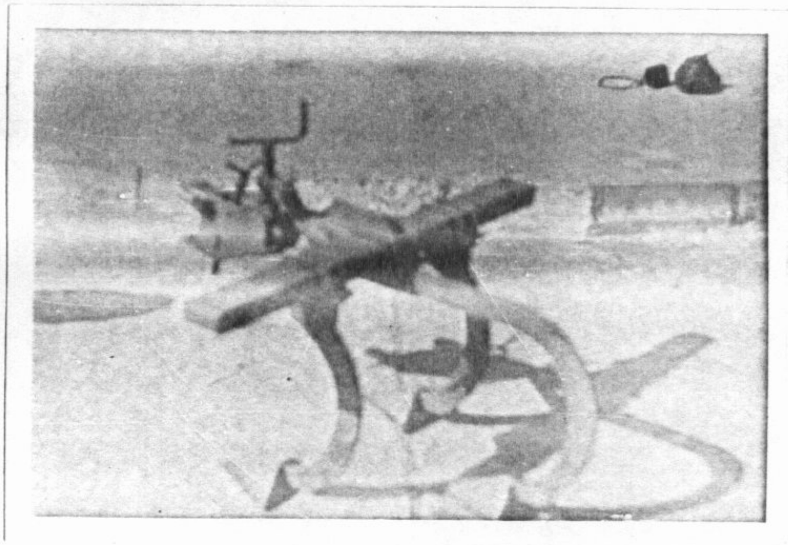

Fig. (3-8): The three shares chisel plough of 0.6 m, width.

3.1.3. Greenhouses:

Two different sizes of plastic tunnels were used as shown in Fig. (3-9 and 3-10). Both of them were established under the same conditions of: soil, irrigation, tunnels design and type of plastic cover. variations were only in the dimentions of tunnel. The dimentions and characteristics of each greenhouse is given in Table (3-3).

3.1.4. Measuring instruments:

a. Spring dynamometer:

In the present work spring dynamometer was used as shown in Fig. (3-11). The dynamometer was developed by Elbanna and Obaia. It was calibrated at the Faculty of Engineering, El-Mansoura University, before starting the experimental work, as shown in Table (3-4) and Fig. (3-12) (Obaia, 1991).

b. Stop watch:

Stop watch was used during calculating forward speed, time lost in turning at greenhouse ends and transportation from one greenhouse into another, and time for consuming fuel.

3.1.5. Tape, arrows and pins:

Tapes and arrows were used for measuring and determining longitudinal dimensions. Pins were used for hitching the dinamometer from both sides.

Table (3-3): Dimensions and characteristics of greenhouses.

No.	Specifications	Tunnel model	
		No. 1	No. 2
1	Tunnel design	Quon-set design	Quon-set design
2	Covering material	Plastic film from polyethylene	Plastic film from polyethylene
3	Tunnel size	Large	Medium
4	Length (m)	60	40
5	Width (m)	8.5	6
6	Height (m)	3.25	2.85
7	Active width (m)	5.50	4.20
8	Crop support height (m)	2	2
9	Total ground area (m^2)	510	240

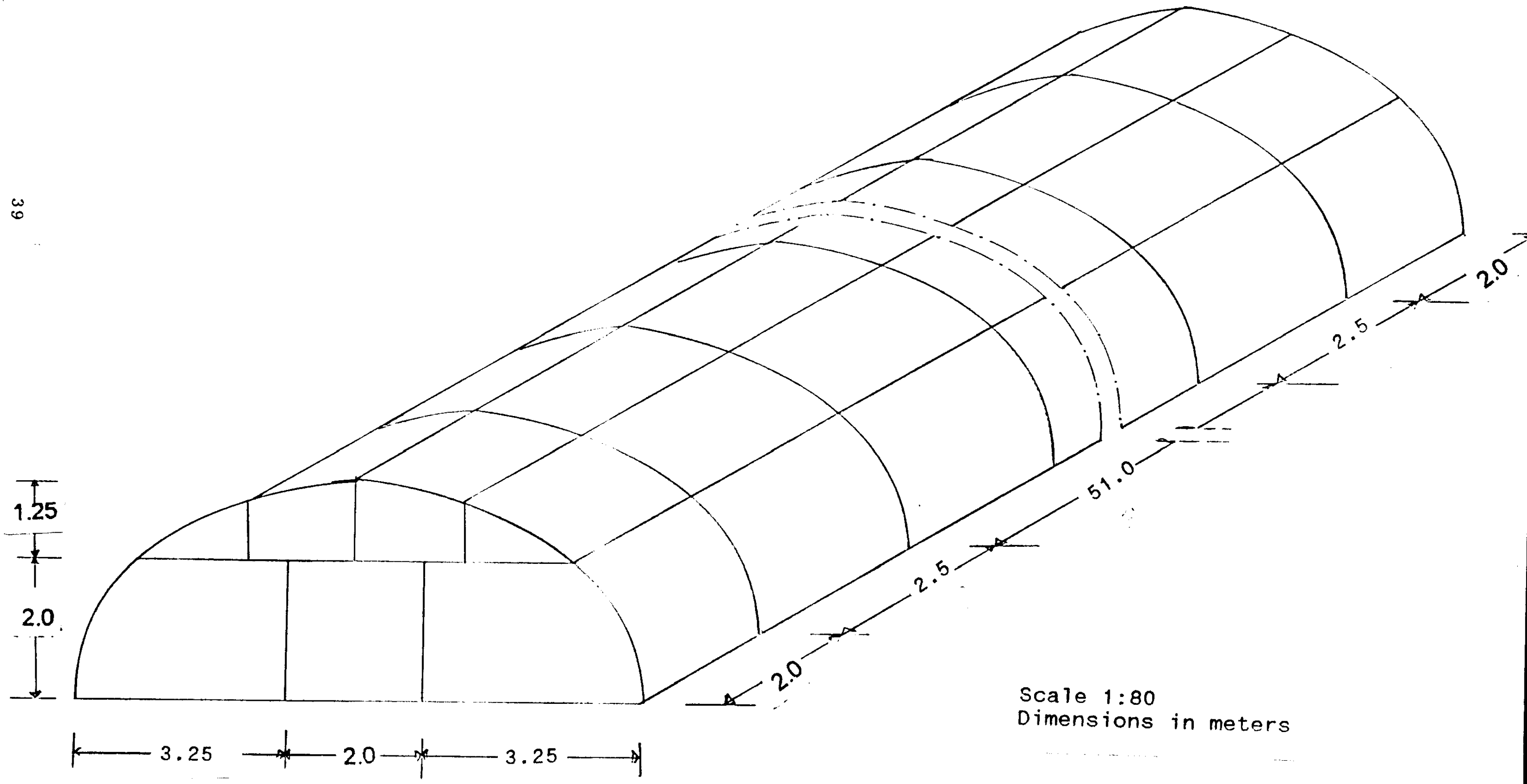

Fig. (3-9): Large greenhouse (Quon-set).

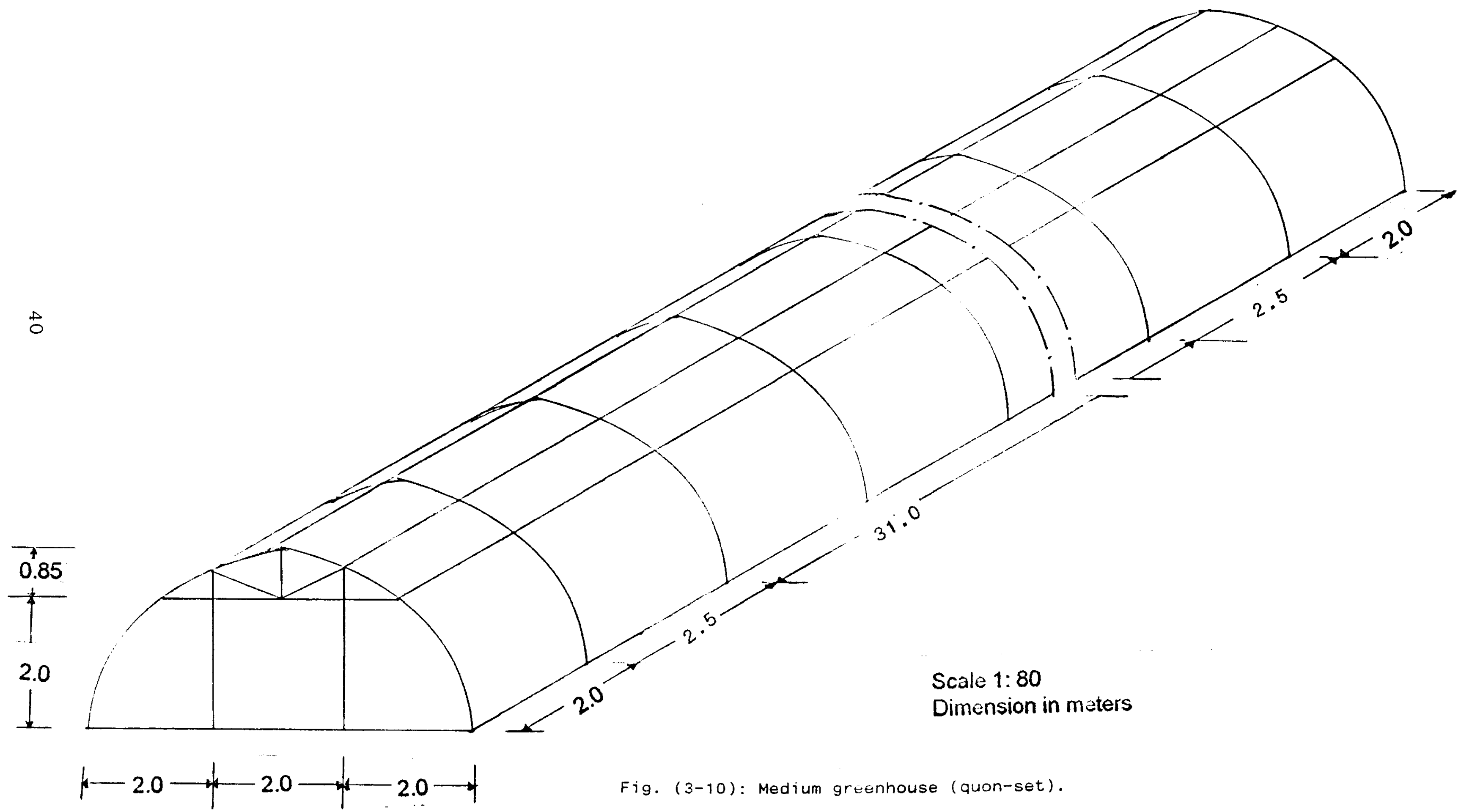

Fig. (3-10): Medium greenhouse (quon-set).

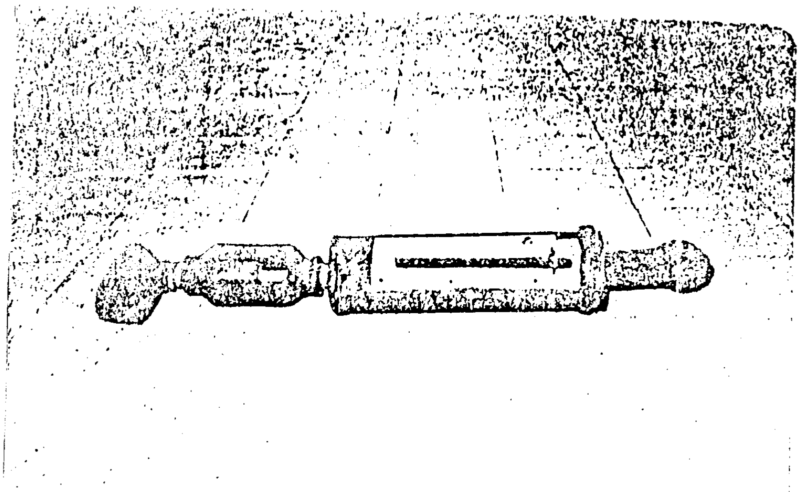

Fig. (3-11): Spring dynamometer.

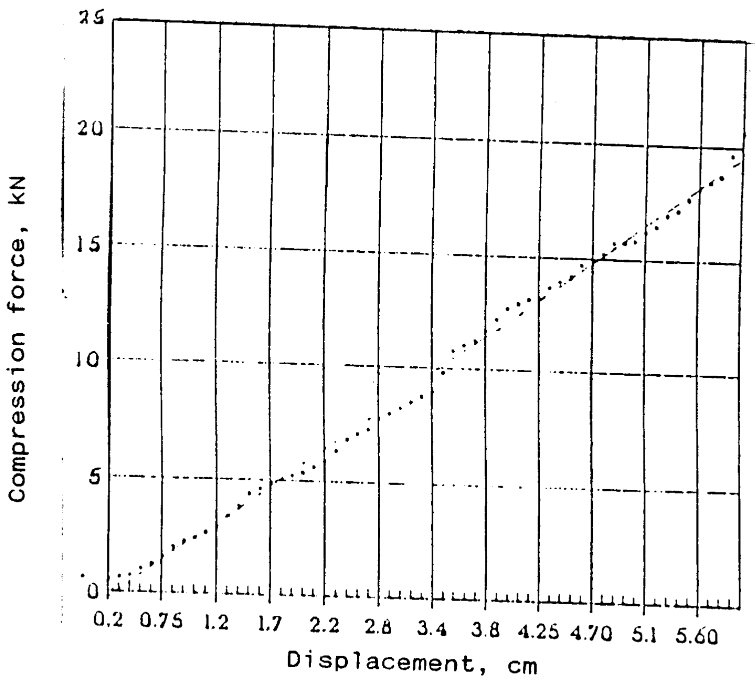

Fig. (3-12): Spring compression force plotted against displacement (source: from Fac. Eng. Mansoura Univ.), (Obaia, 1991).

Table 3-4: Spring dynamometer calibration at Faculty of Engineering (Mansoura University), (Obaia, 1991).

Displacement (cm)	Tension force, (KN)	Displacement (cm)	Tension force (KN)
0.20	0.49035	3.50	9.80700
0.30	0.58842	3.60	10.78770
0.40	0.68649	3.70	11.03290
0.50	0.98070	3.75	11.27810
0.60	1.17684	3.80	11.76840
0.75	1.47105	3.90	12.25880
0.80	1.96140	4.00	12.74910
0.96	2.45175	4.10	12.94524
1.00	2.50080	4.20	13.14138
1.10	2.54982	4.25	13.23945
1.20	2.94210	4.30	13.72980
1.30	3.43245	4.40	13.97500
1.40	3.92280	4.50	14.22020
1.50	4.41315	4.60	15.71050
1.60	4.65833	4.70	14.45570
1.70	4.90350	4.75	15.20090
1.80	4.90350	4.80	15.69120
1.90	5.24675	4.90	15.74020
2.00	5.39390	5.00	15.78930
2.10	5.63900	5.10	16.18125
2.20	5.88420	5.20	16.42670
2.35	6.37460	5.25	16.67190
2.40	6.86490	5.30	16.91810
2.50	7.11010	5.40	17.16230
2.60	7.35530	5.50	17.65260
2.80	7.84560	5.60	18.14300
3.00	8.09080	5.70	18.38813
3.10	8.33600	5.80	18.63330
3.20	8.58110	5.85	19.61400
3.30	8.82630	5.90	20.59470
3.40	9.07150	6.00	21.09680

3.2. Methods

3.2.1. Experimental procedures:

The experiments were carried out during agricultural season 1991/92 in order to determine optimum tractor size under local greenhouse conditions. They were performed at Sakha Farm, Kafr El-Sheikh Governorate. The type of soil was clay loam with clay ratio of about 42.8%. In the present experiments five types of tractors were used in two different sizes of plastic tunnels at optimum soil moisture content of about 19% and three forward speeds. The speeds were estimated by measuring the time through a travel length of twenty meters long. The range of ploughing depth was from 10-16 cm. This depth difference was due to the model of each chisel plough, traction power available and soil specific resistance.

3.2.2. Soil physical properties:

a. Moisture content:

The soil moisture content was determined by using standard oven method. Nine samples were obtained from 10 cm depth and the same number from 20 cm before executing ploughing operation. Samples were weighted and dried to constant weight at 105^{0}C for 24 hours. Soil moisture content was determined on dry basis using the following equation:

Moisture content (M.C.)= [(mass of water in soil sample)/(dry mass of soil sample)] x 100.

b. <u>Soil structure:</u>

Soil samples which taken from the experimental area were analyzed in the laboratory at Sakha Research Station, Kafr El-Sheikh Governorate, to obtain the mechanical analysis, particle size distribution, $CaCO_3$, and soil textural class as described by Piper, (1950). The analysis is given in Table (3-5).

