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Economics of drip irrigation for apple (*Malus domestica*) orchards in Turkey

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Abstract Agricultural growers need investment and cost guidelines for drip irrigation to evaluate the economics of getting crops into production as quickly as possible and to avoid the impact of drought during the productive life of apple (*Malus domestica*). The benefits of irrigation may include: better apple quality, earlier crop production, greater yields, efficient nutrient distribution, less plant stress, reduced yield variability, and improved crop quality. This research was conducted to help Turkish apple growers evaluate the financial investment in drip irrigation systems. Net present value (NPV) criterion was used to determine the discounted break-even investment results from published responses to drip irrigation systems. Growers with typical drip irrigation systems can expect an initial investment of US$1415 per ha when the orchard blocks are c. 5 ha in size. Analysis of survey findings indicate that net present values were US$2584 for 'Granny Smith' and US$909 for 'Golden Delicious', respectively, after an initial investment of US$1415 per ha. On the other hand, the analysis indicates that in present value terms, a grower could spend up to US$3999 for 'Granny Smith' and US$2324 for 'Golden Delicious' per ha for drip irrigation systems and still break even.

Keywords apple orchards; drip irrigation; economics; investment decisions

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INTRODUCTION

The use of modern irrigation systems provides opportunities for producers to reap larger benefits in comparison with the investment in irrigation systems. When controlled irrigation is applied with fertiliser, pesticides, and other technologies, higher productivity and income can be obtained (Carruthers & Clark 1983).

On the other hand, the choice of an irrigation system is an issue for the producer. The choice of the irrigation system is affected by many factors such as water source, land characteristics, irrigation period, plant and soil type, and potential irrigation equipment.

Turkey has an important place in the world's apple production, having a 3.4% share of total apple production. As one of the leading production areas, the Bursa province produces 7.2% of total apple production in Turkey. The Inegöl district within the Bursa province accounts for 49% of the total apple crop.

The research area is a region with limited surface and subsurface water resources. Water is the most dominant limiting factor for crop diversification and production. Partly because of urbanisation and increasing population, the competition for limited water resources for domestic and industrial needs is increasing significantly. Therefore, it is essential to formulate and invest in an efficient, reliable, and economically viable irrigation management strategy to irrigate more land area with existing water resources.

Sizing drip irrigation systems is critical to the productivity of apple trees. Drip systems must be designed to deliver enough water to meet maximum crop demand (Wolfe 1995). The basic concept of drip irrigation is to prevent moisture stress by maintaining high soil moisture (all the water that the soil can hold after drainage) in 20–40% of the root system area. A definite advantage of drip irrigation is that it does not interfere with spraying, mowing, and other cultural practices (Worthington 1994). In general, furrow and sprinkler are the most common methods of water delivery in the study region. However, drip irrigation is becoming more popular because of numerous advantages over other methods. The benefits of drip irrigation may include: better crop survival, earlier harvest, greater yields, more efficient distribution of nutrients, less plant stress, reduced yield variability, and improved crop quality (Doorenbos & Kassam 1979).

This study will assist apple growers in making investment decisions by estimating fixed and annual operating costs and expected returns from a drip irrigation system. To realise these benefits, the research objective was to gather information from growers, plant scientists, and published reports to establish a methodology for growers to evaluate the economics of irrigation. Additionally, the study was carried out to examine the effect of irrigation, total cost and net returns to apple production to assess the economics of the drip irrigation system in the study region.

MATERIALS AND METHODS

In this study the financial feasibility of the drip irrigation system was investigated in the Inegöl district of Bursa province where irrigation systems could be converted from conventional to drip irrigation systems for apple production. Therefore the analysis was based on the available surface irrigation system.

Data required for economic analysis were collected from 47 sample farms by field survey along with information available from the Department of Agricultural Engineering and Horticulture, Agricultural Faculty, Uludag University. In the surveyed farms, the average area devoted to apple production was 5.14 ha.

Four different apple cultivars are widely grown in the area of interest. Table 1 lists these apple cultivars according to their harvest time (Yücel & Bektöre 1986).

