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Determining the Field Performance and Cost Analysis of Walk Behind Type Semi-Automatic Hand Feed Vegetable Transplanter

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Abstract: This study was carried out to determine field performance of walk behind type semi-automatic hand feed vegetable transplanter with one row. Experiments were conducted in region of Menderes, Bayındır, Torbalı and Çeşme in İzmir. During the experiments, walk behind type semi-automatic hand feed vegetable transplanter with one row (WBM) was compared with tractor mounted semi-automatic hand feed transplanter with three-row (TMM) and hand planting (CP) widely used in the regions aforementioned above. Plant spacing, depth of planting and holding force to soil of tomato and pepper seedlings planted with WBM, TMM and CP were measured and take-root rates of these seedlings were calculated. In addition to field capacity of WBM, TMM and CP, total cost analysis of WBM, TMM and CP were comparatively given with fuel consumption of WBM and TMM.
Key words: Walk behind type planter, performance and cost analysis

INTRODUCTION

Turkey provides an opportunity to grow many fruits and vegetables with its favorable climate characteristics and fertile agricultural lands. Some vegetables (tomatoes, aubergines, cabbage, etc.) and tobacco are multiplied beforehand in seedbed. In Turkey, mostly hand planting technique is used. In the hand planting of the seedlings, first the rows are drawn, the pits are opened, the seedlings are placed in the pits, the roots are covered with soil and the water is given and pressed. In hand planting of seedlings, one worker can plant 6 seedlings per minute and 360 seedlings per hour. In the planting with the machine, the work efficiency is 5-6 times more than the manual planting. The mechanization of the planting of seedlings facilitates the work of the workers, reduces the hand labor, increases the productivity of the work (Önal, 2017). Hand planting is a time consuming and exhausting process that can be done in small areas. Because only 6 seedlings can be planted per minute and during the work they are continuously leaning (Orel and Acar, 2012). 43-48 seedlings can be planted per minute with the production of large areas using seedling planting machines and the reduction of human labor rate (Gökçebay, 1986); (Orel and Acar, 2012) (Ülger et al., 1996).

Countries like U.S.A., China, Holland, Japan and Canada is transplanting the vegetable seedlings by using semi- automatic or fully automatic transplanters. Both feeding and metering are done mechanically in fully automatic transplanters, wheras in semi-automatic transplanters feeding is done manually and metering is done mechanically (Kavitha and Duriasamy, 2007). According to Tsuga (2000), fully automatic transplanters are costly as compared to semi automatic type transplanters and the minimum economical area for using automatic transplanters is 8.21 hectares.

Kumar and Tripathi (2016), reported that plant population was found less by machine transplanting while the average plant height, number of branches per plant, plant mortality, yield/m^2, seedling missing,

and leaf area index was found more by machine transplanting and also time saving, labour saving, less cost of operation were achieved in machine transplanting as compare to manual transplanting.

The purpose of the study is to determine the field performance and cost analysis of walk behind type semi-automatic hand feed vegetable transplanter with one row. For this reason, this machine was compared to tractor mounted semi-automatic hand feed vegetable transplanter with three-row and hand planting, because these planting methods are widely used in Aegean Region.

MATERIALS and METHODS

This study was carried out in four different regions with three different planting methods. Experiments were conducted in region of Menderes, Bayındır, Torbalı and Çeşme in İzmir. During the experiments, walk behind type semi-automatic hand feed vegetable transplanter with one row (WBM) was compared with tractor mounted semi-automatic hand feed transplanter with three-row (TMM) and hand planting (CP) widely used in the regions aforementioned above. WBM was compared to CP in Menderes, Bayındır and Çeşme, whereas TMM was used in Tire where the region the soil structure resembles the other regions.

Walk behind type semi-automatic hand-feed vegetable transplanter with one row is an imported machine. It has a gasoline engine with 1.85 kW and controlled by one person. Track width and underbeam clearance of WBM could adjust. So, it can work on greenhouses and small areas, effectively.

Tractor mounted semi-automatic hand feed vegetable transplanter with three-row is an imported machine, too. It has three adjustable row. During the planting, three people for planting and one tractor operator must be assigned. Furthermore, a tractor must be used for planting. Because of TMM's working width, it is used for large fields. It is very important for the cost analysis.

Hand planting is widely used for small area. Planting quality depends on labor's experience. One person's labor cost for hand planting with in Aegean Region is between 8 ₺/h and 7₺/h.

As aforementioned above, the purpose of the study is to determine field performance and cost analysis for planting. Within this scope, the method of this study divides into two section.

