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# Study on tractor implement combination and optimum field capacity for some selected farms

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**ABSTRACT :** In this study, the optimum size of tractor and optimum field capacity requirements of implements for three different farms *i.e.,* Agricultural Engineering Farm (AEF), Adhartal Farm (AF), and Dusty Acre Farm (DAF) of Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur was analyzed. Primary data were obtained through log book, history book and field survey of the university farms. Results showed that an optimum hp requirement for AEF was maximum (138.59hp). For DAF and AF it was 101.19 and 124.92 hp, respectively. The optimum field capacity of plough for all the three farm varied between 0.23 – 0.46 ha/h, cultivator was between 0.82 - 1.40 ha/h, disk harrow was between 0.90 – 1.52 ha/h and for seed drill was 1.00 – 2.01 ha/h when the labour cost varies between Rs. 100 – 180. For the selected farms the size of plough ranged between 2bottom-30cm to 4 bottom-35cm, the size of the cultivator and seed drill varied 9 – 19 tynes and for disk harrow between 8 – 16 disk.

**KEY WORDS :** Farm equipment, Optimum size, Power, Tractor

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Power is needed on the farm for operating different tools, implements and machinery for various operations. Farm Power is an essential input in agriculture for timely field operations for operating different types of farm equipment for operating tillage, sowing, harvesting, threshing, shelling, cleaning, grading, and irrigation equipment. At present in India, tractors are being used for tillage of 22.78 per cent of total area and sowing 21.30 per cent of total area (Anonymous, 2012). During last 50 years the average farm power availability in India has increased from about 0.25 kW/ha in 1951 to about 1.35 kW/ha in 2001 and 1.64 kW/ha in 2010.

For an agricultural enterprise, tractors are the most expensive farming input. The primary purpose of agricultural tractors, especially those in the middle to high power range, is to perform drawbar work. The value of a tractor is measured by the amount of work accomplished relative to the cost incurred in getting the work done. Therefore, the ideal tractor converts all the energy from the fuel into useful work at the drawbar. By using accurate draft data, the operating costs of both tractors and implements can be minimized. Correct matching of implements should result in the optimum use of the tractor and the attached implement for a particular farm situation.

It is important to use the tractor of optimum size with due consideration to its economy. Because if the power available from it is less than the required it will not be possible to cover the entire field in the stipulated time effectively, whereas, it will be under used if the power available is greater than the desired. Thus, machinery selection and management technique are of great interest to both the designer and user of farm machinery. This is necessitated in farm situations where the availability of tractors and implements are limited in number. It is rather beneficial and cost effective to select an implement for a specific tillage operation and to determine the correct size of the tractor. The object of this study was to optimize the tractor power requirement with matching implement combination for optimum field capacity at some selected farms of JNKVV Jabalpur.

Literature exists on the selection of optimum combinations of implement and tractor for performing a specified operation or for performing a limited number of operations for a single enterprise. Chancellor (1969) developed a model for optimum size of tractor of a farm. He also applied his model, for single and multiple tractor farms and concluded that, for single tractor farms, there exists an economical optimum sized tractor, and for multiple tractor farms, there exists an economically optimum level of rated horse power per hectare which applies to tractors of all sizes. Singh and Kawade (2003) they have give the different selection criteria for the tractor. According to them selection of tractor is based on timeliness in operation, hp required, custom hiring, fuel efficiency, purchase price, special technical features, after sale service and resale value and also carried out a study on availability of tractors in India. They have computed horse power range for a 50 ha land and suggested a 30-35 PTO HP tractor is best suited for it. Mishra and Dhakad (2004) carried out a study at some selected farms of Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur regarding to the optimum sized tractor and they reported that excess tractor on the farm can be effectively used for crop harvesting by utilizing their power with matching equipment such as tractor driven combine.

## METHODOLOGY

### General information about study area :

Jabalpur district lying between $22^0 49'$ and $24^0 8'$ north latitude and $78^0 21'$ and $80^0 58'$ east longitude. The area has an annual rainfall of 1214 mm. The cropping patterns followed in the farm are paddy-wheat, paddy-berseem, urd-wheat and follow-linseed. Information regarding location of farms, area under cultivation and list of tractors at different farms are given in Table A and B.