Table (3-5): Soil mechanical analysis, $CaCO_3$, and soil textural class.

Soil fraction					$CaCO_3$ %	Soil textural class
Clay %	Silt %	Clay silt %	Sand %			
			Fine	Coarse		
42.83	26.33	69.16	28.41	2.43	1.95	Clay loam

3.2.3. <u>Determination of tractive force (Out put):</u>

a. <u>Determination of the rolling resistance:</u>

Rolling resistance is the force required to keep the equipment moving at a constant speed. It is proportional to equipment weight (Hunt, 1983). Determination of the rolling resistance of the tractor was necessary in order to calculate the net drawbar pull required for the machine at different speeds.

The rolling resistance of tractor equiped with mounted chisel plough was determined at no load by fixing the spring dynamometer between it and another rubber wheel tractor.

b. Determination of net drawbar pull:

The net drawbar pull is the force in the direction of travel produced by the vehicle at the drawbar (ASAE, 1984).

The spring dynamometer was fixed between a rubber wheel tractor and the agricultural working unit (tractor and plough under test) during ploughing operation.

Net drawbar pull was calculated as follows:

$$np = B - A$$

Where

A = Rolling resistance for the working unit (tractor and plough).

B = The recorded pull with the use of chisel plough.

np = Net drawbar pull.

3.2.4. Determination of slip percentage of the tractor:

A mark on the tractor drive wheel was made with coloured tape. The distance which the tractor moves forward per 10 revolutions of power wheels is measured under no load and on the same surface and with the same number of revolutions with load. The slip percntage or travel reduction (S%) was determined by using the following formula:

$$S\% = \frac{L_1 - L_2}{L_1} \times 100 \quad (\%)$$

Where:

L_1 : Advance per 10 revolutions of power wheel with no load (m).

L_2 : Advance per 10 revolutions of power wheel with load (m).

3.2.5. Power requirement:

3.2.5.1. Drawbar power (Dbp):

$$Dbp = (F \times V)/C$$

Where:

Dbp = Drawbar power (KW)

F = Net pull (KN)

V = Forward working speed (km/h)

C = Constant (3.6).

3.2.5.2. Power consumed by rolling resistance (RRP):

$$RRP = (R.R. \times V)/C$$

Where:

RRP = Rolling resistance power (KW).

RR = Rolling resistance (KN)

V = Forward working speed (km/h).

3.2.5.3. Power consumed by slip:

$$S.P. = [Db.P + R\,R\,P] \times \frac{S}{100-S}$$ (Nasr, 1985)

Where:

S.P. = Power consumed by slip (KW)

D.b.p. = Drawbar power (KW)

R.R.P. = Rolling resistance power (KW)

S = Slip in percent (%).

3.2.6. Determination of the tractive efficiency:

Tractive efficiency is the ratio of drawbar power to axle power, i.e.,

$$\eta_T = \frac{Db.P.}{Axle\ P.}$$

(Barger *et al.*, 1963 and Hunt, 1983)

3.2.7. Determination of the field efficiency:

a. The theoretical field capacity is calculated by using the following formula:

$$C_{th} = \frac{W \times S}{4.2} \quad (Fed/h)$$

Where:

C_{th} = Theoretical field capacity (fed/h).

W = Theoretical width of plough (m).

S = Average working forward speed (km/h).

b. The effective field capacity is calculated as follows:

$$C_{eff} = \frac{1}{T_{eff}} \quad (fed/h)$$

Where:

C_{eff} = Effective field capacity.

T_{eff} = Effective total time in hours required per feddan.

C. The field efficiency is calculated by using the following formula:

$$\eta_f = \frac{C_{eff}}{C_{th}} x100$$

3.2.8. Determination of fuel consumption:

Fuel consumption per unit time is determined by measuring the volume of fuel consumed during ploughing time. It is measured as follows: feul tank is filled to full capacity before and after the test. Amount of refueling after the test is the fuel consumption for the test. It is calculated by using the following formula.

F.C. = (F/t) x C

Where:

F.C. = Fueld consumption (L/h)

F = Volume of fuel consumed (cm^3)

t = Time of ploughing (Sec)

C = 3.6

4. RESULTS AND DISCUSSION

Field experiments were conducted in heavy texture soil with clay ratio of about 42.83%. Ploughing operation was executed in the first and second pass under two different sizes of greenhouse by using five different tractors equipped with different chisel ploughs at three forward speeds and mean soil moisture content of about 19%. Ploughing depth was varied from 10 and 16 cm. The depth differences are due to the model of each chisel plough and the traction power available. The first and second ploughing passes were in the same direction.

The results and discussion will be presented under the following headings:

1. The field performance characteristics of different powered tractors during ploughing operation under local greenhouse conditions.
2. Comparison between two wheel drive and four wheel drive low powered tractors.
3. Effect of greenhouse size on the performance of tractors.

4.1. <u>The field performance characteristics of different powered tractors during ploughing operation under local greenhouse conditions:</u>

The performance of farm tractors can be expressed by the relationships between the working forward speed and the following variables: rolling resistance, drawbar pull, drawbar power, percent of wheel slip, tractive efficiency, actual field capacity, field efficiency, fuel consumption and total costs for ploughing operation.

4.1.1. Rolling resistance:

From the obtained data presented in Tables from (4-1) to (4-4) and Fig. (4-1), it is clear that, for all powered tractors, the rolling resistance increased with increasing the forward speed during first and second ploughing passes.

It is also obvious that the rolling resistance increased during second ploughing pass compared with first ploughing pass. The mean percentages of increasing rolling resistance were found to be 25.8% and 23.06% during second ploughing pass compared with first ploughing pass at large and medium greenhouse, respectively.

Analysis of variance in Table (A-1) in the Appendix indicates that the type of tractor, ploughing pass and forward speed had a highly significant effect on the rolling resistance for both greenhouse sizes.

The maximum values of rolling resistance were found to be 1.408 , 1.961, 1.7, 1.112 and 0.946 kN at forward speeds of about 4.4, 4.0, 3.17, 3.53 and 3.53 km/h for powered tractors of about 24.61, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively during second ploughing pass in large greenhouse.

Table 4-1: The effect of tractor type and forward speed on the performance characteristics at first pass of ploughing operation in large greenhouse.

Tractor type	24-63 kW			18.66 kW (4WD)			18.66 kW (2WD)			14.93 kW			10.44 kW		
Forward working speed (km/h)	1.90	2.20	4.20	1.60	2.10	3.82	1.21	1.80	2.73	1.34	1.97	3.16	1.34	1.97	3.16
Rolling resistance (kN)	0.621	0.750	1.373	0.886	0.981	1.438	0.686	0.786	1.177	0.523	0.588	0.883	0.409	0.553	0.784
Drawbar pull (KN)	5.067	6.129	7.518	4.904	5.672	7.110	4.495	5.476	6.293	3.106	3.596	4.086	2.516	2.942	3.105
Slip %	3.940	4.073	5.677	4.977	5.833	7.933	9.600	11.023	14.71	5.957	7.050	8.473	14.737	18.040	22.140
Tractive efficiency	0.854	0.842	0.803	0.817	0.799	0.763	0.772	0.765	0.712	0.799	0.765	0.749	0.699	0.684	0.638
Actual field capacity (fed/h)	0.454	0.520	0.924	0.373	0.476	0.780	0.284	0.401	0.552	0.249	0.357	0.544	0.180	0.271	0.371
Field efficiency	0.803	0.792	0.739	0.781	0.762	0.687	0.769	0.746	0.683	0.784	0.761	0.723	0.814	0.779	0.762
Fuel consumption (L/h)	2.311	2.500	4.180	2.409	2.705	3.342	2.103	2.311	2.681	1.610	1.987	0.399	1.213	1.509	1.898
Fuel consumption (L/fed)	5.078	4.808	3.411	5.644	5.050	3.879	6.757	5.501	4.795	6.552	7.603	4.620	6.739	5.707	5.128

Table 4-2: The effect of tractor type and forward speed on the performance characteristics at second pass of ploughing operation in large greenhouse.

Tractor type	24-63 kW			18.66 kW (4WD)			18.66 kW (2WD)			14.93 kW			10.44 kW		
Forward working speed (km/h)	2.00	2.40	4.40	1.60	2.27	4.00	1.20	1.97	3.17	1.54	2.13	3.54	1.54	2.13	3.54
Rolling resistance (kN)	0.883	0.981	1.408	0.981	1.112	1.961	0.843	1.112	1.700	0.621	0.686	1.112	0.550	0.603	0.946
Drawbar pull (KN)	4.250	5.018	6.538	4.740	5.263	6.129	4.086	4.969	5.181	2.942	3.105	3.596	2.141	2.664	2.680
Slip %	4.137	4.377	5.953	5.300	6.267	8.500	10.88	12.57	15.41	6.513	7.433	9.017	15.457	18.010	20.143
Tractive efficiency	0.806	0.802	0.778	0.787	0.727	0.692	0.742	0.675	0.645	0.812	0.761	0.699	0.676	0.658	0.574
Actual field capacity (fed/h)	0.474	0.558	0.953	0.381	0.507	0.834	0.283	0.428	0.612	0.285	0.380	0.599	0.199	0.279	0.399
Field efficiency	0.795	0.781	0.730	0.771	0.740	0.668	0.790	0.732	0.655	0.776	0.750	0.712	0.807	0.779	0.750
Fuel consumption (L/h)	2.203	2.490	3.714	2.007	2.601	3.284	1.908	2.309	2.659	1.622	2.070	2.568	1.153	1.473	1.789
Fuel consumption (L/fed)	4.648	4.449	3.852	5.267	4.929	3.918	6.736	5.394	4.542	5.797	5.564	4.510	6.293	5.464	5.091

Table 4-3: The effect of tractor type and forward speed on the performance characteristics at first pass of ploughing operation in medium greenhouse.

Tractor type	24.53 kW			18.66 kW (4WD)			18.66 kW (2WD)			14.93 kW			10.44 kW		
Forward working speed (km/h)	1.91	2.17	4.15	1.57	2.05	3.76	1.17	1.72	2.62	1.30	1.91	3.08	1.32	1.96	3.13
Rolling resistance (kN)	0.621	0.750	1.308	0.786	0.901	1.177	0.688	0.786	1.112	0.523	0.560	0.830	0.490	0.522	0.784
Drawbar pull (KN)	5.067	6.129	7.518	4.904	5.672	7.028	4.495	5.394	5.884	3.105	3.596	4.086	2.516	2.942	3.105
Slip %	3.960	4.100	5.717	5.020	6.363	7.933	9.607	11.097	14.757	5.970	7.083	8.517	14.757	17.577	20.590
Tractive efficiency	0.864	0.852	0.803	0.826	0.818	0.753	0.772	0.751	0.712	0.801	0.799	0.753	0.699	0.690	0.639
Actual field capacity (fed/h)	0.421	0.469	0.814	0.327	0.410	0.658	0.244	0.335	0.463	0.224	0.315	0.471	0.144	0.202	0.310
Field efficiency	0.742	0.727	0.660	0.701	0.672	0.588	0.705	0.652	0.592	0.723	0.693	0.642	0.765	0.723	0.692
Fuel consumption (L/h)	2.303	2.529	4.196	2.271	2.697	3.497	2.054	2.212	2.507	1.631	1.978	2.325	1.223	1.574	1.796
Fuel consumption (L/fed)	5.493	5.390	3.937	6.311	5.860	4.557	8.393	7.506	5.617	7.260	6.312	4.932	8.490	7.790	5.794

Table 4-4: The effect of tractor type and forward speed on the performance characteristics at second pass of ploughing operation in medium greenhouse.

Tractor type	24.63 kW			18.66 kW (4WD)			18.66 kW (2WD)			14.93 kW			10.44 kW		
Forward working speed (km/h)	2.07	2.37	4.36	1.58	2.20	3.90	1.17	1.89	3.07	1.49	2.07	3.46	1.58	2.13	3.50
Rolling resistance (kN)	0.883	0.981	1.373	0.981	1.146	1.700	0.883	1.006	1.438	0.621	0.635	1.046	0.555	0.601	0.901
Drawbar pull (KN)	4.250	5.018	6.538	4.740	5.263	6.048	3.923	4.885	5.067	2.942	3.105	3.596	2.141	2.647	2.664
Slip %	4.143	4.400	5.967	5.343	6.317	8.560	10.847	12.590	15.457	6.873	7.467	9.080	16.433	18.763	20.163
Tractive efficiency	0.806	0.792	0.752	0.787	0.740	0.713	0.738	0.730	0.674	0.676	0.757	0.689	0.670	0.653	0.583
Actual field capacity (fed/h)	0.455	0.502	0.848	0.325	0.424	0.664	0.239	0.359	0.507	0.255	0.335	0.523	0.171	0.235	0.340
Field efficiency	0.739	0.712	0.654	0.692	0.647	0.572	0.689	0.636	0.555	0.720	0.680	0.635	0.757	0.709	0.679
Fuel consumption (L/h)	2.177	2.476	3.944	2.110	2.485	3.243	1.940	2.200	2.565	1.685	1.976	2.501	1.192	1.467	1.703
Fuel consumption (L/fed)	4.844	4.536	3.650	6.498	5.860	4.939	8.184	6.432	5.035	6.320	5.755	4.975	7.886	6.901	4.998

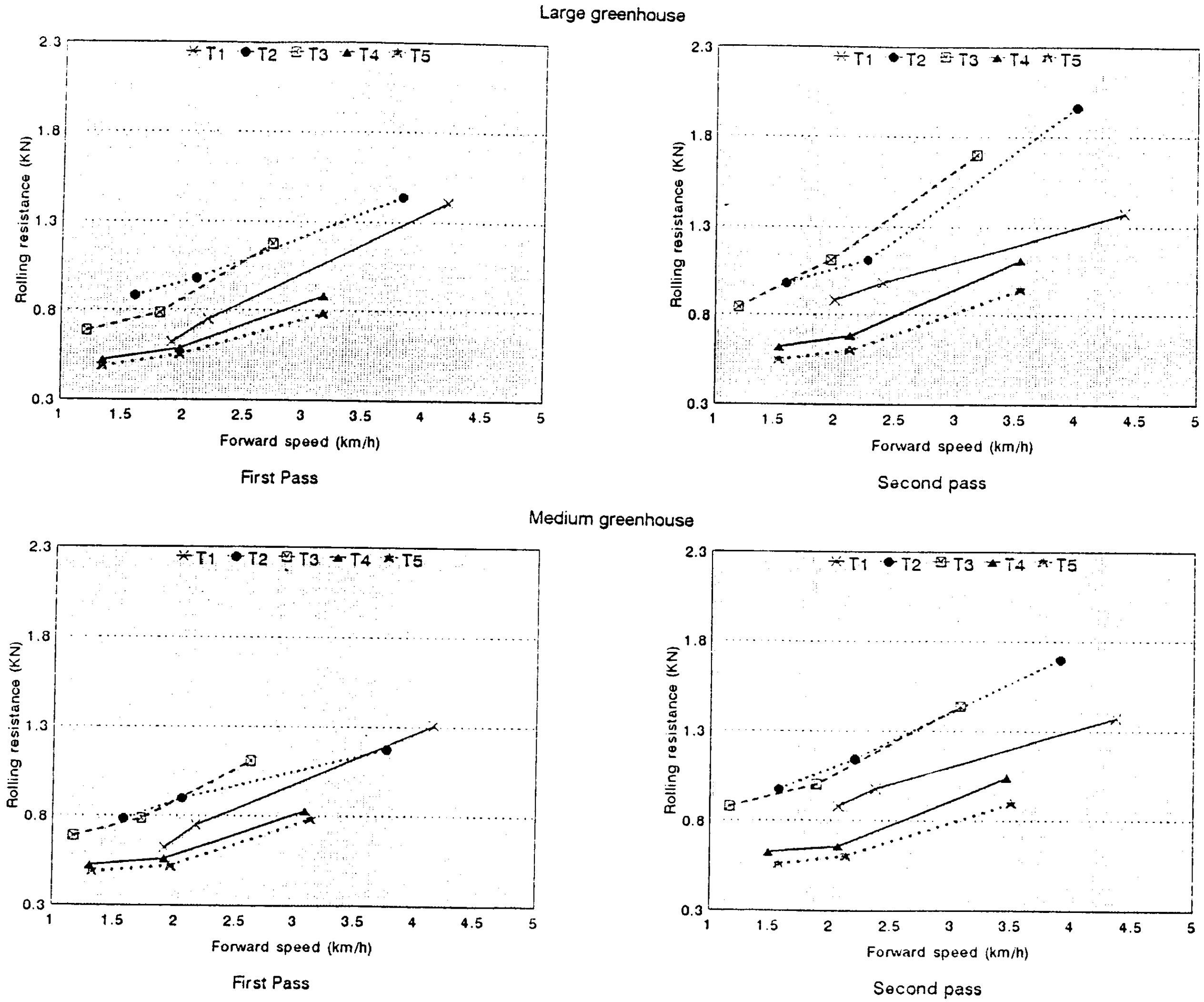

Fig. (4-1): The effect of tractor type, forward speed and ploughing pass on rolling resistance of tractors for both large and medium greenhouses

4.1.2. Drawbar pull:

From the obtained data presented in Tables from (4-1) to (4-4) and Fig. (4-2), it is shown that for all powered tractors the drawbar pull increased by increasing the working forward speed during first and second ploughing passes. It was also obvious that the drawbar pull was decreased during second ploughing pass compared with first ploughing pass. The mean percentages of decreasing the drawbar pull was found to be 12.08% during second ploughing pass compared with first ploughing pass.