'Golden Delicious' is an early apple cultivar and 'Granny Smith' is the latest apple cultivar, which presents a price advantage over other apple cultivars. According to the farm survey, 21.5% of the apples grown are 'Granny Smith' and 30.7% are 'Golden Delicious'. The economic analyses presented in this study are based on these two apple cultivars.

Prices for 2002, used along with a 10-year economic apple life, were considered for investment, operating cost, and the investment benefits. Gross incomes of the investment in drip irrigation were estimated based on the observed real yield increases between 1993 and 2002 and calculations were made for each of the two apple cultivars previously described. All financial values were converted to 2002 US$.

In the financial analysis the net present value (NPV) criterion was used:

NPV = PV of benefits – PV of costs (Beierlein et al. 1986).

This equation can be rewritten as (Erkuş & Rehber 1998):

$$NPV = \sum_{t=0}^{n} \frac{R_t}{(1+f)^t}$$

where: NPV= net present value; R = net cash flows; f = interest rate; and t = year (from zero to n).

In addition, four break-even prices were estimated considering total operating costs, total costs, total costs plus depreciation on investment, and total investment plus opportunity costs. Finally, annual break-even yield was estimated based on 2002 market prices.

RESULTS AND DISCUSSION

Drip irrigation system investment

Modern agricultural technology has created opportunities for crop production which markedly increase the return on investment in irrigation. However, a controlled water supply produces the

Table 1 Apple (*Malus domestica*) cultivars according to their harvest time.

Cultivars	Harvest time
Golden Delicious	13–27 Sep
Starking Delicious	13–27 Sep
Starkrimson Delicious	15 Sep–7 Oct
Granny Smith	10–30 Oct

highest yield response when used in conjunction with other inputs such as cultivar, fertiliser, crop protection from pests and disease, high quality land preparation, and timely weeding and harvesting (Carruthers & Clark 1983). In addition to this, drip irrigation offers many unique agronomic, agro-technical, and economic advantages (Nakayama & Bucks 1986).

The main determinants of an irrigation system are power source and ultimately the amount of capital investment depending on (Yazgan et al. 2000): (1) distance from desired use, elevation differential, and availability of water source; (2) type of crop and soil; (3) hectares to be irrigated and frequency of application; and (4) existing farm equipment.

Total investment costs and the main items for drip irrigation of apple orchards are presented in Table 2. These financial data cover a new 5.14 ha block of land with drip-line distribution and an available electrical power source. Many of the apple growers did not know how long the drip-line would last; the economic life for the drip-line system was thought to be 10 years. Investment costs per ha used were typical. The power source, filters, valves, main pipe, manifold, drip-line, and other fittings are the main items (Table 2).

Operating costs

Annual operating costs will vary depending upon the frequency of irrigation, amount of water applied per irrigation, irrigation water cost, number of irrigated zones, and the degree of mechanisation. Variable and fixed costs were taken into account to calculate irrigation costs (Rehber & Çetin 1998).

In general, the variable costs are proportional to the amount of water pumped. It can be said that one of the important variable costs is labour, which is for monitoring, repair, maintenance, and any required hose or pipe moving. Fixed costs occur regardless of water quantity used and generally consist of depreciation and interest costs based upon the amount of investment.

Annual operating costs for drip irrigation are presented in Table 3 as the average of the 10-year period. The power source item includes electric, gas, or diesel fuel expenses. Repair costs have been reported as nominal in earlier years. Labour costs cover leak detection. The labour cost of repair is small for plastic inserts or plugs compared to the labour required in routine checking of the system.

Fertigation

Fertigation allows nutrients dissolved in water to be more effectively delivered to the root zone. Proper fertilisation, irrigation, and good orchard management controls the size, sugar content, and quality of the fruit (Gregory 1988). This is an additional potential benefit of drip irrigation that may impact apple yield, quality, and growth. The fertigation costs will vary depending upon whether fertigation is used for supplemental or all nutrient applications. Those farms that applied fertiliser through irrigation felt that they must purchase water soluble nutrients and closely monitor the system for any leaks or blowouts (Cuykendall et al. 1999).