### Computation of optimum size of tractor :

Selection of tractor for a particular farm was associated with farm size, cropping area, cropping pattern, cultural practices, yield, prevalent trends and purchase price of machine. Sufficient power should be available from the tractor to complete the farm operations. Two different models are used to calculate the optimum size tractor for a farm. They are Hunt's model (1983) which includes transport operations and the other is Chancellor's model which excludes transport operations

### Hunt's model :

Optimum power required for the field and transport operations was calculated by Hunt's formula (1983) as:

$$P_{opt} = [\sum(pd_i) + \sum(Pt_j)]^{1/2} \quad \text{.........(i)}$$

Power required for drawbar operation (Pd) was calculated as:

$$P_d = \frac{100 \text{ x A x Exn}}{r(F_c\,\%)p_t} \text{x} \left( L + \frac{\text{K xYxVx A}}{S_c x N_t \text{ x Ux h}} \right) \quad \text{.........(ii)}$$

where,

$$E = \frac{\text{BHP x LCF x 10}}{\text{W x S x } E_f}$$

Power required for transport operations ($P_t$) was calculated as :

$$P_t = \frac{100 \text{ x } 0.27 \text{ x (D) x (w) x } (L_t)}{(F_c\,\%)(P_{pt})} \quad \text{.........(iii)}$$

**Table A: Information regarding location of farms and area under cultivation**

| Farms | Location | | | Total area (ha) | Area under production (ha) | Cropping intensity (%) |
|---|---|---|---|---|---|---|
| | Latitude | Longitude | Altitude | | | |
| Agricultural engineering farm (AEF) | 23°13'06.00"N | 79°57'41.80"E | Elevation 391.66 m | 107.6 | 103.6 | 165 |
| Dusty acre farm (DAF) | 23°12'52.70"N | 79°57'50.79"E | Elevation 392.88 m | 96.25 | 87.5 | 118 |
| Adhartal farm (AF) | 23°12'42.74"N | 79°56'47.42"E | Elevation 391.97 m | 105 | 90 | 154 |

**Table B : List of tractors at different farm**

| Farms | Registration number | HP | Year of purchase | Cost of purchase (Rs.) | Expenditure on repair and maintenance (Rs.) |
|---|---|---|---|---|---|
| | MP 20 / 4298 | 50 | 1990 | 142197.50 | NIL |
| | MKJ / 1963 | 35 | 1982 | 85622.98 | 16436.00 |
| AEF | MP 20 / H 5403 | 35 | 1996 | 211421.00 | 28087.00 |
| | MP 20 / HA 5712 | 55 | 2003 | 358000.00 | 4324.00 |
| | MP 20 / HA 5078 | 35 | 2003 | 250000.00 | 2920.00 |
| | MBK 176 | 35 | 1982 | 65622.96 | Nil |
| | MP 20 / D 9757 | 35 | 1991 | 148425.00 | 3330.00 |
| DAF | MP 20 / H 3506 | 59 | 1994 | 246744.00 | 64192.00 |
| | MP 20 / H 9907 | 55 | 1999 | 289154.64 | 11812.00 |
| | MP 20 / HA 8319 | 42 | 2005 | 306000.00 | 10517.00 |
| | MP 20 H 3505 | 35 | 1993 | 300000.00 | 35653.00 |
| | MP 20 H 5659 | 35 | 1996 | 210000.00 | 38531.00 |
| AF | MP 20 H 4858 | 35 | 1996 | 245000.00 | 28782.00 |
| | MP 20 AA 0747 | 50 | 2006 | 329250.00 | 15445.00 |
| | MP 20 AA 748 | 50 | 2006 | 329250.00 | 15523.00 |
| | MP 20 AA 1064 | 40 | 2007 | 297168.00 | 14920.00 |

**Computation of minimum horse power requirements :**

From past experiences, estimated numbers of critical days are available to complete the various field operations and determined the size of implement needed. Once the size of implement was decided the total draft of implement and drawbar horsepower needed to pull implement calculated. Then PTO power (hp) equal to db power and multiplication factors for different soil conditions (firm untilled soil, previously tilled soil and soft or sandy soil was 1.5. 1.8 and 2.1, respectively). In our case, multiply factor was 2.1 as our field is sandy soil. Therefore, PTO power = DBP X 2.1 for determined rated engine power needed by dividing the PTO power by 0.85, since 85 per cent power gets transmitted from engine to PTO.