The maximum drawbar pull values were found to be 7.52, 7.11, 6.29, 4.09 and 3.11 kN at forward speeds 4.20, 3.82, 2.73, 3.16 and 3.16 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 KW, respectively, during first ploughing pass, in large greenhouse.

Analysis of variance in Table (A-2) in the Appendix indicates that the type of tractor, forward speed and ploughing pass had a highly significant effect on the drawbar pull of both greenhouse sizes.

4.1.3. Slip ratio and tractive efficiency:

From the obtained data presented in Tables from (4-1) to (4-4) and Figs (4-3) and (4-4), it is clear that, for all powered tractors increasing the forward speed tends to increase the slip ratio and decrease the tractive efficiency

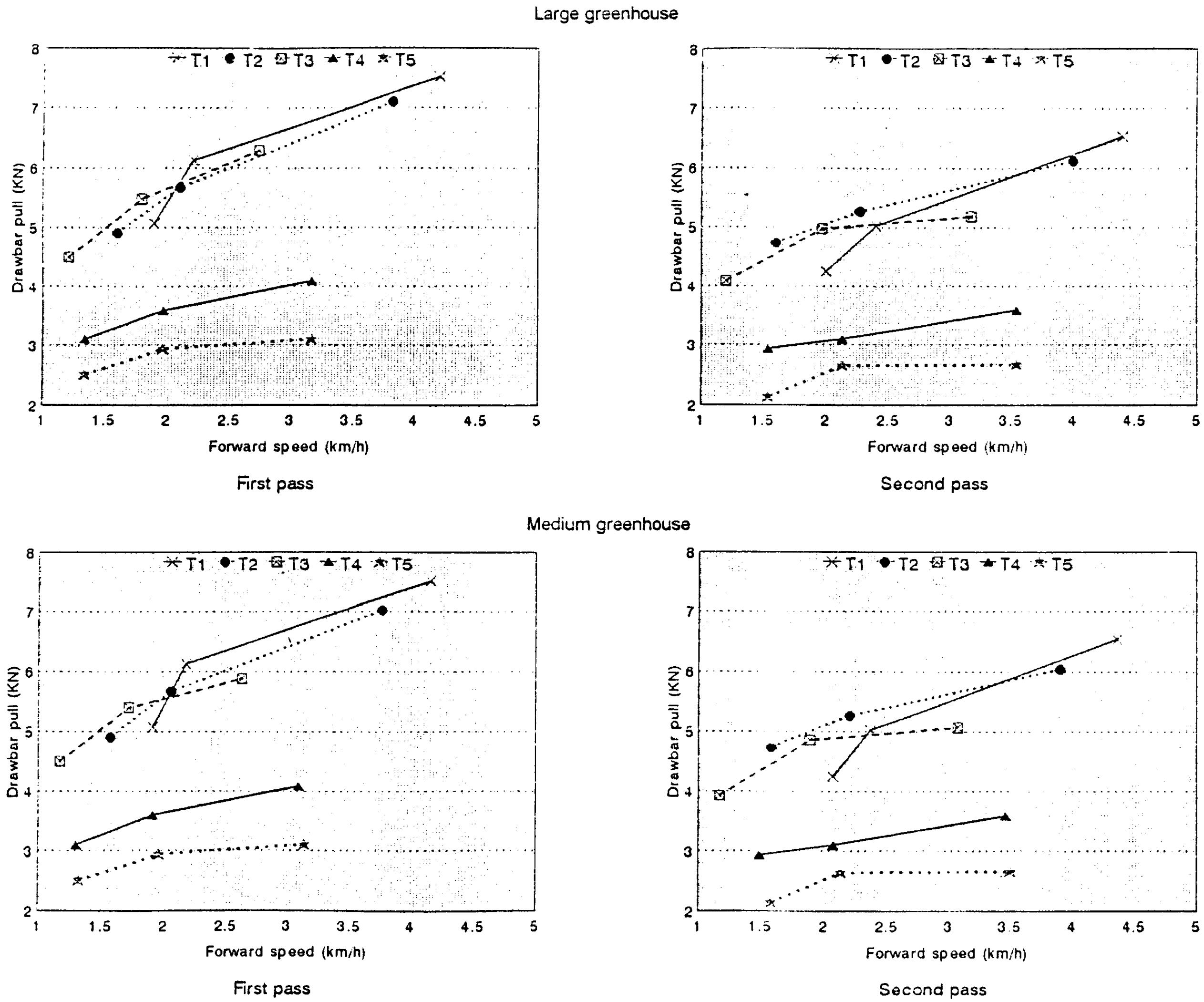

Fig. (4-2): The effect of tractor type, forward speed and ploughing pass on the pull required for ploughing operation for both large and medium greenhouses

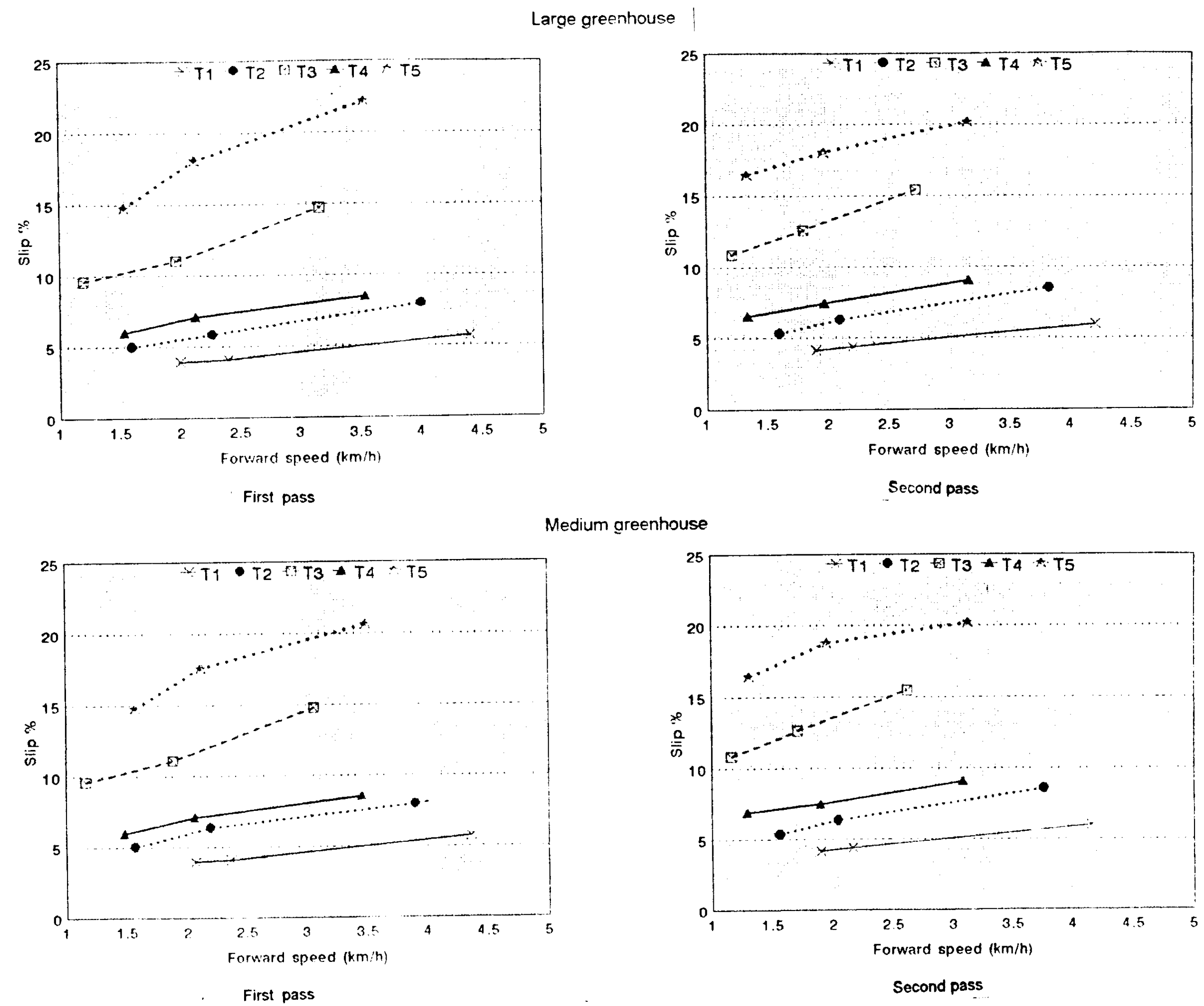

Fig. (4-3). The effect of tractor type, forward speed and ploughing pass on the slip percentage of tractors for both large and medium greenhouses

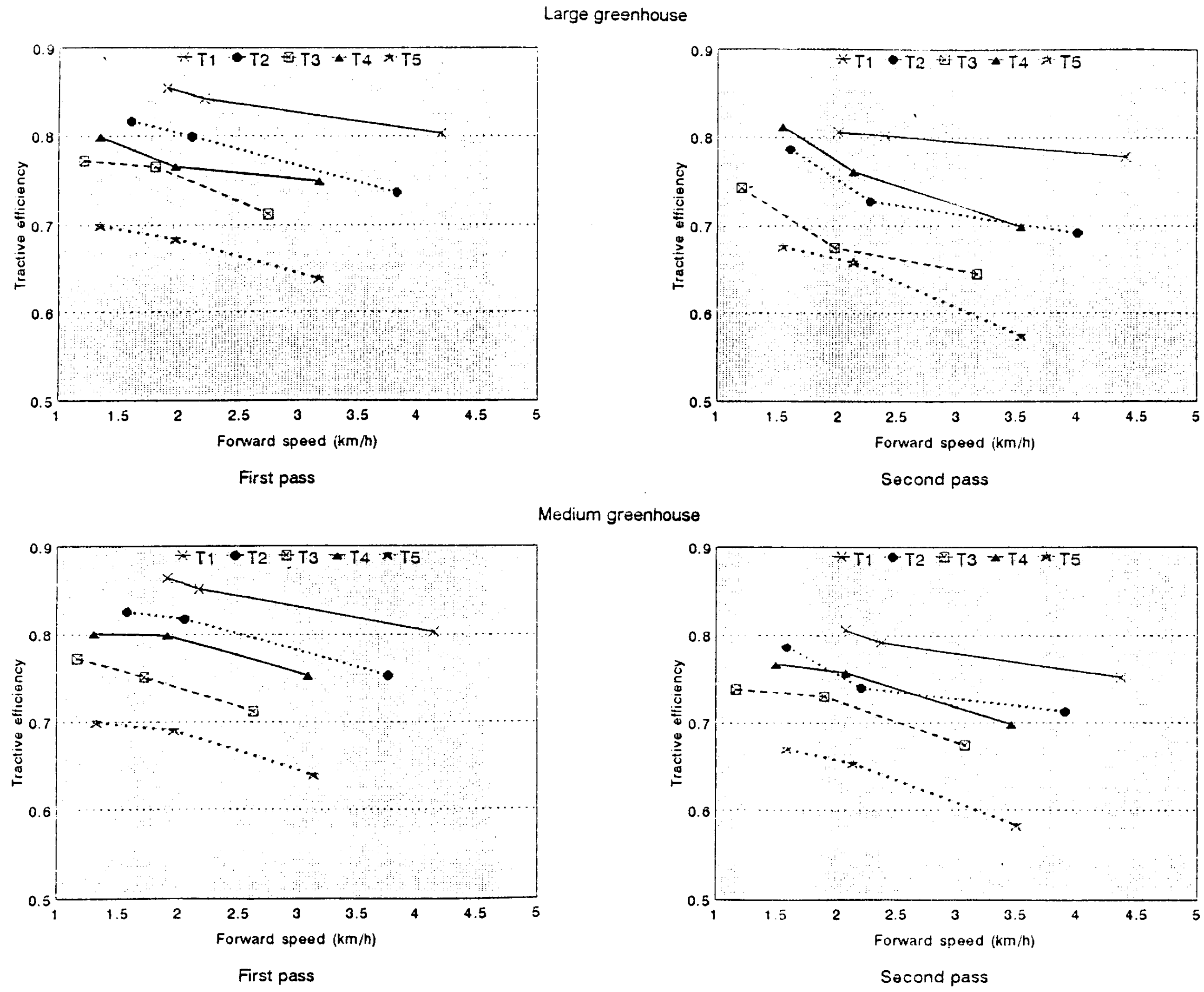

Fig. (4-4): The effect of tractor type, forward speed and ploughing pass on tractive efficiency of tractors for both large and medium greenhouses during first and second ploughing passes. It is also obvious that the tractive efficiency decreased during second ploughing pass compared with first ploughing pass.

Analysis of variance in Tables (A-3 and A-4) in the Appendix indicates that the type of tractor, ploughing pass and forward speed had a highly significant effect on the slip ratio and the tractive efficiency of both greenhouse sizes.

The maximum values of slip ratios were found to be 5.97, 8.56, 15.46, 9.08 and 20.16% at forward speeds of 4.15, 3.76, 2.61, 3.08 and 3.13 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively during second ploughing pass for medium greenhouse.

The maximum values of tractive efficiency were found to be 0.864, 0.826, 0.772, 0.801 and 0.699 at forward speeds of 1.91, 1.57, 1.17, 1.3 and 1.32 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively, during first ploughing pass for medium greenhouse. On the other hand, they were found to be 0.806, 0.787, 0.738, 0.767 and 0.670 at forward speeds 2.07, 1.58, 1.17, 1.49 and 1.58 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively during second ploughing pass.

From the obtained data presented in Table (4-5), it is clear that the arrangement of different powered tractors according to the average values of slip percentage during ploughing operation by using chisel plough was found to be in the following descending order: 10.44 kW > 18.66 kW (2WD) > 14.93 kW > 18.66 kW (4WD) 24.63 kW.

From the results of the statistical analysis, it is clear that there is a high significant difference between all powered tractors themselves, this trend is due to that there is a variance in traction members of tractors and variance in static and dynamic loads.

From the obtained data presented in Table (4-6), it is clear that the arrangement of different powered tractors according to the average values of tractive efficiency was found to be in the following descending order: 24.63 kW > 18.66 kW (4WD) > 14.93 kW > 18.66 kW (2WD) > 10.44 kW.

It is also clear that there is a high significant difference between the tractor of 24.6 kW when compared with other tractors according to the tractive efficiency, this is because its four wheel drive were in equal sized wheels.

4.1.4. Actual field capacity and field efficiency:

Increasing the forward speed tends to increase the actual field capacity and decrease the field efficiency during first

Table 4-5: Average values of percentage slip of different tractors at first and second passes of ploughing operation in large medium greenhouse.