Field performance tests

First section is field performance tests. Determination of plant spacing, plant depth, holding force to soil and take-root rate of seedlings was done according to Principles and Methods of Agricultural Machinery Tests for agricultural machines (Anonymous, 2006) which were used in Turkey.

For determination of plant spacing's uniformity, all spacing in each row are measured. Coefficient of Variance (%) is calculated for each row. Average CV (%) of all rows is evaluated according to Table 1. As seen on the Table 1, avarage CV (%) of all rows must be less than 20%.

Table 1. Evaluation criteria of plant spacing's uniformity for transplanters

% CV	Evaluation
≤ 5	Very good
5.1 – 10	Good
10.1 – 15	Moderate
15.1 – 20	Acceptable
> 20	Inappropriate

For determination of plant depth's uniformity, at least twenty seedlings of each row are uprooted and measured the planting depth. Coefficient of Variance (%) of planting depth is calculated for each row's seedlings. Average CV (%) of all rows is evaluated and it must be less than 15%.

For determination of seedlings' holding force to soil, a thread is knitted to random selected seedlings. At least 20 seedlings of each row are pulled vertically with hand dynamometer (Figure 1). The average of holding force is evaluated. If seedling is uprooted by less than 3 N, the machine or methods is inappropriate for planting.

Figure 1. Measurement of holding force with hand dynamometer

For determination of seedlings' take-root rate, planting seedlings are counted during the tests. Seven days after planting, living seedlings are counted. Then, Equation 1 is used. Lower limit of take-root rate for vegetable seedlings is 90%.

$$TRR = \frac{LS}{PS} * 100 \quad (1)$$

TRR : Take root rate (%)

LS : Number of living seedlings

PS : Number of planting seedlings

Cost analysis

The second section is cost analysis. Fuel consumption was measured, besides area capacity, ownership and operating cost were calculated.

As well known, the field efficiency is about waste time on the field. So, waste of time is measured and area capacity is calculated with Equation 2.

$$C_a = \frac{s * w * E_f}{10} \quad (2)$$

C_a : Area capacity (ha h^{-1})

s : Field speed (km h^{-1})

w : Working width (m)

E_f : Field efficiency (decimal)

Cost factors divide into two section. One of them is ownership or fixed costs, the other one is operation or variable costs. Ownership costs consist of depreciation, interest, taxes (T), housing (H) and insurance (Ins) whereas operation costs consist of repair and maintenance, fuel consumption, engine oil consumption and labor costs.

Equation 3, 4 and 5 are used for depreciation, interest and total of taxes, housing and insurance, respectively. For the salvage value, C_N, ASAE standarts (ASAE EP496.3, 2006 (R2011)) were used. Taxes, housing and insurance cost is 2% of purchase price.

$$D = \frac{C_0 - C_N}{N} \quad (3)$$

$$I = \frac{C_0 + C_N}{2} * i \quad (4)$$

$$T + H + Ins = C_0 * 0{,}02 \quad (5)$$

D : Depreciation (₺ $year^{-1}$)

C_0 : Purchase price (₺)

C_N : Salvage value (₺)

N : Machine life (N)

I : Interest rate (decimal)

i : Annual interest rate (decimal)

Equation 6, 7, 8, and 9 are used for repair and maintance, fuel, oil and labor costs, respectively. Repair and maintanence factors and time of machine using values taken from (ASAE D497.7, 2011). Besides the same standart was used for engine oil consumption calculation.

$$C_{rm} = (RF1) * C_0 * \left[\frac{h}{1000}\right]^{(RF2)} \quad (6)$$

$$C_{fuel} = FC * FP \quad (7)$$

$$C_{Oil} = OC * OP * C_a \quad (8)$$

$$C_{labor} = \frac{LP}{C_a} \quad (9)$$

C_{rm} : Repair and maintanence costs (₺)

RF1 and RF2 : Repair and maintanence factors

C_0 : Purchase price (₺)

h : Time of machine using (h)

C_{fuel} : Fuel cost (₺)

FC : Fuel consumption (l ha^{-1})

FP : Fuel price (₺ l^{-1})

C_{oil} : Oil cost (₺)

OC : Oil consumption (l ha^{-1})

OP : Oil price (₺ l^{-1})

C_a : Area capacity (ha h^{-1})

C_{labor} : Labor cost (₺)

LP : Labor price (₺ h^{-1})

Equivalent Cost Analysis (Equation 10) is a simple analysis for comparison two systems. After the calculation, the unit of value is hectare per year. If you have the area of this size, you can use either system A or B. But it must be considered that the work has to be done throughout the year.

$$ECA = \left| \frac{C_{own_A} - C_{own_B}}{C_{op_A} - C_{op_B}} \right| \quad (10)$$

ECA : Equivalent cost analysis (ha year^{-1})

C_{own} : Ownership costs (₺ year^{-1})

C_{op} : Operation costs (₺ ha^{-1})

RESULTS and DISCUSSION

Uniformity of plant spacing

Table 2 shows the average plant spacing (cm) on the row measured at the planting area in four regions and the calculated CV (%) of each row.