**Chancellor's model :**

The procedure adopted for evaluating the optimum size involves the minimization of the total annual cost with respect to the horsepower input. The total annual cost was the sum of fixed cost, energy cost and time cost. The K factor for different hp ranges was calculated on the basis of latest market prices and hp of tractor are given in Table C.

Hence,

$$Z = \frac{F.K_c.H + B.A.Wh + C.A.W}{H} \qquad .........(iv)$$

Taking derivative with respect to H we get

$$\frac{dz}{dH} = FK_c - \frac{CAW_h}{H^2}$$

Equating to zero for minimum cost we get

$$H = A_t\left(\frac{Wh}{FK_c} x \frac{C}{A}\right)^{0.5} \qquad .........(v)$$

**Determination of optimum field capacity :**

The field capacity giving least total cost for an individual machine was determined by combining all the cost equations into one equation and differentiating with respect to field capacity. The following resultant equation has been used:

$$C_{aopt} = \sqrt{\frac{A}{C_{os}}\left(L_c + T_{fc} + \frac{K_t AYV}{\lambda o TP_{wd}}\right)} \qquad .........(vi)$$

This equation is based on the timeliness of the power. Thus, if timeliness is not considered, the smallest machine would be most economical. However, timeliness cost rise sharply when machines are too small to complete the work in a timely manner. A value for $T_{fc}$ was determined by using the following equation :

$$T_{fc} = \frac{C_{oat}}{\tau A} \qquad .........(vii)$$

where,

$$C_{oat} = (1 - S_v)\left[\frac{I_r(1+I_r)\tau_L}{(1+I_r)\tau_L - 1}\right] + \frac{K_{tis}}{100} \qquad .........(viii)$$

A value for unit price function was calculated by the following equation:

$$K_p = \frac{10p_w}{v\eta_f} \qquad .........(ix)$$

The value for timeliness loss factor was taken as 0.0001 and annual cost of taxes, insurance and shelter as per cent of purchase price is 2 per cent *i.e.*, 0.02. The fixed cost percentage (Fc %) of tractor was calculated using expected life of 10 years and it is found to be about 15 per cent. The actual number of hours utilized per day has been assumed to be 8 hours and fractional utilization of total time is assumed to be 0.7. The value of $N_t$ is assumed the same as the number of operations of each implement. The value for labour cost L is Rs. 100 and $L_t$ was assumed to be Rs. 180.

## ■ RESULTS AND DISCUSSION

The results of the present study as well as relevant discussions have been presented under following sub heads:

**Table C : Market prices of different tractors in different hp ranges used in study**

| Manufacturer | 30 hp model | Price (Rs) | 40 hp model | Price (Rs) | 45-50 hp model | Price (Rs) |
|---|---|---|---|---|---|---|
| $T_1$ | $T_1M_1$ | 415638 | $T_1M_3$ | 446332 | $T_1M_5$ | 498668 |
| | $T_1M_2$ | 426732 | $T_1M_4$ | 488435 | | |
| $T_2$ | $T_2M_1$ | 390333 | $T_2M_2$ | 495815 | $T_2M_3$ | 497815 |
| | | | | 446142 | | 503305 |
| $T_3$ | $T_3M_1$ | 417165 | $T_3M_3$ | 433125 | $T_3M_5$ | 515340 |
| | $T_3M_2$ | 421995 | $T_3M_4$ | 470715 | | |
| $T_4$ | $T_4M_1$ | 412075 | $T_4M_2$ | 452015 | $T_4M_6$ | 534715 |
| $T_5$ | - | - | $T_5M_1$ | 472810 | $T_5M_3$ | 595630 |
| | | | $T_5M_2$ | 480810 | | 617760 |
| $T_6$ | - | - | $T_6M_1$ | 453613 | $T_6M_2$ | 496238 |
| $T_7$ | - | - | $T_7M_1$ | 443315 | $T_7M_2$ | 505622 |

**Optimum size of tractor by Hunt's model :**

Hunt has proposed the equation for the optimum size of tractor taking in consideration the transportation operations. Before computing the minimum horse power requirements we compute the width of implement of for different operation.