Yield response

Crop growth is dependent upon water which is generally derived from soil moisture reserves. These reserves may be built up by rain or irrigation. To achieve maximum plant growth, soil moisture levels should fluctuate only within a narrow range between field capacity and permanent wilting point (Carruthers & Clark 1983). However, drought in

Table 2 Investment costs in a drip irrigation equipment for apple (*Malus domestica*) orchards (for a 5.14 ha parcel size).

Equipment	(US$)
10.0 HP electric pump	1630
Full filter system	1085
Diam. 75 mm Polyethylene, 6 Atm pipe	1150
Fittings, valves and clamps	775
Diam. 16–75 mm, 4 litres/h drip line	950
Trencher	610
Labour	600
Other (equipment transportation)	475
Total	7275
Per ha	1415

Table 3 Annual operating costs (per ha) for drip irrigation (US$).

Power source	46
Repairs	84
Labour	200
Additional fertilisers, pesticide, and application cost	265
Additional product harvesting, hauling and marketing*	–
Irrigation water cost	55
Total	650
Per ha	126

*Used harvest and hauling cost of apple (*Malus domestica*) production is US$42.50/t and added to the annual cost.

apple production will reduce the yield if water becomes limited in the root zone. In recent years the use of drip irrigation has become more important for agricultural production because of reduced water resources.

Table 4 shows apple yields of 'Granny Smith' and 'Golden Delicious' affected by drip irrigation and surface irrigation methods. In each year there was a positive effect of drip irrigation on apple yield (Table 4). Finally, the overall yield response indicated that average yield increased 2.955 t/ha for 'Granny Smith' and 2.595 t/ha for 'Golden Delicious'.

The gross return on investment income was estimated by considering the yield increases after the establishment of the drip irrigation systems over the whole economic life. The additional operating costs in response to the yield increases have been estimated and differences between the value of yield

Table 4 Effect on drip irrigation on annual yields of apple (*Malus domestica*) (t/ha).

Years	1	2	3	4	5	6	7	8	9	10
Granny Smith										
Surface irr.	17.405	15.516	16.910	15.317	17.508	15.712	17.780	15.646	16.845	15.705
Drip irr.	20.815	18.967	19.705	18.910	19.766	18.947	20.745	17.843	19.205	18.869
Yield incr.	3.410	3.451	2.915	3.593	2.258	3.235	2.965	2.197	2.360	3.164
Golden Delicious										
Surface irr.	12.490	13.560	12.740	12.935	13.145	12.675	13.400	11.905	12.780	13.080
Drip irr.	15.950	16.700	14.818	15.040	16.125	15.106	16.700	13.945	14.760	15.217
Yield incr.	3.460	3.140	2.078	2.405	2.980	2.431	3.300	2.040	1.980	2.137

Table 5 Net present value (NPV) of the installation of drip irrigation.

Years	Inc. yield (t/ha) (1)	Gross income (US$) (1)xprice*	Additional costs (US$)	Net income (US$)	10% discount rate	NPV (US$)	Cumulative NPV (US$)
Granny Smith							
						–1415	–1415
1	3.410	955	271	684	1.00	684	–731
2	3.451	966	273	693	0.91	631	–100
3	2.915	816	250	566	0.83	470	370
4	3.593	1006	279	727	0.75	545	915
5	2.258	632	222	410	0.68	279	1194
6	3.235	906	264	642	0.62	398	1592
7	2.965	830	252	578	0.56	324	1916
8	2.197	615	220	395	0.51	201	2117
9	2.360	661	224	434	0.47	204	2321
10	3.164	886	261	625	0.42	263	2584
Total						2584	–
Golden Delicious							
1	3.460	761	273	488	1.00	488	–927
2	3.140	691	259	432	0.91	393	–534
3	2.078	457	214	243	0.83	202	–332
4	2.105	463	215	248	0.75	186	–146
5	2.980	656	252	404	0.68	275	129
6	2.431	535	229	306	0.62	190	319
7	3.300	726	266	460	0.56	258	577
8	2.040	449	213	236	0.51	120	697
9	1.980	436	210	226	0.47	106	803
10	2.137	470	217	253	0.42	106	909
Total						909	–

*Price of 1 kg apple (*Malus domestica*) US$0.28 and US$0.22 respectively.

increase and the additional cost are estimated for each year and are presented in Table 5 as net income in the fourth column.