Green-house size	Tractor power / Ploughing pass	Slip %					L.S.D.
		24.63 kW	18.66 kW (4WD)	18.66 kW (2WD)	14.93 kW	10.44 kW	
Large	First pass	4.563	6.248	11.778	7.160	17.639	at 0.05=0.662
	Second pass	4.822	6.689	12.953	7.654	18.442	at 0.01=0.455
Medium	First pass	4.892	6.972	11.820	7.190	17.674	at 0.05=0.440
	Second pass	4.837	6.740	12.964	7.807	18.453	at 0.01=0.303

Table 4-6: Average values of tractive efficiency of different tractors at first and second passes of ploughing operation in large and medium greenhouses.

Green-house size	Tractor power / Ploughing pass	Tractive efficiency					L.S.D.
		24.63 kW	18.66 kW (4WD)	18.66 kW (2WD)	14.93 kW	10.44 kW	
Large	First pass	0.833	0.793	0.750	0.781	0.674	at 0.05=0.245
	Second pass	0.792	0.735	0.712	0.754	0.636	at 0.01=0.356
Medium	First pass	0.839	0.799	0.748	0.784	0.676	at 0.05=0.114
	Second pass	0.794	0.747	0.714	0.751	0.639	at 0.01=0.166

and second ploughing passes as indicated in Tables (4-1) to (4-4) and Figures (4-5) and (4-6). It is also obvious that the actual field capacity was increased by 6.63% and 6.49% during second ploughing pass compared with first ploughing pass for large and medium greenhouse, respectively. On the other hand, the field efficiency was decreased by 1.57% and 2.0% during second ploughing pass compared with first ploughing pass for large and medium greenhouses, respectively. This trend is due to the increase of the forward speed during second ploughing pass compared with first ploughing pass.

Analysis of variance in Table (A-5 and A-6) in the Appendix indicates that the type of tractor, ploughing pass and forward speed had a highly significant effect on the actual field capacity as well as field efficiency for both greenhouse sizes.

The maximum values of actual field capacity were found to be 0.953, 0.834, 0.612, 0.599 and 0.399 fed/h at forward speeds of about 4.4, 4.0, 3.17, 3.54 and 3.54 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively during second ploughing pass.

The maximum values of field efficiency were found to be 0.795, 0.771, 0.789, 0.778 and 0.807 at forward speeds of about 2.0, 1.6, 1.2, 1.54 and 1.54 km/h for powered tractors

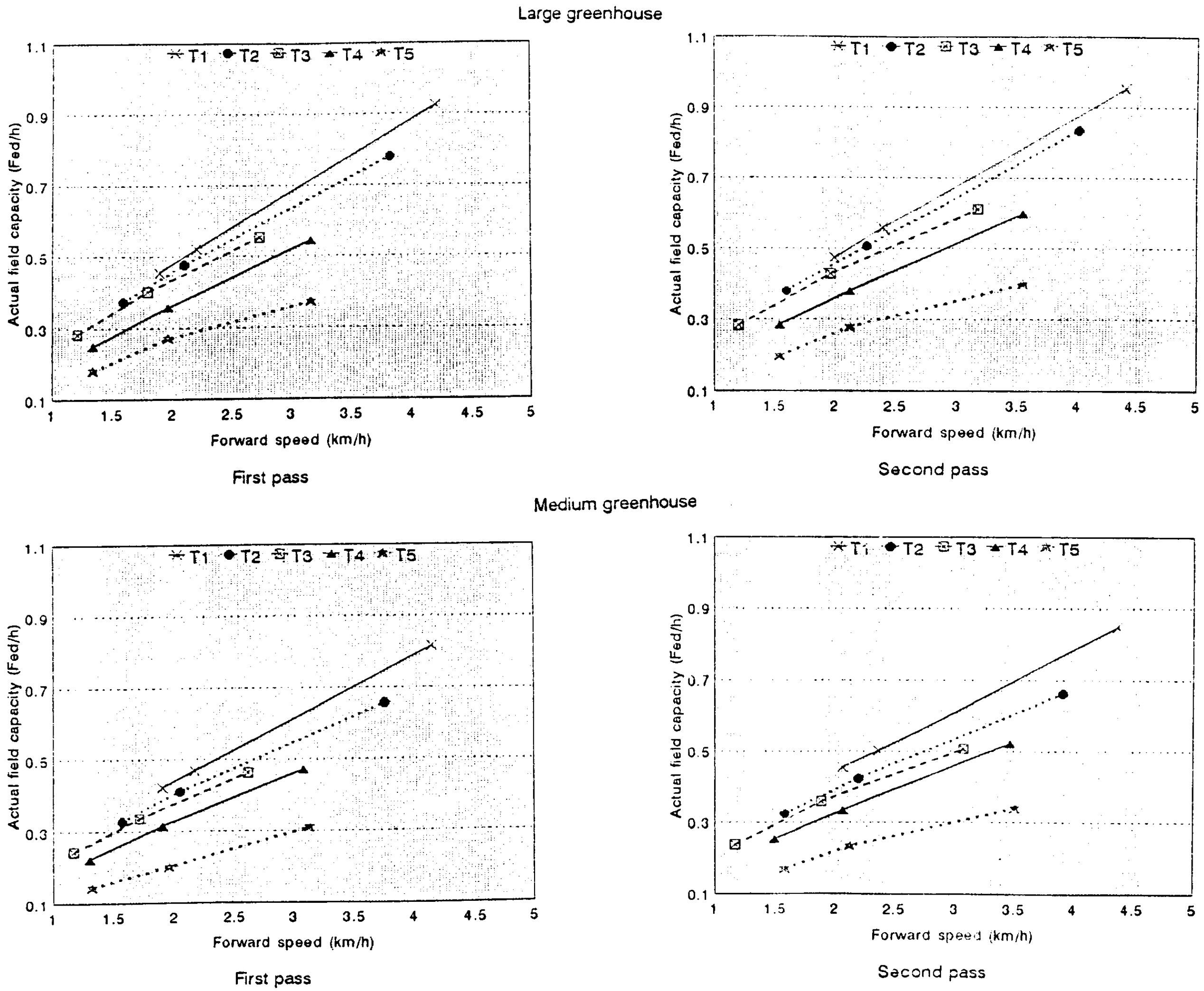

Fig. (4-5): The effect of tractor type, forward speed and ploughing pass on effective field capacity of different tractors for both large and medium greenhouses

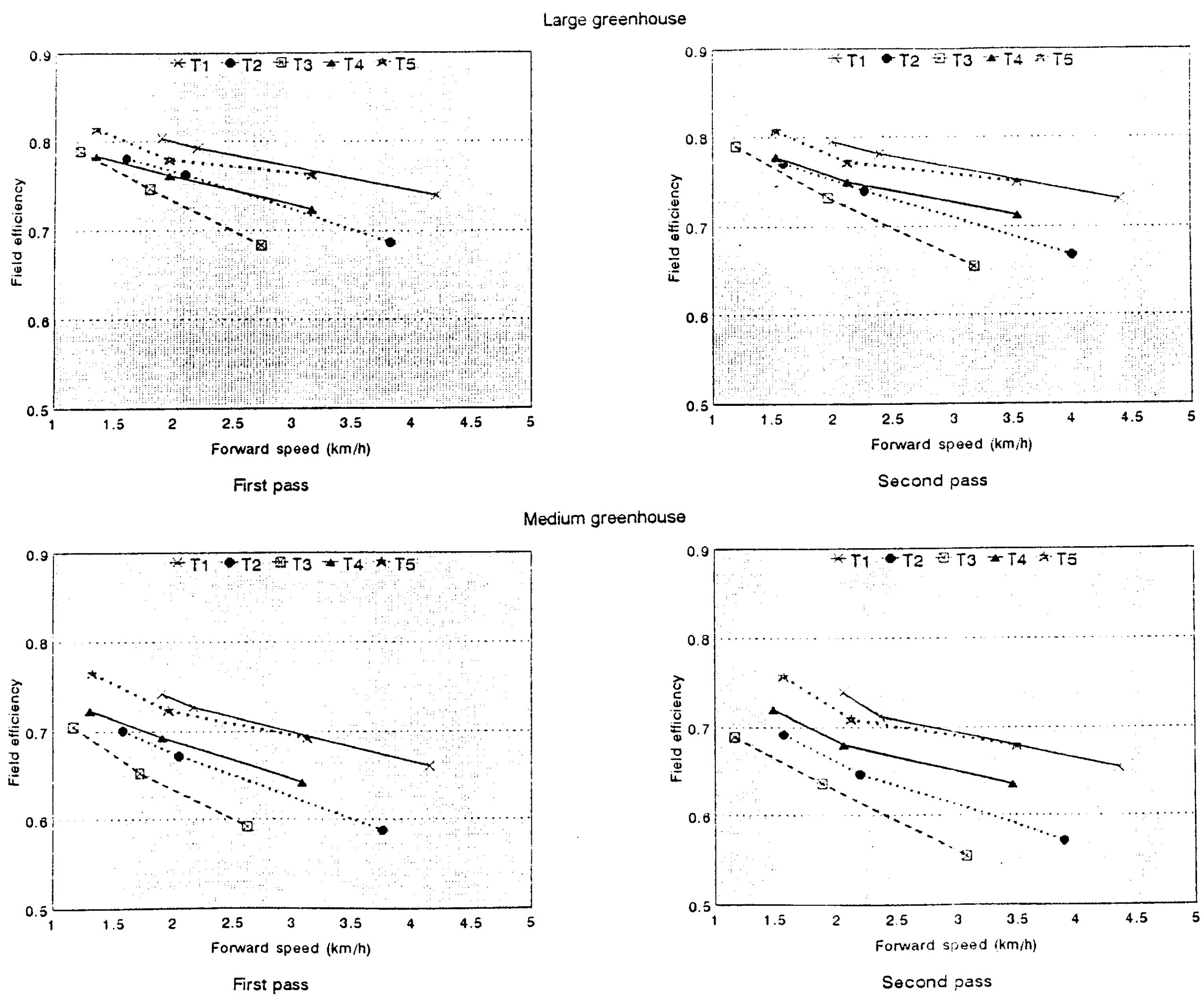

Fig. (4-6): The effect of tractor type, forward speed and ploughing pass on field efficiency during ploughing operation for both large and medium greenhouses of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively during second ploughing pass.

Table (4-7) presents the average value of actual field capacity of different tractors at first and second passes of ploughing operation in large and medium greenhouse. It is clear that the arrangement of different powered tractors according to actual field capacity (Fed/h) during ploughing operation by using chisel plough was found to be in the following descending order : 24.63 kW > 18.66 kW (4WD) > 18.66 kW (2WD) > 14.93 kW > 10.44 kW. this trend is due to the forward speed obtained from the high powered tractors which is greater than the possible speeds obtained from other lower powered tractors. Another factor is related to the width of the machine possible to be attached with different powered tractors. It is also clear that there is a high significant difference between the two tractors of 24.6 kW and 18.7 kW (4WD) when compared with other tractors.

It is shown from the obtained data presented in Table (4-8), that the arrangement of different power tractors according to their field efficiency percentages during ploughing operation by using chisel plough is found to be in the following descending order: 10.44 kW > 24.63 kW > 14.93 kW > 18.66 kW (4WD) > 18.66 kW (2WD). It is also clear that there is a high significant difference between the walking tractor of 10.44 kW and the articulated frame steering tractor of

Table 4-7: Average values of actual field capacity of different tractors during first and second passes of ploughing operation in large and medium greenhouses.

Green-house size	Tractor power / Plough-ing pass	Actual field capacity (Fed/P)					L.S.D.
		24.63 kW	18.66 kW (4WD)	18.66 kW (2WD)	14.93 kW	10.44 kW	
Large	First pass	0.633	0.543	0.413	0.383	0.291	at 0.05=0.035
	Second pass	0.662	0.574	0.441	0.421	0.312	at 0.01=0.050
Medium	First pass	0.568	0.465	0.317	0.337	0.219	at 0.05=0.012
	Second pass	0.602	0.471	0.328	0.371	0.249	at 0.01=0.017

Table 4-8: Average values of field efficiency of different tractors during first and second passes of ploughing operation.

Green-house size	Tractor power / Plough-ing pass	Field efficiency					L.S.D.
		24.63 kW	18.66 kW (4WD)	18.66 kW (2WD)	14.93 kW	10.44 kW	
Large	First pass	0.778	0.743	0.739	0.756	0.785	at 0.05=0.011
	Second pass	0.768	0.726	0.725	0.746	0.775	at 0.01=0.016
Medium	First pass	0.710	0.654	0.650	0.686	0.727	at 0.05=0.062
	Second pass	0.702	0.637	0.626	0.678	0.715	at 0.01=0.090

24.63 kW when compared with other tractors. This is because of the turning time of these two tractors was less than the turning time of another three tractors. The walking tractor (10.44 kW) is steered and guided by hand but the articulated tractor of about 24.63 kW is steered by pivoting in the centre.

4.1.5. Fuel consumption:

From the obtained data presented in Tables from (4-1) to (4-4) and Figures (4-7) and 4-8), it is clear that for all powered tractors, increasing the forward speed tends to increase fuel consumption (L/h) and decreasing fuel consumption per unit rate of work (L/fed). It was also obvious that the fuel consumption (L/fed) was decreased by 6.19% and 8.3% during second ploughing pass compared with first ploughing pass for large and medium greenhouses, respectively.

The maximum values of fuel consumption were found to be 4.18, 3.34, 2.68, 2.39 and 1.89 L/h at forward speeds of about 4.2, 3.82, 2.73, 3.16 and 3.16 km/h for the following powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively during first ploughing pass.

The maximum values of fuel consumption per unit rate of work in L/fed were found to be 5.08, 5.64, 6.76, 6.55 and 6.74 L/fed at forward speeds of about 1.9, 1.6, 1.2, 1.3, and 1.3 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66

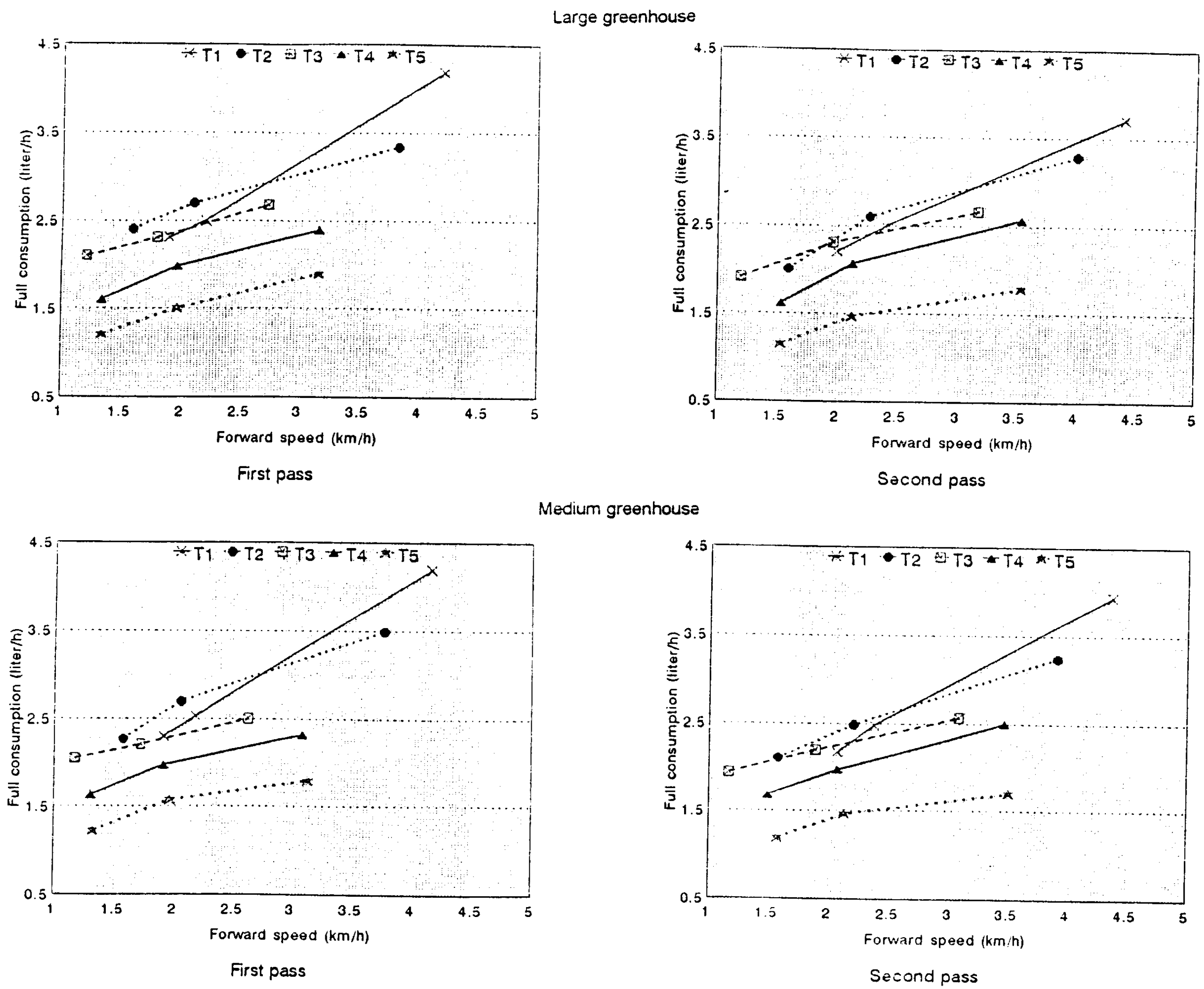

Fig. (4-7): The effect of tractor type, forward speed and ploughing pass on the fuel consumption (L/h) during ploughing operation for both large and medium greenhouses