**Width of implement :**

Due to the seasonal nature of farm work, farm machinery is used during critical period of the year. With growth in average farm sizes, machine of high capacity are required to accomplish their task during these short periods. Obtained width for different implements of different farms are given in Table 1.

**Computation of total draft, drawbar power, PTO power and rated engine power**

The total draft, drawbar power, PTO power, and rated engine power for different implements of the selected farms were calculated. Table 1shows total draft, drawbar power, PTO power, rated engine power for different implements of the selected farm. The minimum horse power requirement for the AEF, DAF and AF was 84.39, 37.11, 65.22 hp, respectively. The primary tillage operation (ploughing) was the critical operation to decide the minimum hp requirement of the tractor.

**Computation of optimum size of tractor :**

Table 3 shows power required at drawbar for field operations, power required for transport operations in terms of hp. The values of variable used were taken from previous Table 2. The optimum horse power requirement for AEF comes out to be 138.59 hp. As per availability of tractor in the market, the optimum power (138.59 hp) is divided into three tractors of 55, 50, and 35 hp. This will also facilitate the early completion of the various works. In the similar manner, two tractors of 55 and 50 hp may be used to obtain 101.19 hp for the DAF, and, three tractors of 35, 45, and 50 hp may be recommended for AF for obtained power of 124.92 hp. The optimum size of tractor per hectare for AEF, DAF, and AF was 0.80, 0.98, and 0.90 hp/ha respectively. On an average the optimum size per hectare for these farms varies between 0.8 to 1.0 hp/ha.

**Table 1 : Total width, draft, drawbar power, PTO power and rated engine power for different machinery**

| Farm | Implement | Area (ha) | Width (m) | Total draft (N) | Drawbar power (kW) | PTO power (kW) | Rated engine power (kW) | REP (hp) |
|---|---|---|---|---|---|---|---|---|
| AEF | Plough | 85.5 | 2.22 | 3117.2 | 25.48 | 53.5 | 62.95 | 84.4 |
| | Cultivator | 171.1 | 4.24 | 1909.6 | 18.21 | 38.2 | 44.99 | 60.3 |
| | Disc harrow | 171.1 | 3.03 | 1154.4 | 17.30 | 36.3 | 42.74 | 57.3 |
| | seed drill | 100.6 | 3.32 | 299.4 | 3.67 | 7.7 | 9.07 | 12.2 |
| DAF | Plough | 37.6 | 0.98 | 1370.8 | 11.21 | 23.5 | 27.68 | 37.1 |
| | Cultivator | 102.95 | 2.55 | 1149.0 | 10.96 | 23.0 | 27.07 | 36.3 |
| | Disc harrow | 102.95 | 1.83 | 694.6 | 10.41 | 21.9 | 25.72 | 34.5 |
| | seed drill | 68.05 | 2.25 | 202.52 | 2.48 | 5.22 | 6.14 | 8.2 |
| AF | Plough | 66.08 | 1.72 | 2409.2 | 19.69 | 41.4 | 48.65 | 65.2 |
| | Cultivator | 138.3 | 3.43 | 1543.52 | 14.72 | 30.94 | 36.37 | 48.8 |
| | Disc harrow | 138.3 | 2.46 | 933.12 | 13.98 | 29.4 | 34.55 | 46.3 |
| | seed drill | 121.52 | 4.02 | 361.7 | 4.43 | 9.31 | 10.96 | 14.7 |