Economics of drip irrigation

NPV has been used in the financial analysis. Net present value shows the difference between the present value of benefits and the present value of costs. The index of profitability of the NPV technique is to accept all projects that have a positive net present value. Briefly, discounted benefits must numerically exceed discounted costs (Osburn & Schneeberger 1983). A 10% discount factor (8% interest + 2% risk) was considered as the opportunity cost of capital.

The discount factor expresses the conversion of a future value to a present value by adjusting the future value by its opportunity cost to reflect the time before it is received (Beierlein et al. 1986).

The present value was estimated as US$2584 for 'Granny Smith' and US$909 for 'Golden Delicious' after an initial investment of US$1415/ha. If a loan was obtained to finance the drip system, repayment of the investment would start in the third year for 'Granny Smith' and fifth year for 'Golden Delicious'.

Four break-even prices have been estimated to indicate the sensitivity of the investment to different cost items. Table 6 shows the break-even selling price for different levels of enterprise costs. The first break-even price (US$ 0.08/kg for 'Granny Smith.' and US$ 0.09/kg for 'Golden Delicious') is what is necessary to cover total operating costs. The second break-even price is necessary to cover total cash costs, assuming no interest on outstanding loans or land rent is being paid. If other cash costs exist on an individual's orchard, these costs must be identified and included in the cash cost break-even calculations (Hinman & Griffin 1986). The third break-even price is that of total cash cost, plus depreciation on investment. The fourth break-even price is the price farmers must receive to earn back their establishment costs along with the opportunity costs they forego from their investment. Only if this break-even price is received will owner-operators be able to cover all out-of-pocket expenses, plus realise a fair return to their management, to equity capital invested in equipment and to operating capital. Failure to receive this break-even price means that owner-operators will not obtain a return on management and capital contributions equivalent to what could be earned in an alternative use. Realisation of a price above the break-even level means that in addition to covering all cash and opportunity costs, the operator will get a return to the risk assumed in taking on the enterprise. Break-even selling prices for apple, calculated according to average yield increase per hectare for 10 years, are US$0.18 and US$0.19 for 'Granny Smith' and 'Golden Delicious' respectively (Table 6).

CONCLUSIONS

The results of the study indicate that all growers reported positive results with the drip irrigation system. Drip irrigation is profitable for both 'Granny Smith' and 'Golden Delicious' despite the relatively high initial investment. The NPV analysis showed that drip irrigation would be a profitable investment

Table 6 Break-even selling price for apple (*Malus domestica*) production under drip irrigation (with increased yield). (All costs/prices are in US$.)

	Granny Smith 2955 t/ha		Golden Delicious 2595 t/ha	
	Costs	Break-even price	Costs	Break-even price
(1) Operating cost	252	0.08	236	0.09
plus insurance (0.2%)	3		3	
Tax (3%)*	25		17	
(2) Total cash cost	280	0.09	256	0.10
plus depreciation (10%)	142		142	
(3) Total cash cost plus deprec.	422	0.14	398	0.15
plus interest (8%)	113		113	
(4) Total cost	535	0.18	511	0.19

*Tax is 3% of gross receipts.

because of the high market price of apples. The production system reached a discounted payback in the third year for 'Granny Smith' and fifth year for 'Golden Delicious' after investment. The break-even selling prices for apple were calculated as US$0.18 /kg for 'Granny Smith' and US$0.19/kg for 'Golden Delicious' according to the NPV analysis in the study area.

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