Table 2. Plant spacing's uniformity on the tests

Regions	Plantıng Methods	Plant Spacin g (cm)	CV (%)	Evaluatıon
Menderes	WBM	40.69	24.59	Inappropriate
	CP	41.44	9.94	Good
Bayındır	WBM	24.54	17.84	Acceptable
	CP	28.26	11.77	Moderate
Tire	TMM	33.78	31.88	Inappropriate
Çeşme	WBM	50.11	23.43	Inappropriate
	CP	45.69	13.62	Moderate

WBM's plant spacing was adjusted for 35 cm in Menderes. So, it was said that the person who planted by hand should do the planting at a distance of 35 cm. WBM was run two rows whereas hand planting was conducted on a row. After the planting, plant spacing values were measured. Average plant spacing has increased because 13 seedlings have to be planted was not planted on one row with WBM. If all seedlings have to be planted were planted, 38 cm of plant spacing and 6% of CV would achived. There were no seedlings that were planted with hand planting. However, the person who planted can not plant the seedlings 35 cm of plant spacing. Three people who have further experience on planting have planted the seedlings with TMM. It was said that the person who planted by TMM should do the planting at a distance of 35 cm. After the planting, plant spacing of 30.15 cm, 32.46 cm and 38.72 cm were measured and CV of 14.72 %, 27.85 % and 53.06 % of were calculated on three rows. According to these results, it was determined that the skill of the people working in the planting with the TMM is important on plant spacing's uniformity.

Uniformity of plant depth

Table 3 shows the average plant depth (cm) on the row measured at the planting area in four regions and the calculated CV (%) of each row.

Table 3. Plant depth's uniformity on the tests

Regions	Planting Methods	Plant Depth (cm)	CV (%)	Evaluation
Menderes	WBM	7.35	5.75	Adequate
	CP	6.68	6.01	Adequate
Bayındır	WBM	10.08	9.30	Adequate
	CP	9.25	10.35	Adequate
Tire	TMM	9.03	6.57	Adequate
Çeşme	WBM	6.50	16.28	Inadequate
	CP	8.67	6.66	Adequate

The uniformity of the plant depth is the desired level in the experiments performed with three different planting methods seedling machines at the three regions except Çeşme. WBM's plant depth is higher and its plant depth's uniformity is better than CP's in Menderes and Bayındır. According the results, WBM is inappropriate for planting in Çeşme. Yet, there are some reasons of inappropriate planting depth uniformity. Seedbed preperation is not proper for WBM and WBM operator have not enough experience to run the machine.

Seedlings' holding force to soil

Table 4 shows the seedlings' minimum and maximum holding force to soil (N) on the row measured at the planting area in four regions and evaluation of machines and methods.

The seedlings' holding force to soil is the desired level in the experiments performed with three different planting methods seedling machines at the three regions except Çeşme. Three people weighing 60 kg, 60 kg and 58 kg hold 25 kg, 30 kg and 25 kg extra weight for better compacting for planting with TMM, respectively. According the results, WBM is inappropriate for planting in Çeşme as unifromity planting depth's evaluation. The same reasons have effected seedlings' holding force to soil.

Table 4. Evaluation of seedlings' holding force to soil

Regions	Planting Methods	Holding Force (N)		Evaluation
		Min.	Max.	
Menderes	WBM	3.1	4.9	Adequate
	CP	2.9	4.6	Inadequate
Bayındır	WBM	6.4	10.6	Adequate
	CP	5.4	9.1	Adequate
Tire	1st row of TMM	8.6	11.7	Adequate
	2nd row of TMM	10.7	15.6	Adequate
	3rd row of TMM	8.6	12.2	Adequate
Çeşme	WBM	1.9	5.3	Inadequate
	CP	5.1	8.1	Adequate

Seedlings' take-root rate

Table 5 shows the seedlings' take root rate in four regions and evaluation of machines and methods.