**Table 2 : Total production and crop value at different farms**

| Farm | Implement | Area (ha) | Total production (Tonnes) | Total value of produce (Rs.) | Yield of crop (Tonnes/ha) | Value of crop (Rs/Tonnes) |
|---|---|---|---|---|---|---|
| AEF | Plough | 85.50 | 118.50 | 1390055.00 | 1.386 | 11730.42 |
| | Cultivator | 171.10 | 272.55 | 1753665.00 | 1.592 | 6434.19 |
| | Disc harrow | 171.10 | 272.55 | 1753665.00 | 1.592 | 6434.19 |
| | seed drill | 100.60 | 158.07 | 494330.00 | 1.571 | 3127.30 |
| DAF | Plough | 37.60 | 40.19 | 968368.00 | 1.068 | 24095.35 |
| | Cultivator | 102.95 | 136.80 | 1221011.60 | 1.328 | 8925.85 |
| | Disc harrow | 102.95 | 136.80 | 1221011.60 | 1.328 | 8925.85 |
| | seed drill | 68.05 | 97.09 | 267971.60 | 1.426 | 2760.17 |
| AF | Plough | 66.08 | 97.39 | 4671073.00 | 1.473 | 47963.54 |
| | Cultivator | 138.30 | 269.77 | 11635713.00 | 1.950 | 43132.30 |
| | Disc harrow | 138.30 | 269.77 | 11635713.00 | 1.950 | 43132.30 |
| | seed drill | 121.52 | 235.89 | 10147991.00 | 1.941145 | 43020.38 |

**Optimum size of tractor by Chancellor's model :**

Chancellor proposed the equation for the optimum size of tractor without considered the transportation operation *i.e.,* considering field operation only. Before optimizing the size of tractor K factor for different hp range tractor was calculated. Table 3 has provided different ranges of tractor power and market price used in the study. From available information the value of K was calculated as 13799.65, 11552.56, and 10589.09 Rs./hp for 30, 40 and 50 hp, respectively. Therefore, the weighted mean was 11712.88 Rs/hp. This shows that the value of K was decreased with the increase in the hp ranges. So, higher hp range may provide a lesser total annual

**Table 3 : Calculation for optimum oower requirement**

| Farm | Name of implement | Area (ha) | E (kwh/ha) | Yield (Tonnes/h) | Value of crop (Rs / Tonnes) | $P_d$ | $P_t$ | Total ($\Sigma P_d$+$\Sigma P_t$) | $P_{opt}$ (kw) | $P_{opt}$ (hp) | Recommended hp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Agri. Engg. | Plough | 85.5 | 82.47 | 1.39 | 11730.42 | 2774.65 | 17.4564 | 6325.042 | 79.530 | 106.60 | 138.59 |
| | Cultivator | 171.1 | 26.51 | 1.59 | 6434.19 | 1785.33 | | | | | |
| | Disc harrow | 171.1 | 22.38 | 1.59 | 6434.19 | 1507.84 | | | | | |
| | Seed drill | 100.6 | 6.06 | 1.57 | 3127.31 | 239.76 | | | | | |
| Groundnut unit | Plough | 37.6 | 82.46 | 1.06 | 24095.35 | 1219.85 | 9.6681 | 3372.38 | 58.072 | 77.84 | 101.19 |
| | Cultivator | 102.95 | 26.50 | 1.32 | 8925.85 | 1073.83 | | | | | |
| | Disc harrow | 102.95 | 22.38 | 1.32 | 8925.85 | 906.88 | | | | | |
| | Seed drill | 68.05 | 6.05 | 1.42 | 2760.175 | 162.14 | | | | | |
| Adhartal | Plough | 66.08 | 82.46 | 1.47 | 47963.54 | 2148.74 | 16.6507 | 5138.91 | 71.686 | 96.09 | 124.92 |
| | Cultivator | 138.3 | 26.50 | 1.95 | 43132.30 | 1452.89 | | | | | |
| | Disc harrow | 138.3 | 22.38 | 1.95 | 43132.30 | 1228.10 | | | | | |
| | Seed drill | 121.52 | 6.05 | 1.94 | 43020.38 | 292.51 | | | | | |