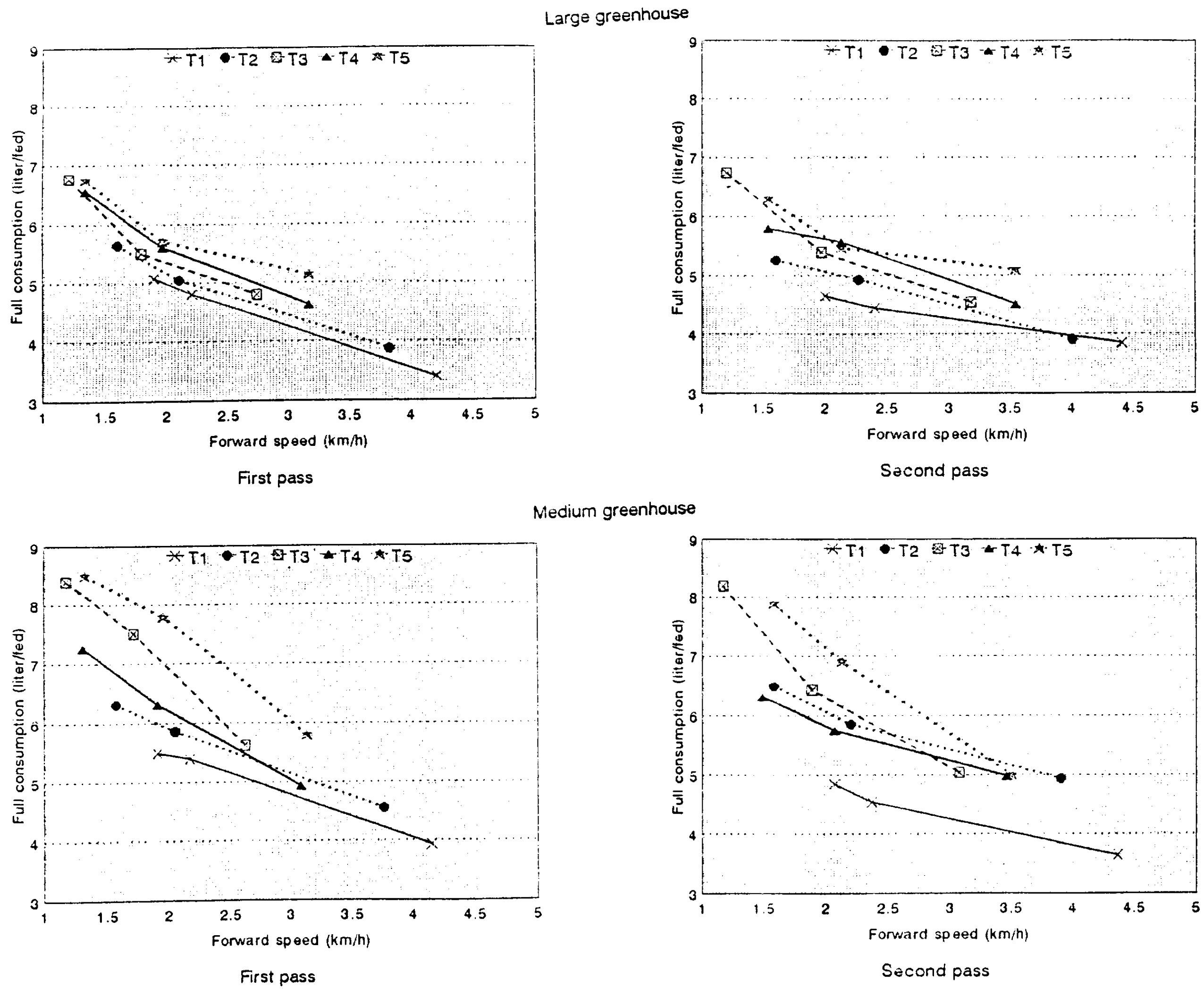

Fig. (4-8): The effect of tractor type, forward speed and ploughing pass on fuel consumption (L/fed) during ploughing operation for both large and medium greenhouses

(2WD), 14.93 and 10.44 kW, respectively during first ploughing pass.

Analysis of variance shown in Table (A-7 and A-8) in the Appendix indicates that the type of tractor and the working forward speed had a highly significant effect on the rate of fuel consumption in (L/h) as well as fuel consumption per unit rate of work in (L/fed).

It was also clear that the ploughing pass had a highly significant effect on the fuel consumption (L/fed) but it had no significant effect on the rate of fuel consumption measured in (L/h).

It is clear from the obtained data, presented in Table (4-9) that the arrangement of different powered tractors according to the average values of fuel consumption (L/h) during ploughing operation by using chisel plough was found to be in the following descending order: 24.63 kW > 18.66 kW (4WD) > 18.66 kW (2WD) > 14.93 kW > 10.44 kW.

According to the average values of fuel consumption per unit rate of work (L/fed), this arrangement was found to be in the following descending order : 10.44 kW > 18.66 kW (2WD) > 14.93 kW > 18.66 (4WD) > 24.63 kW as presented in Table (4-10).

Table 4-9: Average values of rate of fuel consumption (L/h) for different tractors at first and second passes during ploughing operation in large and medium greenhouses.

Green-house size	Tractor power / Plough-ing pass	Fuel consumption l/h					L.S.D.
		24.63 kW	18.66 kW (4WD)	18.66 kW (2WD)	14.93 kW	10.44 kW	
Large	First pass	2.664	2.518	2.275	1.999	1.240	at 0.05=0.201
	Second pass	2.802	2.597	2.292	2.087	1.105	at 0.01=0.292
Medium	First pass	2.676	2.488	2.391	1.978	1.267	at 0.05=0.266
	Second pass	2.866	2.513	2.235	2.054	1.082	at 0.01=0.386

Table 4-10: Average values of fuel consumption (l/fed) for different tractors at first and second passes during ploughing operation in large and medium greenhouses.

Green-house size	Tractor power / Plough-ing pass	Fuel consumption (l/fed)					L.S.D.
		24.63 kW	18.66 kW (4WD)	18.66 kW (2WD)	14.93 kW	10.44 kW	
Large	First pass	4.433	4.858	5.684	5.492	5.818	at 0.05=0.360
	Second pass	4.317	4.705	5.491	5.157	5.579	at 0.01=0.524
Medium	First pass	4.940	5.576	7.172	6.168	7.358	at 0.05=0.626
	Second pass	4.810	5.766	6.450	5.717	6.562	at 0.01=0.911

It is also clear that there is a high significant difference between the powered tractor 10.44 kW and other tractors.

4.1.6. Cost analysis:

Tables (4-11), (4-12) and Figures (4-9), (4-10) indicate the effect of tractor type, forward speed and ploughing pass on the total costs of ploughing operation in both large and medium greenhouses.

It is clear that for all powered tractors, increasing the forward speed tends to increase the total costs in L.E./h and decrease the total costs per unite rate of work (L.E./fed) during first and second ploughing passes. This trend is due to the increase of both fuel consumption and actual field capacity by increasing the forward speed.

From the same Tables it is noticed that the minimum values of total costs during ploughing operation were found to be 12.43, 11.98, 10.92, 8.27 and 7.35 L.E./h at forward speeds of about 2.07, 1.58, 1.17, 1.49 and 1.58 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively, during second ploughing pass in large greenhouse.

It is also noticed that the minimum values of total costs per unit rate of work for first ploughing pass in large

Table 4-11: The effect of tractor type and forward speed on the total costs during first and second pass of ploughing operation in large greenhouse.

Tractor type	24.63 kW			18.66 kW (4WD)			18.66 kW (2WD)			14.93 kW			10.44 kW		
First pass															
Forward working speed (km/h)	1.900	2.203	4.200	1.600	2.100	3.820	1.210	1.803	2.730	1.337	1.973	3.160	1.337	1.973	3.160
Plough cost, L.E./h	0.400	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.27	0.27	0.27	0.22	0.22	0.22
Tractor cost, L.E./h	12.09	12.18	12.95	11.70	11.84	12.13	10.60	10.69	10.86	7.96	8.13	8.32	7.25	7.39	7.53
Total costs, L.E./h	12.49	12.58	13.35	12.10	12.24	12.53	11.00	11.09	11.26	8.23	8.40	8.59	7.47	7.61	7.75
Total costs, L.E./fed	27.51	24.19	14.50	32.43	25.71	16.06	38.73	27.66	20.4	33.05	23.53	17.79	41.5	28.08	20.88
Second pass															
Forward working speed (km/h)	2.00	2.40	4.40	1.60	2.27	4.00	1.20	1.97	3.17	1.54	2.13	3.54	1.54	2.13	3.54
Plough cost, L.E./h	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.27	0.27	0.27	0.22	0.22	0.22
Tractor cost, L.E./h	12.04	12.18	12.73	11.53	10.81	12.12	10.50	10.69	10.85	7.97	8.17	8.40	7.14	7.33	7.43
Total costs, L.E./h	12.44	12.58	13.13	11.93	11.21	12.52	10.90	11.09	11.25	8.24	8.44	8.67	7.36	7.55	7.65
Total costs, L.E./fed	26.24	22.54	13.78	31.31	22.1	15.01	38.5	25.91	18.38	28.91	22.2	14.47	36.98	27.06	19.17

Table 4-12: The effect of tractor type and forward speed on the total costs during first and second pass of ploughing operation in medium greenhouse.

Tractor type	24.63 kW			18.66 kW (4WD)			18.66 kW (2WD)			14.93 kW			10.44 kW		
First pass															
Forward working speed (km/h)	1.91	2.17	4.15	1.57	2.05	3.76	1.17	1.72	2.62	1.30	1.91	3.08	1.32	1.96	3.13
Plough cost, L.E./h	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.27	0.27	0.27	0.22	0.22	0.22
Tractor cost, L.E./h	12.09	12.19	12.96	11.66	11.85	12.22	10.57	10.64	10.78	7.97	8.13	8.29	7.17	7.38	7.53
Total costs, L.E./h	12.49	12.59	13.36	12.06	12.25	12.62	10.97	11.04	11.18	8.24	8.40	8.56	7.39	7.60	7.75
Total costs, L.E./fed	29.66	26.84	16.41	36.88	29.88	19.18	44.96	32.96	24.15	36.79	26.66	18.17	51.32	37.62	25.00
Second pass															
Forward working speed (km/h)	2.07	2.37	4.36	1.58	2.20	3.90	1.17	1.89	3.07	1.49	2.07	3.46	1.58	2.13	3.50
Plough cost, L.E./h	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.27	0.27	0.27	0.22	0.22	0.22
Tractor cost, L.E./h	12.03	12.17	12.83	11.58	11.76	12.11	10.52	10.64	10.81	8.00	8.13	8.37	7.13	7.33	7.50
Total costs, L.E./h	12.43	12.57	13.23	11.98	12.16	12.51	10.92	11.04	11.21	8.27	8.40	8.64	7.35	7.55	7.72
Total costs, L.E./fed	27.32	25.04	15.60	36.86	28.67	18.84	45.69	30.75	22.11	32.43	25.07	16.52	42.98	32.13	22.71

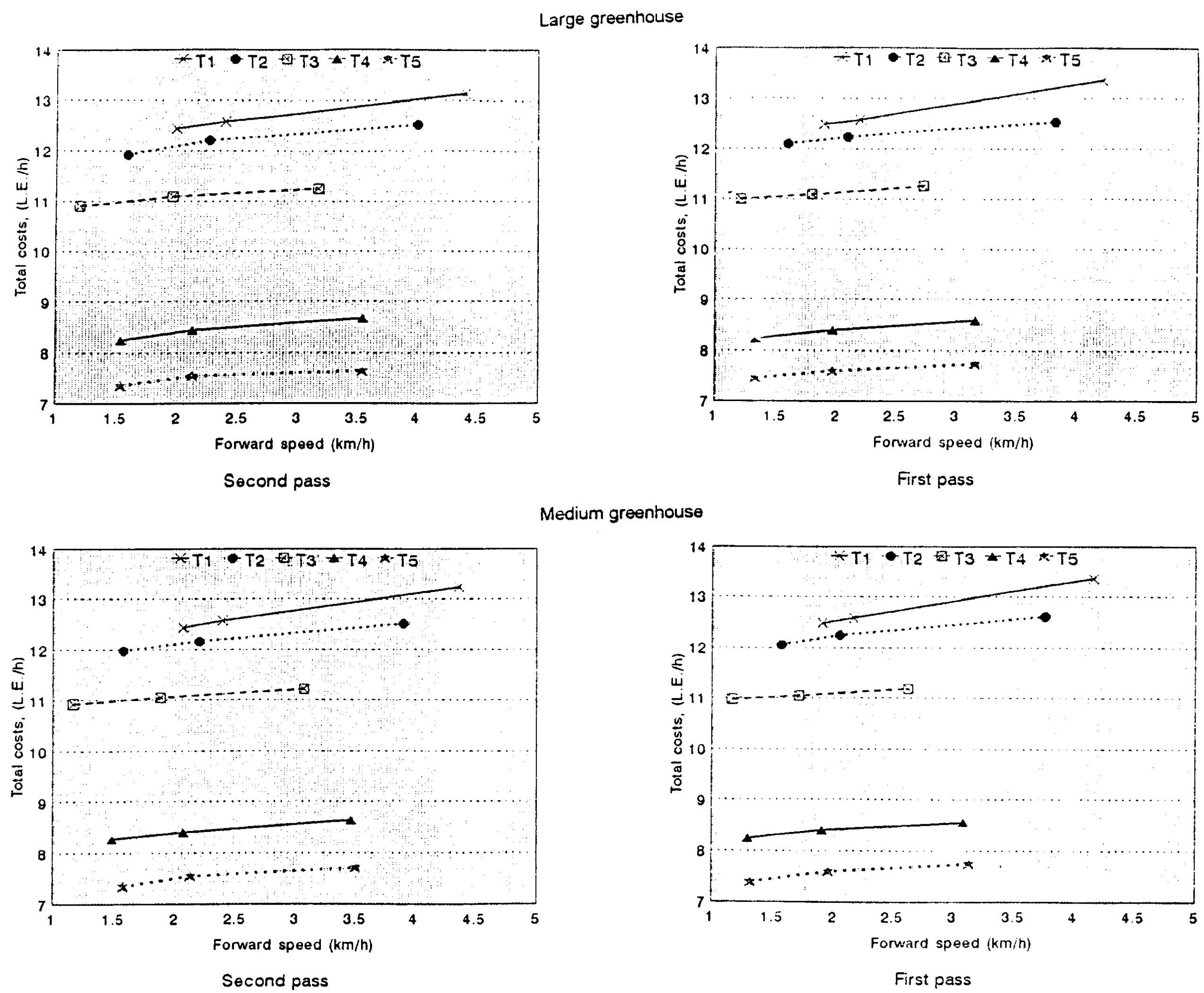

Fig. (4-9): The effect of tractor type, forward speed and ploughing pass on total costs (L.E./h) during ploughing operation for both large and medium greenhouses