Table 5. Evaluation of seedlings' take-root rate

Regions	Planting Methods	Take root rate of seedlings (%)	Evaluation
Menderes	WBM	92.0	Adequate
	CP	99.0	Adequate
Bayındır	WBM	95.9	Adequate
	CP	96.3	Adequate
Tire	1st row of TMM	96.4	Adequate
	2nd row of TMM	95.7	Adequate
	3rd row of TMM	98.0	Adequate
Çeşme	Because of no irrigation after planting, take root rate of seedlings not measured.		

According the results of experiments conducted in Menderes, Bayındır and Tire, all planting methods are adequate with regards to take root rate of seedlings due to at least 92% take root rate. Take root rate of seedlings not measured since seedlings are not watered after planting.

Area capacity and fuel consumption

Table 6 shows the seedlings' minimum and maximum holding force to soil (N) on the row measured at the planting area in four regions and evaluation of machines and methods.

Table 6. Area capacity and fuel consumption* of planting methods

Regions	Planting Methods	Area Capacity (ha h^{-1})	Fuel Consumption (l ha^{-1})
Menderes	WBM	0.049	6.89
	CP	0.014	
Bayındır	WBM	0.032	9.71
	CP	0.012	
Tire	TMM	0.112	11.28
Çeşme	WBM	0.034	11.33
	CP	0.028	

*The fuel type of WBM is gasoline while TMM's is diesel.

According to calculation, TMM have the best area capacity. But its fuel consumption is not as good as its area capacity. Due to these outcomes, the cost analysis must be done and the choice of method should be made according to cost analysis.

Cost analysis

Table 7 shows total ownership and operating costs of planting methods depanding on the results of experiment.

Table 7. The cost analysis of planting methods

Planting Methods	Total Ownership Cost (₺ $year^{-1}$)	Total Operating Cost (₺ ha^{-1})
WBM	5562	263
TMM + Tractor	11439	377
CP	0	413

Tractor's ownership cost must be considered while the cost of TMM have been calculated. Planting can be done for 40 days in these regions. So, 40-day ownership cost have been added to TMM's cost. The purchase price of WBM, TMM and tractor are 30 000 ₺, 54 000 ₺ and 65 000 ₺, respectively.

Equivalent cost analysis

Table 8 and Table 9 show equilavent cost analysis for CP versus WBM and CP versus TMM, respectively.

Table 8. Equilavent cost analysis for CP and WBM

Choice to be Made	Planting Area per Year (ha $year^{-1}$)	Area Capacity (ha h^{-1})
CP	<37.14	0.018
WBM	>37.14	0.039
CP or WBM	=37.14	

Table 9. Equilavent cost analysis for CP and TMM

Choice to be Made	Planting Area per Year (ha year^{-1})	Area Capacity (ha h^{-1})
CP	<320.62	0.018
TMM	>320.62	0.112
CP or TMM	=320.62	

According to this analysis, two planting methods can be comparable. If the choice between WBM and CP will be made, Table 8 will assist in selection. If planting area is smaller than 37.14 ha year^{-1} for planting, CP have to be choosen. If not, WBM have to be choosen. The same perspective for choice between TMM and CP can be applicable according to Table 9. It should not be forgotten that it is necessary to plant 365 days a year for use equilavent cost analysis method.

Total cost analysis

Table 10 shows the total cost of planting methods with Turkish Liras per year. According to table, if the planting area is smaller than 11.93 ha year^{-1} or between 15.45 ha year^{-1} and 44.89 ha year^{-1}, CP must be choosen. If the planting area is between 11.93 ha year^{-1} and 15.44 ha year^{-1}, WBM must be choosen. Otherwise, TMM must be choosen.

Table 10. Total cost analysis for different planting areas

Planting Area per Year (ha year^{-1})	₺ year^{-1}		
	WBM	TMM	CP
1	5580	11447	56
11.93	7992	12636	7992
15.44	9628	13443	13374
15.45	15196	13445	13391
44.89	51054	28379	113048
44.90	51070	39824	113098

CONCLUSIONS

In consequences of observations during the test and calculations;

- Transplanters must be used for vegetable planting instead of hand planting and have as much as possible rows,
- Proper soil preparation for planting is important for success of transplanters,
- Planting workers' performances were gradually decrease in time. For this reason, a study about planting workers' performance in a day have planned and it will be started next year.
- For total cost analysis, lots of variable which are varied depend on time and working people have been used as field efficiency, purchase price, annual interest rate, fuel, oil and labor price. Thus, using a software which can be used for choice of method will be functional for farm management.

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