**Table 4 : Calculation of energy input for different farms**

| Crop | Energy input (unit area MJ/ha | AEF | | DAF | | AF | |
|---|---|---|---|---|---|---|---|
| | | Area (ha) | Total energy input (MJ) | Area (ha) | Total energy input (MJ) | Area (ha) | Total energy input (MJ) |
| Paddy | 258 | 70.5 | 18185 | 34.9 | 9004.2 | 16.78 | 4329.2 |
| Soyabean | 190 | 7 | 1330 | 0 | 0 | 45.2 | 8588.0 |
| Sunhemp | 145 | 5 | 725 | 0 | 0 | 0 | 0 |
| Arhar | 131 | 2 | 262 | 2.7 | 353.7 | 6.3 | 825.3 |
| Nizer | 129 | 2 | 258 | 0.5 | 64.5 | 0 | 0 |
| Wheat | 131 | 53.1 | 6956.1 | 47 | 6157 | 23.68 | 3102.1 |
| Gram | 108 | 17 | 1836 | 3.95 | 426.6 | 29.96 | 3235.7 |
| Lentil | 138 | 4 | 552 | 0 | 0 | 3.05 | 420.9 |
| Mustard | 120 | 0.5 | 60 | 0.4 | 48 | 0.78 | 93.6 |
| Berseem | 160 | 6 | 960 | 5 | 800 | 1.3 | 208.0 |
| Coriander | 140 | 2 | 280 | 0 | 0 | | |
| Oat | 138 | 1 | 138 | 3.5 | 483 | 0.9 | 124.2 |
| Moong | 143 | 1 | 143 | 4 | 572 | | |
| Linseed | 149 | 0 | 0 | 1 | 149 | 0.2 | 29.8 |
| Maize H) | 15 | 0 | 0 | 0 | 0 | 6.1 | 91.5 |
| Pea | 110 | 0 | 0 | 0 | 0 | 4.65 | 511.0 |
| Coriander | 149 | 0 | 0 | 0 | 0 | 0.1 | 14.0 |
| Total | | 171.1 | 31689.1 | 102.95 | 18058 | 139 | 21573.3 |

**Table 5 : Optimum power range by Chancellor's model**

| Farm | Total area sown in year (ha) | $W_h$ (MJ/ha) | $W_h$ (h/ha) | $W_h$ (hp-h/ha) | H (hp) |
|---|---|---|---|---|---|
| AEF | 171.1 | 305.88 | 84.97 | 115.60 | 61.75 |
| ADF | 103.0 | 206.38 | 57.33 | 78.00 | 39.34 |
| AF | 139.0 | 239.70 | 66.58 | 90.59 | 49.27 |

cost per hp and timely operations.

**Energy input for different crops :**

Maximum energy input was 18185 and 9004.2 MJ in paddy crop at AEF and DAF, respectively. Soyabean consume maximum energy at AF was 8588 MJ. Total energy input for a year of AEF, DAF and AF was 31689.1, 18058 and 21573.3 MJ, respectively as shown in Table 4.

Table 5 shows optimum size of tractor for different farms by Chancellor's Model. The optimum horse power requirement for AEF come out to be 61.75 hp. As per availability of tractor in the market, the optimum power (61.75 hp) was divided into two tractors of 35 and 30 hp or a single tractor of approximately 60 hp was recommended. In the similar manner, one tractor of 40 hp was sufficient to obtain 39.34 hp for the DAF, and, one tractor of 50 hp may be recommended for AF for obtained hp of 49.27.

The values obtained for the optimum size of the tractor by Hunt's method are higher than the values obtained by Chancellor's method because Chancellor had not considered transportation operation. Since, the tractor is a versatile prime mover which can be used for field operation, transportations of implements and farm produce as well as for other haulage purpose. Therefore, the values obtained by Hunt's formula are more practical.