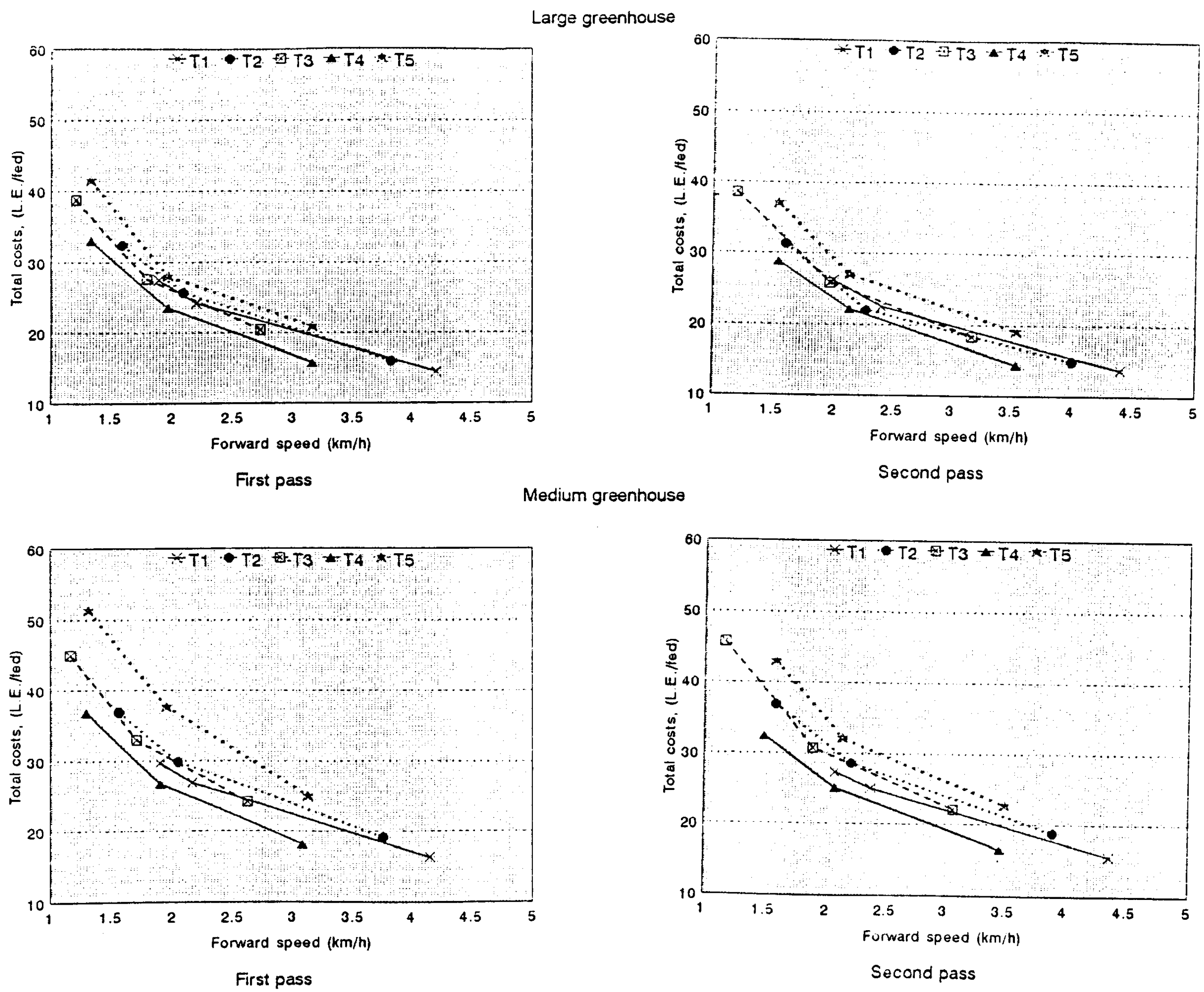

Fig. (4-10): The effect of tractor type, forward speed and ploughing pass on total costs (L.E./fed) during ploughing operation for both large and medium greenhouses greenhouse were found to be 14.5, 16.06, 20.4, 15.79 and 20.88 L.E./fed at forward speeds of about 4.20, 3.82, 2.73, 3.16 and 3.16 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively.

The minimum values of total costs per unit rate of work for second pass in large greenhouse were found to be 13.78, 15.01, 18.38, 14.47 and 19.17 L.E./fed, at forward speeds of about 4.40, 4.00, 3.17, 3.54 and 3.54 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.4 kW, respectively.

The minimum values of total costs per unit rate of work for the first ploughing pass in medium greenhouse were found to be 16.41, 19.18, 24.15, 18.17 and 25.00 L.E./fed, at forward speeds of about 4.15, 3.76, 2.62, 3.08 and 3.13 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively.

The minimum values of total costs per unit rate of work for the second ploughing pass in medium greenhouse were found to be 15.6, 18.84, 22.11, 16.52 and 22.71 L.E./fed, at forward speeds of about 4.36, 3.90, 3.07, 3.46 and 3.50 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively.

It is clear from the obtained data, presented in Table (4-13), that the arrangement of different powered tractors according to the average values of total costs (L.E./h) is found to be in the following descending order: 24.63 kW > 18.66 kW (4WD) > 18.66 kW (2WD) > 14.93 kW > 10.44 kW.

The arrangement of different powered tractors according to the average values of total costs per unit rates of work (L.E./fed) is found to be in the following descending order: 10.44 kW > 18.66 kW (2WD) > 18.66 kW (4WD) > 14.93 kW > 24.63 kW as shown in Table (4-14). It is also obvious from the same mentioned above Table that the total costs per unit rate of work (L.E./fed) are decreased during second ploughing pass compared with first ploughing pass, for all powered tractors for large and medium greenhouses.

4.2. Comparison between two wheel drive and four wheel drive low powered tractors:

Low powered four-wheel drive tractors (16-35 HP) (11.94-25 kW) have been successfully introduced in recent years and are popular for agricultural production in Egypt. Therefore, a field comparison of the performance characteristics of two and four wheel drive low powered tractors was carried out during ploughing operation by chisel plough under local greenhouse conditions.

Table 4-13: Average values of total costs (L.E./h) of different tractors during first and second passes of ploughing operation in large and medium greenhouses.

Green-house size	Tractor power / Ploughing pass	Total costs in L.E./h					L.S.D.
		24.63 kW	18.66 kW (4WD)	18.66 kW (2WD)	14.93 kW	10.44 kW	
Large	First pass	12.80	12.29	11.12	8.41	7.61	at 0.05=0.455
	Second pass	12.71	11.88	11.08	8.45	7.52	at 0.01=0.662
Medium	First pass	12.81	12.31	11.06	8.40	7.58	at 0.05=0.303
	Second pass	12.74	12.21	11.06	8.44	7.54	at 0.01=0.404

Table 4-14: Average values of total costs (L.E./fed) of different tractors during first and second pass of ploughing operation in large and medium greenhouses.

Green-house size	Tractor power / Ploughing pass	Total costs in L.E./fed					L.S.D.
		24.63 kW	18.66 kW (4WD)	18.66 kW (2WD)	14.93 kW	10.44 kW	
Large	First pass	22.07	24.73	28.93	24.12	30.15	at 0.05=0.360
	Second pass	20.85	22.81	27.60	21.86	27.74	at 0.01=0.524
Medium	First pass	24.30	28.64	34.02	27.21	37.98	at 0.05=0.636
	Second pass	22.65	28.12	32.85	24.67	32.60	at 0.01=0.911

4.2.1. Working forward speed:

It is clear from data presented in Table (4-15) and (4-16) that the average working forward speeds of four wheel drive tractor are highly significantly and greater than the two-wheel drive for both large and medium greenhouses.

4.2.2. Slip ratio and tractive efficiency:

It is clear from data presented in Tables (4-15 and 4-16) that the average percentage of slip with four wheel drive tractor were 47.7 and 44.67% lower than that of the two-wheel drive tractor in large and medium greenhouses, respectively. It is shown from the same Tables that the average tractive efficiency of the four-wheel drive tractor were 4.53 and 5.73% higher than the two-wheel drive tractor in large and medium greenhouses, respectively. This is because the four-wheel drive tractor works under better traction with less slippage due to its heavier weight and positive drive on all wheels.

4.2.3. Actual field capacity and field efficiency:

It is clear from Tables (4-15 and 4-16) that, the average values of actual field capacity for the four-wheel drive tractor is significantly greater than the two-wheel drive tractor. This trend is due to the obtained forward speed from the four wheel drive tractor is greater than the forward speed obtained from the two wheel drive tractor at the same year.

Table 4-15: Average values of performance characteristics of two and four wheel drive powered tractors of about 18.66 kW in large greenhouse.

Performance characteristics	2-wheel drive tractor	4-wheel drive tractor	Difference		
			Amount	%	Statis-tical
1. Actual working speed (km/h)	2.014	2.566	+0.552	27.41	**
2. Slip percentage	12.366	6.468	-5.898	47.70	**
3. Tractive efficiency (%)	73.091	76.404	-3.313	4.53	*
4. Actual field capacity (fed/h)	0.427	0.558	+0.131	30.68	**
5. Field efficiency (%)	73.251	73.480	+0.229	0.03	NS
6. Fuel consumption (L/h)	2.284	2.558	+0.274	12.0	*
7. Fuel consumption (L/fed)	5.587	4.781	-0.806	14.43	**
8. Total cost (L.E./h)	11.1	12.09	+0.990	8.92	*
9. Total cost (L.E./fed)	28.27	23.77	-4.5	15.92	**

Table 4-16: Average values of performance characteristics of two and four wheel drive powered tractors of about (18.66 kW) in medium greenhouse.

Performance characteristics	2-wheel drive tractor	4-wheel drive tractor	Difference		
			Amount	%	Statis-tical
1. Actual working speed (km/h)	1.939	2.510	0.571	29.45	**
2. Slip percentage	12.392	6.856	-5.536	44.67	**
3. Tractive efficiency (%)	73.111	77.298	+4.187	5.73	**
4. Actual field capacity (fed/h)	0.318	0.468	+0.15	47.17	**
5. Field efficiency (%)	63.814	64.540	+0.726	1.14	*
6. Fuel consumption (L/h)	2.313	2.500	+0.187	8.08	NS
7. Fuel consumption (L/fed)	6.811	5.671	-1.14	16.74	**
8. Total cost (L.E./h)	11.06	12.26	+1.2	10.85	*
9. Total cost (L.E./fed)	33.44	28.38	-5.06	15.13	**

On the other hand, there is no significant difference can be noticed between the field efficiency by using the two mentioned above tractors.

4.2.4. Fuel consumption:

The average values of fuel consumption (measured in L/h) of the four wheel drive tractor is greater than the average values of fuel consumption of two wheel drive tractor as indicated in Tables (4-15 and 4-16).

On the other hand, the average values of fuel consumption per unit rate of work (L/fed) of the four wheel drive tractor is lesser than the average values of fuel consumption of the two wheel drive. This is while the actual field capacity of the four-wheel drive tractor is greater than the actual field capacity of the two wheel drive tractor.

The fuel consumption (L/h) is significantly higher for four wheel drive than for two wheel drive in large greenhouse. The fuel consumption (L/h) has no significant difference between two and four wheel drive in the medium greenhouse.

4.2.5. Total cost of ploughing operation:

The average values of total cost for ploughing operation (L.E/h) by using four wheel drive tractor is greater than the two wheel drive tractor by 8.92% and 10.85% in large and medium greenhouse respectively as shown in Tables (4-15) and

(4-16). This trend is due to the list price as well as the fuel consumption in (L/h) of the four wheel drive tractor are greater than the two wheel drive tractor. On the other hand, the average values of total cost per unit rate of work (L.E./fed) for the four wheel drive tractor is lower than the total cost of the two wheel drive tractor. This trend is due to the actual field capacity of the four wheel drive tractor is greater than the actual field capacity of the two wheel drive tractor.

4.3. Effect of greenhouse size on the performance of tractor:

The factors affecting the performance of tractor under greenhouse conditions are not similar to these factors affecting the performance of tractor in open field. Greenhouse geometrical shape, area, distance between greenhouses are considered as the important factors affecting the performance of tractor as well as its cost.

The actual field capacity of the same powered tractors decreases as the greenhouse size changed from large to medium as indicated in Table (4-17). It is also clear that with the same size of greenhouse the actual field capacity decreases as the result of using smaller powered tractor. The percentages of decreasing actual field capacity during ploughing operation in medium greenhouse compared with large greenhouse were found to be 9.58, 16.13, 23.19, 11.94 and 5.96 for powered tractors

Table 4-17: Average values of actual field capacity by using different power tractors during ploughing operation in large and medium greenhouses.

Tractor power / Green house size	Actual field capacity		Difference	
	Large	Medium	Amount	%
24.63 kW	0.647	0.585	+0.062	9.58
18.66 kW (4WD)	0.558	0.468	+0.090	16.13
18.66 kW (2WD)	0.427	0.358	+0.069	16.16
14.93 kW	0.402	0.354	+0.048	11.94
10.44 kW	0.302	0.284	+0.018	5.96

Table 4-18: Average values of field efficiency of different powered tractors during ploughing operation in large and medium greenhouses.

Tractor power / Green house size	Field efficiency		Difference	
	Large	Medium	Amount	%
24.63 kW	0.773	0.706	0.067	8.67
18.66 kW (4WD)	0.735	0.645	0.090	12.25
18.66 kW (2WD)	0.733	0.638	0.095	12.96
14.93 kW	0.751	0.682	0.069	9.19
10.44 kW	0.780	0.721	0.059	7.56

of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively.

For all tractor sizes, the field efficiency of the same powered tractors decreases as the greenhouse size changed from large to medium as indicated in Table (4-18). The decrease in the field efficiency is due to the increase of time loss in turning at greenhouse ends and the length of transportation stroke from one greenhouse into another. The percentages of decreasing field efficiency during ploughing operation in medium greenhouse compared with large greenhouse were found to be 8.67, 12.25, 12.96, 9.19 and 7.56 for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively.

The arrangement of different powered tractors according to percentage of decreasing in actual field capacity and field efficiency is found to be in the following descending order, 18.66 (2WD) > 18.66 (4WD) > 14.93 > 24.63 > 10.44 kW respectively as shown in Tables (4-17 and 4-18).

The fuel consumption (l/h) for the same powered tractors had no significant difference between large and medium greenhouse as indicated in Table (4-19).

On the other hand, the fuel consumption per unit rate of work (L/fed) for the same powered tractors increases as the

Table 4-19: Average values of fuel consumption L/h of different powered tractors during ploughing operation in different sizes of greenhouses.

Tractor power / Green house size	Fuel consumption (L/h)		Difference	
	Large	Medium	Amount	%
24.63 kW	2.733	2.771	-0.038	1.39
18.66 kW (4WD)	2.558	2.500	0.058	2.27
18.66 kW (2WD)	2.284	2.313	-0.029	1.27
14.93 kW	2.043	2.016	0.027	1.32
10.44 kW	1.173	1.175	-0.002	0.10

Table 4-20: Average values of fuel consumption (L/fed) of different powered tractors during ploughing operation in large and medium greenhouses.

Tractor power / Green house size	Fuel consumption (L/fed)		Difference	
	Large	Medium	Amount	%
24.63 kW	4.375	4.875	-0.5	11.43
18.66 kW (4WD)	4.781	5.671	-0.89	18.61
18.66 kW (2WD)	5.587	6.811	-1.224	21.91
14.93 kW	5.324	5.942	-0.618	11.61
10.44 kW	3.949	5.241	-1.292	32.72

greenhouse size changed from large into medium as shown in Table (4-20). This increment is due to the decrease in the actual field capacity and field efficiency for all powered tractors in medium greenhouse compared with large greenhouse. The percentages of increment fuel consumption (L/fed) during ploughing operation in medium greenhouse compared with large greenhouse were found to be of about 11.43, 18.61, 21.91, 11.61 and 32.72 (L/fed) for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively.

The arrangement of different powered tractors according to the percentage of the increment fuel consumption (L/fed) is found to be in the following descending order: 10.44 > 18.66 (2WD) > 18.66 (4WD) > 14.93 > 24.63 kW, respectively.

The total cost per unit rate of work (L.E./fed) for the same powered tractors increases as the greenhouse size changed from large into medium as shown in Table (4-21). This is due to the decrease in the actual field capacity and field efficiency for all powered tractors in medium greenhouse compared with large greenhouse.

Table 4-21: Average values of total cost (L.E./fed) of different powered tractors during ploughing operation in large and medium greenhouse.