**Optimum field capacity :**

The optimum field capacity for AEF, when labour cost is Rs. 100 came out to be 0.349, 1.068, 1.173, 1.220 ha/h for plough, cultivator, disk harrow, and seed drill, respectively whereas, when labour cost is Rs. 180 *i.e.*, operator cost and labour cost, the value of optimum field capacity was increased to 0.459, 1.400, 1.524, 1.616 ha/h for plough, cultivator, disk harrow and seed drill, respectively. The optimum field capacity for DAF, when labour cost is Rs. 100 came out to be 0.229, 0.818, 0.897 and 0.996 ha/h for plough, cultivator, disk harrow, and seed drill, respectively whereas, when labour cost is Rs. 180 *i.e.*, operator cost and labour cost, the value of optimum field capacity was increased to 0.30319, 1.07788, 1.17287 and 1.32429 ha/h for plough, cultivator, disk harrow, and seed drill, respectively. The optimum field capacity for AF, when labour cost is Rs. 100 came out to be 0.328, 1.144, 1.247 and 1.604 ha/h for plough, cultivator, disk harrow and seed drill, respectively whereas, when labour cost is Rs. 180 *i.e.*, operator cost and labour cost, the value of optimum field capacity was increased to 0.420, 1.404, 1.523 and 1.982 ha/h for plough, cultivator, disk harrow and seed drill, respectively (Table 6).

The machinery costs per hectare increase with machine size but larger machine decreases the labour cost by completing the work more quickly. The optimum field capacity is increased, when additional labour is used. For plough the optimum field capacity was minimum, whereas, optimum field capacity was found

Table 6 : Calculation of optimum field capacity

| | Implements | Purchase price of machine (in Rs.) | $C_a$ (Rs. / yr) | Th (Rs. / h) | $K_p$ (Rs. h / ha) | Area (ha) | $\left(\frac{A}{Cos K_p}\right)$ | Yield (To/ha) | Crop value (in Rs.) | $K_t AYV / \lambda_0 100 P_{wd}$ | $C_{opt}$ ($L_c$ = 100) | $C_{opt}$ ($L_c$ = 180) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AEF | Plough | 20000 | 2808.76 | 2.8087 | 546806.65 | 85.50 | 0.0011 | 1.3860 | 111730.03 | 6.68296 | 0.349 | 0.459 |
| | Cultivator | 22000 | 3089.64 | 3.0896 | 119047.62 | 171.1 | 0.0102 | 1.5929 | 64341.19 | 8.43108 | 1.068 | 1.400 |
| | Disc harrow | 56000 | 7864.53 | 7.8645 | 102941.18 | 171.1 | 0.0118 | 1.5929 | 64341.19 | 8.43108 | 1.173 | 1.524 |
| | seed drill | 26000 | 3651.39 | 3.6513 | 51020.41 | 100.6 | 0.0140 | 1.5712 | 31271.31 | 2.37659 | 1.220 | 1.616 |
| DAF | Plough | 22000 | 3089.64 | 3.0896 | 546806.65 | 37.60 | 0.00049 | 1.0688 | 24095.35 | 4.65562 | 0.229 | 0.30319 |
| | Cultivator | 20000 | 2808.76 | 2.8087 | 119047.62 | 102.9 | 0.00616 | 1.3287 | 8925.85 | 5.87025 | 0.818 | 1.07788 |
| | Disc harrow | 52000 | 7302.78 | 7.3027 | 102941.18 | 102.9 | 0.00712 | 1.3287 | 8925.85 | 5.87025 | 0.897 | 1.17287 |
| | seed drill | 24000 | 3370.51 | 3.3705 | 51020.41 | 68.05 | 0.00950 | 1.4266 | 2760.18 | 1.28833 | 0.996 | 1.32429 |
| AF | Plough | 20500 | 2878.98 | 2.8789 | 546806.65 | 66.08 | 0.0008 | 1.4737 | 47963.54 | 22.45708 | 0.328 | 0.420 |
| | Cultivator | 18000 | 2527.89 | 2.5278 | 119047.62 | 138.3 | 0.0082 | 1.9506 | 43132.30 | 55.94093 | 1.144 | 1.404 |
| | Disc harrow | 48000 | 6741.03 | 6.7410 | 102941.18 | 138.3 | 0.0095 | 1.9506 | 43132.30 | 55.94093 | 1.247 | 1.523 |
| | seed drill | 21000 | 2949.20 | 2.9492 | 51020.41 | 121.5 | 0.0169 | 1.9411 | 43020.38 | 48.78842 | 1.604 | 1.982 |

**Table 7: Matching equipment width with optimum field capacity**

| Farm | Name of implements | Speed (km/h) | Optimum field capacity (ha/h) | | Width | |
|---|---|---|---|---|---|---|
| | | | If $L_c$=100 | If $L_c$=180 | If $L_c$=100 | If $L_c$=180 |
| AEF | Plough | 4 | 0.349 | 0.459 | 0.872 | 1.148 |
| | Cultivator | 4 | 1.068 | 1.400 | 2.670 | 3.500 |
| | Disc harrow | 5 | 1.173 | 1.524 | 2.346 | 3.048 |
| | seed drill | 5 | 1.220 | 1.616 | 2.440 | 3.232 |
| DAF | Plough | 4 | 0.229 | 0.303 | 0.574 | 0.757 |
| | Cultivator | 4 | 0.818 | 1.077 | 2.045 | 2.694 |
| | Disc harrow | 5 | 0.897 | 1.172 | 1.795 | 2.345 |
| | seed drill | 5 | 0.996 | 1.324 | 1.993 | 2.648 |
| AF | Plough | 4 | 0.328 | 0.420 | 0.821 | 1.050 |
| | Cultivator | 4 | 1.144 | 1.404 | 2.862 | 3.511 |
| | Disc harrow | 5 | 1.247 | 1.523 | 2.495 | 3.047 |
| | seed drill | 5 | 1.604 | 1.982 | 3.208 | 3.964 |

to be maximum for seed drill in all the selected farms.

**Matching equipments with optimum field capacity :**

Table 7 shows width of matching implements with optimum field capacity. According to obtained optimum field capacity the suitable matching equipments ranged between 3x30 cm – 4x35 cm, 13 – 17 tyne, 12 – 16 disk and, 11 - 15 tyne for plough, cultivator, disk harrow, seed drill, respectively, for AEF. For DAF it ranged between 2x30 cm – 3x30 cm, 9 – 13 tyne, 8 – 12 disk and, 9 - 13 tyne for plough, cultivator, disk harrow, seed drill, respectively and for AF the suitable matching equipments ranged between 3x30 cm – 3x35 cm, 13 – 17 tyne, 12 – 16 disk and, 15 - 19 tyne for plough, cultivator, disk harrow, seed drill, respectively.

**Conclusion :**

The optimum hp required for AEF was 138.59 hp for which three tractors of 55, 50, 35 hp may be suitable for performing all operations within stipulated time. The optimum field capacity for AEF ranged 0.349 to 0.459 ha/h for plough, 1.068 to 1.400 ha/h for cultivator, 1.173 – 1.524 ha/h for disk harrow, 1.220 – 1.616 ha/h for seed drill, when labour cost varied between Rs. 100 -180.

The optimum hp required for DAF is 101.19 hp for which two tractors of 55, 50 hp may be suitable for performing all operations within stipulated time. The optimum field capacity for DAF ranged 0.220 to 0.303 for plough, 0.818 to 1.077 for cultivator, 0.897 – 1.172 for disk harrow, 0.996 – 1.324 for seed drill, when labour cost varied between Rs. 100 and 180.

Three tractors of 35, 45 and 50 hp may be suitable for performing all operations within stipulated time for AF to obtained 124.92 hp. The optimum field capacity for AF ranged between 0.328 to 0.420 for plough, 1.144 to 1.404 for cultivator, 1.247 – 1.523 for disk harrow, 1.604 – 1.982 for seed drill, when labour cost varied between Rs. 100 -180.

For all the three selected farms, the size of plough ranged between 2bottom – 30cm to 4bottom – 35cm, the size of cultivator varied between 9 – 17 tyne, the size of disk harrow varied between 8 – 16 disk, and the size of seed drill varied between 9 – 19 tyne.

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