Tractor power / Green house size	Total cost (L.E./fed)		Difference	
	Large	Medium	Amount	%
24.63 kW	21.46	23.48	2.02	9.41
18.66 kW (4WD)	23.77	28.42	4.65	19.56
18.66 kW (2WD)	28.27	33.44	5.17	18.29
14.93 kW	22.99	25.94	2.95	12.83
10.44 kW	28.95	35.29	6.34	21.89

5. SUMMARY AND CONCLUSIONS

The present work was conducted to study the optimum and most suitable tractor size to operate under local greenhouses. To achieve this goal, five tractors of different powers ranging from 14 to 33 HP (10.44 - 24.63 kW) were used. Each of them was attached with a suitable chisel plough to execute the ploughing operation through two ploughing passes. Ploughing operation was performed under two different sizes of plastic tunnel at optimum soil moisture content of about 19% and three forward speeds. The range of ploughing depth was ranged between 10-16 cm. The dimensions of the plastic tunnels in meters are as follows: 8 m width x 60 m length x 3.25 m height and 6 m width x 40 m length x 2.85 m height. The field experiments were carried out at Sakha Research Station, Ministry of Agriculture, Kafr El-Sheikh Governorate.

The main results obtained from the experiments are summarized under the following main points:

1. The field performance characteristics of different powered tractors during ploughing operation under local greenhouse conditions.
2. Comparison between two wheel drive and four wheel drive tractors of low powers.
3. Effect of greenhouse size on the performance of tractor.

5.1. The field performance characteristics of tractors:

5.1.1. Rolling resistance:

For all powered tractors, the rolling resistance increased with increasing the forward speed during first and second ploughing passes. But, the maximum value was found during second ploughing pass.

The maximum values of rolling resistance were found to be 1.408, 1.961, 1.700, 1.112 and 0.946 kN at forward speeds of about 4.40, 4.00, 3.17, 3.54 and 3.54 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively.

5.1.2. Drawbar pull:

The drawbar pull is increased by increasing the forward speed for all powered tractors during first and second ploughing pass. But, it was found to be of low value during second ploughing pass compared with first pass.

The maximum values of drawbar pull were found to 7.52, 7.11, 6.25, 4.09 and 3.11 kN at forward speeds of about 4.20, 3.82, 2.73, 3.16 and 3.16 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively, during first ploughing pass.

5.1.3. Slip ratio and tractive efficiency:

For all powered tractors, increasing the forward sped tends to increase the slip ratio and decrease the tractive efficiency during first and second ploughing passes. The maximum values of slip ratios were found to be 5.97, 8.56, 15.46, 9.08 and 20.16% at forward speeds of about 4.15, 3.76, 2.61, 3.08 and 3.13 km/h and for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively, during second ploughing pass for medium greenhouse.

The maximum values of tractive efficiency were found to be 0.864, 0.826, 0.772, 0.801 and 0.699 at forward speeds of about 1.91, 1.57, 1.17, 1.3 and 1.32 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively, during first ploughing pass. On the other hand, they were found to be 0.806, 0.787, 0.738, 0.767 and 0.760 at forward speeds of about 2.07, 1.58, 1.17, 1.49 and 1.58 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW respectively during second ploughing pass.

The arrangement of different powered tractors according to the average values of slip percentage during ploughing operation was found to be in the following descending order: 10.44 kW > 18.66 kW (2WD) > 14.93 kW > 18.66 kW (4WD) > 24.63 kW.

The arrangement of different powered tractors according to the average values of tractive efficiency was found to be in the following descending order: 24.63 kW > 18.66 kW (4WD) > 14.93 kW > 18.66 kW (2WD) > 10.44 kW.

5.1.4. <u>Actual field capacity and field efficiency:</u>

Increasing the forward speed tends to increase the actual field capacity and decrease the field efficiency for all powered tractors during first and second ploughing passes. The actual field capacity was high during second ploughing pass compared with first ploughing pass.

The maximum values of actual field capacity were found to be 0.953, 0.834, 0.612, 0.599 and 0.399 fed/h at forward speeds of about 4.4, 4.0, 3.17, 3.54 and 3.54 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, during second ploughing pass, respectively.

The maximum values of field efficiency were found to be 0.795, 0.771, 0.789, 0.778 and 0.807 at forward speeds of about 2.0, 1.6, 1.2, 1.54 and 1.54 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively during second ploughing pass.

The arrangement of different powered tractors according to actual field capacity in fed/h during ploughing operation is found to be in the following descending order: 24.63 kW > 18.66 kW (4WD) > 18.66 kW (2WD) > 14.93 kW > 10.44 kW.

The arrangement of different powered tractors according to their field efficiency during ploughing operation is found to be in the following descending order: 10.44 kW > kW (4WD) > 14.93 kW > 18.66 kW (4WD) > 18.66 kW (2WD).

5.1.6. Fuel consumption:

For all powered tractors, increasing the forward speed tends to increase fuel consumption in l/h and decrease fuel consumption per unit rate of work in l/fed. But, it was low during second ploughing pass compared with first ploughing pass.

The maximum values of fuel consumption were found to be 4.18, 3.34, 2.68, 2.39 and 1.6 in l/h at forward speeds of about 4.2, 3.82, 2.73, 3.16 and 3.16 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively during first ploughing pass.

The maximum values of fuel consumption per unit rate of work in l/fed were found to be 5.08, 5.64, 6.76, 6.55 and 4.52 l/fed., at forward speeds of about 1.9, 1.6, 1.2, 1.3 and 1.3 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66

(2WD), 14.93 and 10.44 kW during first ploughing pass, respectively.

The arrangement of different powered tractors according to fuel consumption in l/h during ploughing operation is found to be in the following descending order: 24.63 kW > 18.66 kw (4WD) > 18.66 (2WD) > 14.93 kW > 10.44 kW.

The arrangement of different powered tractors according to fuel consumption in l/fed, during ploughing operation is found to be in the following descending order: 10.44 kW > 18.66 kW (2WD) > 14.93 kW > 18.66 kW (4WD) > 24.63 kW.

5.1.7. Cost analysis:

Increasing the forward speed tends to increase the total costs in L.E./h and decrease the total costs per unit rate of work in L.E./fed, during first and second ploughing passes.

The minimum values of total costs of ploughing operation were found to be 12.43, 11.98, 10.92, 8.27 and 7.35 L.E./h at forward speeds of about 2.07, 1.58, 1.17, 1.49 and 1.58 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, during second ploughing pass in large greenhouse, respectively.

The minimum values of total costs per unit rate of work for first ploughing pass in large greenhouse were found to be

14.5, 16.06, 20.4, 15.79 and 20.88 L.E./fed, at forward speeds of about 4.20, 3.82, 2.73, 3.16 and 3.16 km/h for powered tractors of about 24.63, 18.66 (4WD) 18.66 (2WD), 14.93 and 10.44 kW, respectively.

The minimum values of total costs per unit rate of work for second ploughing pass in large greenhouse were found to be 13.78, 15.01, 18.38, 14.47 and 19.17 L.E./fed, at forward speeds of about 4.40, 4.00, 3.17, 3.54 and 3.54 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively.

The minimum values of total costs per unit rate of work for first ploughing pass in medium greenhouse were found to be 16.41, 19.18, 24.15, 18.17 and 25.01 L.E./fed at forward speeds of about 4.15, 3.76, 2.62, 3.08 and 3.13 km/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively.

The minimum values of total costs per unit rate of work for the second ploughing pass in medium greenhouse were found to be 15.6, 18.84, 22.11, 16.52 and 22.71 L.E./fed, at forward speeds of about 4.36, 3.90, 3.07, 3.46 and 3.50 kw/h for powered tractors of about 24.63, 18.66 (4WD), 18.66 (2WD), 14.93 and 10.44 kW, respectively.

The arrangement of different powered tractors according to the total costs L.E./h is found to be in the following descending order: 24.63 kW > 18.66 kW (4WD) > 18.66 kW (2WD) > 14.93 kW > 10.44 kW.

The arrangement of different powered tractors according to the total costs per unit rate of work L.E./fed., is found to be in the following descending orders 10.44 kW > 18.66 kW (2WD) > 18.66 kW (4WD) > 14.93 kW > 24.63 kW.

5.2 Comparison-between two- and four wheel drive tractors of low power:

It is clear from the present comparison, that the working forward speed in (km/h), tractive efficiency in %, actual field capacity in (Fed/h) of four wheel drive tractor were found to be higher than that, of the two wheel drive tractor. On the other hand the slip percentage, fuel consumption in (L/fed) and total cost in (L.E./fed) of four wheel drive tractor were found to be lower than that, of the two wheel drive tractor.

5.3. Effect of greenhouse size on the performance of tractor:

For all tractor sizes, the actual field capacity and field efficiency of the same powered tractor decrease as the greenhouse size changed from large into medium. The arrangement of different powered tractors according to the percentage of decreasing in actual field capacity and field efficiency is found to be in the following descending order: 18.66 (2WD) > 18.66 (4WD) > 14.93 > 24.63 > 10.44 kW, respectively.

On the other hand, the fuel consumption per unit rate of work in (L/fed) and the total cost in (L.E./fed) for the same powered tractors increase as the greenhouse size changed from large into medium.

Finally, it is found from the present study that the proper unit to execute the ploughing operation under local greenhouse conditions consists of powered tractors ranged from 18.66 to 24.63 kW attached with 5-shares chisel plough of about 1.25 m width. The tractor must be 4-wheel drive tractor of the articulated type and of equal size wheels in front and rear. It has given the lowest values of slip percentage, fuel consumption and total cost. This type of tractor has given the highest values of actual field capacity, field and tractive efficiency.

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المراجع العربيه

حسن ، أ.ع. ، ١٩٨٨.
تكنولوجيا الزراعات المحميه (الصوبات)
جامعة القاهره

حنا ، ج.ب. ، ١٩٧٦.
الميكنه والجرارات الزراعيه
مطبعه جامعة القاهره

عبد الحميد ابو سبع وعلي يسري كريم ، ١٩٧٠.
الجرارات الزراعيه
(دار المعارف العربيه)

Appendix (A)

Statiscal analysis of data

Mean of square of tractor type (A), ploughing pass (B) and forward speed (C) and their effect on performance characteristics in large and medium greenhouses (G).

Table (A-1): Rolling resistance (R.R.).

S.O.V.	DF	Large greenhouse		Medium greenhouse	
		M.S.	F. Value	M.S.	F. Value
Replication (r)	2	0.073	0.843	0.008	0.153
Tractor type (A)	4	0.899	10.335**	0.714	14.003**
Error (a)	8	0.087		0.051	
Ploughing pass (B)	1	1.026	29.416**	0.772	19.736**
A x B	4	0.041	1.187	0.022	0.569
Error (b)	10	0.035		0.039	
Forward speed (C)	2	2.738	78.491**	1.796	41.286**
A x C	8	0.050	1.437	0.019	0.439
B x C	2	0.064	1.841	0.049	1.123
A x B x C	8	0.021	0.594	0.021	0.482
Error (c)	40	0.035		0.044	
Total	89				

Table (A-2): Drawbar pull

S.O.V.	DF	Large greenhouse		Medium greenhouse	
		M.S.	F. Value	M.S.	F. Value
Replication (r)	2	0.339	1.698	0.030	0.423
Tractor type (A)	4	34.798	174.273**	33.926	472.657**
Error (a)	8	0.200		0.072	
Ploughing pass (B)	1	7.592	34.471**	7.476	33.980**
A x B	4	0.284	1.290	0.273	1.077
Error (b)	10	0.220		0.220	
Forward speed (C)	2	14.696	66.727**	13.573	63.79**
A x C	8	0.910	4.132**	0.904	4.251**
B x C	2	0.321	1.456	0.197	0.924
A x B x C	8	0.064	0.289	0.049	0.230
Error (c)	40	0.220		0.213	
Total	89				

Table (A-3): Slip percentage.

S.O.V.	DF	Large greenhouse		Medium greenhouse	
		M.S.	F. Value	M.S.	F. Value
Replication (r)	2	0.294	0.421	1.620	5.270*
Tractor type (A)	4	528.290	756.538**	516.525	1680.810**
Error (a)	8	0.698		0.307	
Ploughing pass (B)	1	9.063	8.880*	5.862	29.457**
A x B	4	0.584	0.570	1.246	6.261**
Error (b)	10	1.021		0.199	
Forward speed (C)	2	85.437	84.097**	83.921	402.496**
A x C	8	3.169	3.119**	3.536	16.958**
B x C	2	0.303	0.298	0.769	3.678*
A x B x C	8	0.285	0.280	0.743	3.561*
Error (c)	40	1.016		0.209	
Total	89				

Table (A-4): Tractive efficiency %.

S.O.V.	DF	Large greenhouse		Medium greenhouse	
		M.S.	F. Value	M.S.	F. Value
Replication (r)	2	25.291	0.955	2.686	0.517
Tractor type (A)	4	619.339	24.373**	638.997	123.026**
Error (a)	8	25.410		5.194	
Ploughing pass (B)	1	362.926	35.673**	375.650	171.865**
A x B	4	5.397	0.530	3.024	1.383
Error (b)	10	10.173		2.186	
Forward speed (C)	2	393.766	51.167**	256.98	23.495**
A x C	8	10.596	1.376	7.115	0.650
B x C	2	14.556	1.891	3.022	0.276
A x B x C	8	6.970	0.905	4.903	0.448
Error (c)	40	7.696		10.937	
Total	89				

Table (A-5): Actual field capacity (fed/h)

S.O.V.	DF	Large greenhouse		Medium greenhouse	
		M.S.	F. Value	M.S.	F. Value
Replication (r)	2	0.002	1.368	0.000	0.185
Tractor type (A)	4	0.333	183.771**	0.317	390.565**
Error (a)	8	0.002		0.001	
Ploughing pass (B)	1	0.020	9.320*	0.014	55.495**
A x B	4	0.000	0.071	0.001	2.449
Error (b)	10	0.002		0.000	
Forward speed (C)	2	0.904	518.099**	0.623	749.675**
A x C	8	0.031	17.783**	0.017	20.839**
B x C	2	0.002	0.900	0.001	0.602
A x B x C	8	0.000	0.161	0.000	0.277
Error (c)	40	0.002		0.001	
Total	89				

Table (A-6): Field efficiency %.

S.O.V.	DF	Large greenhouse		Medium greenhouse	
		M.S.	F. Value	M.S.	F. Value
Replication (r)	2	0.451	0.085	0.689	0.529
Tractor type (A)	4	84.968	16.136**	237.43	182.22**
Error (a)	8	5.266		1.303	
Ploughing pass (B)	1	31.969	15.554**	40.267	25.408**
A x B	4	0.529	0.257	1.992	1.257
Error (b)	10	2.055		1.585	
Forward speed (C)	2	494.214	237.803**	707.597	395.513**
A x C	8	15.082	7.257**	9.976	5.576**
B x C	2	1.969	0.947	1.680	0.939
A x B x C	8	0.530	0.255	0.623	0.348
Error (c)	40	2.078		1.789	
Total	89				

Table (A-7): Fuel consumption in lit/h.

S.O.V.	DF	Large greenhouse		Medium greenhouse	
		M.S.	F. Value	M.S.	F. Value
Replication (r)	2	0.214	1.587	0.282	1.186
Tractor type (A)	4	6.709	49.642**	6.767	28.459**
Error (a)	8	0.135		0.238	
Ploughing pass (B)	1	0.032	0.230	0.002	0.025
A x B	4	0.050	0.360	0.113	1.370
Error (b)	10	0.139		0.079	
Forward speed (C)	2	6.497	45.004**	5.436	66.218**
A x C	8	0.129	0.894	0.219	2.594*
B x C	2	0.076	0.523	0.093	1.131
A x B x C	8	0.043	0.301	0.080	0.973
Error (c)	40	0.144		0.082	
Total	89				

Table (A-8): Fuel consumption in lit/fed.

S.O.V.	DF	Large greenhouse		Medium greenhouse	
		M.S.	F. Value	M.S.	F. Value
Replication (r)	2	0.338	0.777	2.736	2.072
Tractor type (A)	4	8.103	18.622*	9.831	7.446*
Error (a)	8	0.435		1.320	
Ploughing pass (B)	1	2.124	8.063	5.504	13.934**
A x B	4	0.293	1.111	1.578	3.995*
Error (b)	10	0.260		0.395	
Forward speed (C)	2	14.473	54.938**	21.284	49.989**
A x C	8	0.978	3.713**	1.992	4.677**
B x C	2	0.153	0.581	0.704	1.652
A x B x C	8	0.139	0.527	0.212	0.497
Error (c)	40	0.263		0.426	
Total	89				

APPENDIX (B)

Table (B-1): Cost estimation for different tractors.

Features / Tractor Model	Pasquali 988	Kubota L245 DTP	Kubota L245 FP	Shibaura SP 2040	Grill 113
Initial cost, L.E.	35000	33500	30000	19000	12500
Service life, year	10	10	10	10	8
Annual use, (hour/year)	900	900	900	900	700
Salvage value (L.E.)	3500	3350	3000	1900	1100
Interest rate, %	13	13	13	13	13
Fuel cost, (L.E./L)	0.40	0.4	0.4	0.4	0.4
Fuel consumption	as obtained from tractor test data				
Engine kW	24.6	18.7	18.7	15.0	10.52
Oil cost % of the fuel costs	15	15	15	15	15
Maitenance % depreciation	100	100	100	100	100

Table B-2: Cost estimation for different models of chisel plough.

Features	Chisel plough model		
	No. 1	No. 2	No.3
Initial cost, L.E.	600	400	250
Service life, year	7	7	7
Annual use, (hour/year)	400	400	300
Salvage value (L.E.)	0.00	0.00	0.00
Interest rate, %	13	13	13
Cost of repair and maintenance, % from depreciation	40	40	40

ARABIC SUMMARY

بسم الله الرحمن الرحيم

الملخص العربى

"الحجم الأمثل للجرار للصوبة المحلية"

لقد انتشرت الزراعة المحمية فى مصر خلال العشر سنوات الأخيرة كغيرها من العديد من بلدان العالم التى لجأت للزراعة المحمية كوسيلة حديثة من وسائل التوسع الرأسى فى انتاج الخضر . اذ أن انتاجية وحدة المساحة من محاصيل الخضر المختلفة تتضاعف عدة مرات فى الزراعات المحمية بالمقارنة بالانتاجية فى الحقول المكشوفة بالاضافة الى امكانية انتاجها فى غير موسمها وعلى مدار السنة وبالجودة العالية التى تناسب التصدير .

ويوجد فى مصر الأن ما يزيد عن ٢٠,٠٠٠ صوبة بلاستيك مسطح الصوبة الواحدة ٥٠٠ م٢منتشرة فى منطقة النوبارية ومديرية التحرير ومنطقة الجيزة ومحافظة الشرقية وكفر الدوار .

وهناك العديد من أشكال الصوب الا أن أكثر هذه الأشكال شيوعا هو نظام الصوب الزراعية البلاستيك المفردة ذو مقطع من دائرة The Quonset House (حسن ١٩٨٨) ويعد هذا الشكل أكثر الأشكال شيوعا فى البيوت البلاستيكية المفردة

وبعد انتشار الصوب الزراعية هذا الانتشار الواسع فى ج . م . ع فى الأونة الأخيرة ، أصبح لزاما علينا تطبيق نظم الميكنة الزراعية داخل هذه الصوب الزراعية على الوجة الأمثل .

ونظرا لأن الصوب تختص بانتاج المحاصيل البستانية وخاصة محاصيل الخضروات كما أن تربية النباتات داخل الصوب تربية رأسية لذلك فأن الميكنة داخل الصوب تقتصر على اعداد المهد الجيد للبذرة أو الشتلة .

ونظرا لأن الجرار هو المصدر الرئيسى للقدرة الميكانيكية لهذه العملية كما أن عملية الحرث هى العامل المحدد لقدرة الجرار حيث أنها تستهلك أكبر قدرة يمكن أن يعطيها الجرار مقارنة بالعمليات الزراعية الأخرى . وأن الظروف داخل الصوب تختلف عنها فى الحقل المفتوح لأن أقصى ارتفاع مسموح بة للألات داخل الصوب محدود بارتفاع علاقات الزرع وهو ٢م بالاضافة الى كون جوانب الصوبة على شكل منحنى مما يسبب ترك جانبى الصوبة بدون خدمة اذا لم يستعمل الجرار ذو الحجم المناسب للصوبة .

لذلك كان الهدف من البحث هو دراسة الظروف داخل الصوب الزراعية المحلية لتحديد أنسب المواصفات للجرار الأكثر ملائمة لهذه الظروف ميكانيكيا واقتصاديا والذى يفى بالقدرة التى تتطلبها

العمليات الزراعية وفى نفس الوقت يعطى كفاءة حقلية عالية واقتصاد فى استهلاك الوقود وسهولة الخدمة الحقلية .

ولتحقيق هذا الهدف تم اختيار خمسة جرارات زراعية من الجرارات الشائعة الاستخدام تتراوح قدرتها من ١٤ ـ ٣٣ حصان ميكانيكى (١٠,٤٤ ـ ٢٤,٦٣ ك وات) وتم تجهيز كل جرار بمحراث حفار مناسب لأداء عملية الحرث داخل حجمين مختلفين من الصوب الزراعية (٨,٥ م عرض ×٦٠ م طول × ٣,٢٥ م ارتفاع) و (٦ م عرض × ٤٠ م طول × ٢,٨٥ م ارتفاع) عند المحتوى الرطوبى الأمثل للحرث (حوالى ١٩٪ على أساس الوزن الجاف) وأن عمق الحرث يتراوح فيما بين ١٠ ــ ١٦ سم على حسب نوع المحراث وقدرة الجر المتاحة .

وقد أجريت التجارب الحقلية بوحدة بحوث وتطوير الزراعة المحمية بسخا التابعة لمركز البحوث الزراعية .

ويمكن تلخيص النتائج المتحصل عليها فيما يلى :

أولا: مواصفات الأداء الحقلى للجرارات المستخدمة أثناء اجراء عملية الحرث داخل الصوب الزراعية المحلية .

١ـ مقاومة التدحرج :

بلغت أقصى قيم لمقاومة التدحرج ١,٣٧٣ ، ١,٩٦١ ، ١,٧٠٠ ، ١,١١٢ ، ٠,٩٤٦ كيلو نيوتن عند سرعات أمامية ٤,٤٠ ، ٤,٠٠ ، ٣,١٧ ، ٣,٥٤ ، ٣,٥٤ كم /ساعة باستخدام جرارات ذات قدرات ٢٤,٦٣ ، ١٨,٦٦ (رباعى الدفع) ، ١٨,٦٦ (ثنائى الدفع) ١٤,٩٣ ، ١٠,٤٤ كيلو وات على الترتيب .

٢ـ الشد على قضيب الجر :

- لكل الجرارات المستخدمة فى البحث يزداد الشد على قضيب الجر بزيادة السرعة خلال الوجهه الأول (فك) والثانى (ثنى) .
- بلغت أقصى قيم لقوة الشد ٧,٥٢ ، ٧,١١ ، ٦,٢٩ ، ٤,٠٩ ، ٣,١١ كيلو نيوتن عند سرعات أمامية ٤,٢٠ ، ٣,٨٢ ، ٢,٧٣ ، ٣,١٦ ، ٣,١٦ كم / ساعة باستخدام جرارات ذات قدرات ٢٤,٦٣ ، ١٨,٦٦ (رباعى الدفع) /١٨,٦٦ (ثنائى الدفع) ، ١٤,٩٣ ، ١٠,٤٤ كيلو وات على الترتيب أثناء الفك.

٣ـ نسبة الانزلاق وكفاءة الجر :

- بزيادة السرعة الأمامية أدت الى زيادة نسبة الانزلاق وانخفاض كفاءة الجر لجميع الجرارات المستخدمة فى البحث .
- بلغت أقصى قيم لنسبة الانزلاق ٥,٩٧ ، ٨,٥٦ ،١٥,٤٦ ، ٩,٠٨ ، ٢٠,١٦٪ عند سرعات أمامية ٤,١٥ ، ٣,٧٦ ، ٢,٦١ ، ٣,٠٨ ، ٣,١٣ كم / ساعة باستخدام جرارات ذات قدرات ٢٤,٦٣ ، ١٨,٦٦ (رباعى الدفع) ، ١٨,٦٦ (ثنائى الدفع) ، ١٤,٩٣ ، ١٠,٤٤ كيلو وات على الترتيب أثناء الثنى .

- بلغت أقصى قيم لكفاءة الجر أثناء الفك ٠,٨٦٤ ، ٠,٨٢٦ ، ٠,٧٧٢ ، ٠,٨٠١ ، ٠,٦٩٩ عند سرعات أمامية ١,٩١ ، ١,٥٧ ، ١,١٧ ، ١,٣ ، ١,٣٢ كم / ساعة . باستخدام جرارات ذات قدرات ٢٤,٦٣ ، ١٨,٦٦ (رباعى الدفع) ، ١٨,٦٦ (ثنائى الدفع) ، ١٤,٩٣ ، ١٠,٤٤ كيلو وات على الترتيب . بينما بلغت هذه القيم أثناء الثنى ٠,٨٠٦ ، ٠,٧٨٧ ، ٠,٧٣٨ ، ٠,٧٦٧ ، ٠,٦٧٠ عند سرعات أمامية ٢,٠٧ ، ١,٥٨ ، ١,١٧ ، ١,٤٩ ، ١,٥٨ كم / ساعة .

٤- السعة الحقلية الفعلية والكفاءة الحقلية :

- زيادة السرعة الأمامية أدت الى زيادة السعة الحقلية الفعلية وانخفاض الكفاءة الحقلية لجميع الجرارات المستخدمة فى البحث .
- بلغت أقصى قيم للسعة الحقلية الفعلية ٠,٩٥٣ ، ٠,٨٣٤ ، ٠٦١٢. ، ٠,٥٩٩ ، ٠,٣٩٩ فدان / ساعة عند السرعات الأمامية ٤,٤ ، ٤,٠ ، ٣,١٧ ، ٣,٥٤ ، ٣,٥٤ كم / ساعة باستخدام جرارات ذات قدرات ٢٤,٦٣ / ١٨,٦٦ (رباعى الدفع) / ١٨,٦٦ (ثنائى الدفع) ، ١٤,٩٣ ، ١٠,٤٤ كيلو وات على الترتيب أثناء الثنى .
- بلغت أقصى قيم الكفاءة الحقلية ٠,٧٩٥ ، ٠,٧٧١ ، ٠,٧٨٩ ، ٠,٧٧٨ ، ٠,٨٠٧ عند السرعات الأمامية ٢,٠ ، ١,٦ ، ١,٢ ، ١,٥٤ ، ١,٥٤ كم / ساعة باستخدام جرارات ذات قدرات ٢٤,٦٣ ، ١٨,٦٦ (رباعى الدفع) ، ١٨,٦٦ (ثنائى الدفع) ، ١٤,٩٣ ، ١٠,٤٤ كيلو وات على الترتيب أثناء الثنى .

٥ - استهلاك الوقود :

- زيادة السرعة الأمامية أدت الى زيادة استهلاك الوقود (لتر / ساعة) وانخفاض الاستهلاك بالنسبة لوحدة المساحة (لتر / فدان) . لجميع الجرارات المستخدمة فى البحث .
- أقصى قيم لاستهلاك الوقود كانت ٤,١٨ ، ٣,٣٤ ، ٢,٦٨ ، ٢,٣٩ ، ١,٩ لتر / ساعة عند السرعات الأمامية ٤,٢ ، ٣,٨٢ ، ٢,٧٣ ، ٣,١٦ ، ٣,١٦ كم / ساعة باستخدام جرارات ذات قدرات ٢٤,٦٣ ، ١٨,٦٦ (رباعى الدفع) ١٨,٦٦ (ثنائى الدفع) ، ١٤,٩٣ ، ١٠,٤٤ كيلو وات على الترتيب وذلك أثناء الفك.
- أقصى قيم لاستهلاك الوقود كانت ٥,٠٨ ، ٥,٦٤ ، ٦,٧٦ ، ٦,٥٥ ، ٦,٧٤ (لتر/ فدان) عند السرعات الأمامية الأتية : ١,٩ ، ١,٦ ، ١,٢ ، ١,٣ ، ١,٣ كم / ساعة للجرارات ذات القدرات التالية ٢٤,٦٣ ، ١٨,٦٦ (رباعى الدفع) ١٨,٦٦ (ثنائى الدفع) ، ١٤,٩٣ ، ١٠,٤٤ كيلووات على الترتيب وذلك أثناء الفك.

٦ - تكاليف الحرث :

- زيادة السرعة الأمامية أدت الى زيادة التكاليف الكلية للحرث (جنية / ساعة) وانخفاض التكاليف الكلية للحرث (جنية / فدان) لجميع الجرارات المستخدمة فى البحث
- أقل قيم للتكاليف الكلية أثناء عملية الحرث (جنية / فدان) فى الحرثة الأولى (فك) بلغت ١٦,٤١ ، ١٩,١٨ ، ٢٤,١٥ ، ١٨,١٧ ، ٢٥,٠٠ جنية / فدان عند السرعات الأمامية الأتية ٤,١٥ ، ٣,٧٦ ، ٢,٦٢ ، ٣,٠٨ ، ٣,١٣ كم / ساعة باستخدام جرارات ذات قدرات ٢٤,٦٣ ، ١٨,٦٦ (رباعى الدفع) ، ١٨,٦٦ (ثنائى الدفع) ، ١٤,٩٣ ، ١٠,٤٤ كيلووات على الترتيب . بينما بلغت هذه القيم أثناء الحرثة الثانية (ثنى) ١٥,٦ ، ١٨,٨٤ ، ٢٢,١١ ، ١٦,٥٢ ، ٢٢,٧١ جنية / فدان وذلك عند السرعات الأمامية الأتية : ٤,٣٦ ، ٣,٩٠ ، ٣,٠٧ ، ٣,٤٦ ، ٣,٥٠ كم / ساعة على الترتيب .

ثانيا مقارنة أداء كل من الجرار الثنائى الدفع والرباعى الدفع ذو القدرة المنخفضة :

وجد من مقارنة الجرارات الثنائية الدفع والرباعيه الدفع أن السرعة الأمامية والسعة الحقلية الفعلية والكفاءة الحقلية للجرار رباعى الدفع أعلى منها للجرار ثنائى الدفع وكذلك وجد أن نسبة الانزلاق ، واستهلاك الوقود والتكاليف الكلية للحرث للجرار رباعى الدفع أقل منها للجرار ثنائى الدفع .

ثالثا تأثير حجم الصوبة على أداء الجرار :

وجد أن السعة الحقلية الفعلية والكفاءة الحقلية لنفس الجرار تنخفض بانخفاض أبعاد الصوبة وأقل معدل انخفاض كان للجرار المفصلى رباعى الدفع ذو قدرة تبلغ ٢٤,٦٣ ك وات .

وجد أيضا أن معدل استهلاك الوقود وكذلك التكاليف الكلية لنفس الجرار زادت بانخفاض أبعاد الصوبة وأقل معدل زيادة كان مع الجرار المفصلى رباعى الدفع ذو قدرة ٢٤,٦٣ ك . وات

فى نهاية هذه الدراسة ومن النتائج المتحصل عليها يمكن أن نستخلص أن الجرار المناسب لأداء عملية الحرث تحت ظروف الصوب الزراعية المحلية يجب أن تتراوح قدرتة فيما بين ١٨,٦٦ الى ٢٤,٦٣ ك . وات ملحق به محراث حفار ٥ سلاح بعرض ١,٢٥ متر . كذلك يفضل أن يكون الجرار رباعى الدفع من النوع المفصلى مع تساوى العجل الأمامى والخلفى . حيث أعطى أقل قيمة للانزلاق وكذلك استهلاك الوقود وأقل تكلفة لعملية الحرث مع أعلى قيمة للسعة الحقلية الفعلية والكفاءة الحقلية وكفاءة الجر .

لجنة الاشراف

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رسالة مقدمة من

عبده شوقي عبده العشري

للحصول علي درجة

الماجستير في الميكنه الزراعيه

لجنة المناقشه والحكم علي الرساله:

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بكالوريوس العلوم الزراعيه (شعبه الميكنه الزراعيه)

جامعة طنطا ١٩٨٤

استيفاء للدراسات المقرره للحصول علي

درجة الماجستير

في الميكنه الزراعيه

قسم الميكنه الزراعيه

كلية الزراعه بكفر الشيخ

جامعة طنطا

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