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Estimation of resource use efficiency in clonal and seedling rootstocks of high-density apple in Himachal Pradesh

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ABSTRACT

The present study has made an attempt to estimate the resource use efficiency of clonal rootstock and seedling rootstock of high density planting (HDP) apple by selecting 200 farmers from Mandi, Kullu and Shimla districts of Himachal Pradesh. The study revealed that all the explanatory variables considered together in clonal rootstock of apple explained about 90.20 percent to 92.80 percent of the total variations in gross returns in selected districts of Himachal Pradesh. In case of fertilizer cost variable fertilizer cost (X_6), it had positive elasticity values in all the selected districts (0.17, 0.25 and 0.09) and was significant which meant that use of fertilizer had enhanced the production and quality of apple and finally the gross returns by 12 percent in overall. All the explanatory variables considered together in seedling rootstock explained about 92.90 percent to 93.60 percent of total variations in gross returns in selected districts of Himachal Pradesh. In case of fertilizer cost variable (X_6), it had negative elasticity values in all selected districts (-0.11, -0.08 and -0.46) and was significant which meant that although the use of fertilizer had enhanced the production and quality of apple, but had negatively impacted the gross returns due to their higher costs and same scenario was followed in chemical cost variable pesticide cost (X_7).

Key words: HDP apple, clonal rootstock, seedling rootstock, resource use efficiency and returns to scale.

INTRODUCTION

High Density Plantation (HDP) apple is playing a significant role in improving the apple economy of Himachal Pradesh. It mainly refers to the planting of an increased number of plants per unit area of land at close spacing. This is achieved by using suitable scion varieties grafted on to dwarfing rootstocks to obtain maximum fruit quality, crop yield and profit per unit of tree volume without impairing soil fertility. So, HDP apple is obtained using dwarfing rootstocks (M9, M4, M7, and M106) and several apple varieties used for HDP are Jeromine, Redvelox, Redcap Valtod, Scarlet Spur-II, Superchief, Gale Gala, Redlum Gala, and Auvil Early Fuji (Bakhtaver *et al.,* 2). Further, it facilitates better utilization of available resources like solar radiation, land, water, labour, dwarf rootstocks, spur cultivars, human skills etc. and easy picking with less injuries to the fruit which result in better post-harvest life during storage. These orchards also have better acceptance of modern input saving fruit production techniques such as drip irrigation, fertigation, mechanical harvesting and mechanical pruning (Hassan *et al.,* 7).

These HDP apple orchards are more precocious thus result in earlier returns on investment, which is the key for investment (Wani *et al.,* 17). It results in higher productivity due to increase in bearing surface per unit area. Since, apple growers move to higher-density systems using more dwarfing rootstocks, tree support becomes more of a concern. Most of the very dwarfing rootstocks (Especially clonal rootstocks) need support (Trellis system which is a post-and-wire system supporting high-density plantings, creating a “fruiting wall” for better light, easier management, and higher yields using dwarfing rootstock *i.e.* M9), but there are somewhat more vigorous rootstocks (Seedling rootstocks) that can perform well without support under certain conditions. Also, th technological advancement in HDP apple has also helped in dealing with impacts of climate change as the installed structures (Trellis system, antihail nets etc.) have shown better adaptability towards the harmful effects of hailstorms (Rani *et al.,* 10; Rani and Prasher, 11; Rani and Prasher, 12; Sharma, 14). The present crop yield of traditional Apple is only 20 MT/ha, while the HDP apple yields about 40 to 60 MT/ha (Wani *et al.,* 17). In economics, it becomes more evident to study the cost and returns of these orchards to obtain the resource use efficiency to know weather the apple orchardists are using their resources efficiently or not? The resource use efficiency is generally defined as to the achievement of optimum output so as to maximize profit of these orchards. To study the optimality condition of this efficiency can be developed in terms of single output-multi-input production function such

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as Cobb-Douglas production function (Barwal *et al.,* 3; Chand *et al.,* 4). The recommended optimization principle for resource allocation is to use a resource more until its marginal value product (MVP) equals to its marginal cost (Badiu *et al.,* 1; Guleria *et al.,* 6). Generally, by comparing the marginal productivities of various factors of production with prevailing market prices of inputs, the behaviour of HDP apple growers is evaluated. So, the present study has made an attempt to study the optimality condition of this efficiency between clonal rootstock and seedling rootstock of HDP apple to analyze which type of rootstock is more efficient and since, this kind of economic study has not yet been done before in Himachal Pradesh, it will be meaning for future studies too.

MATERIAL AND METHODS

The primary data was collected from 200 farmers from three selected districts of Himachal Pradesh (Mandi (60 farmers), Kullu (70 farmers) and Shimla (70 farmers)) using multi-stage sampling by personally interviewing the farmers in 2022-23 and main reason behind selecting these districts was because HDP apple was prevalent in terms of area as well as production. For calculating resource use efficiency in HDP apple, the role of various variables including technological tools was also taken in HDP apple (Both in clonal & seedling rootstock) to highlight their importance. Cobb-Douglas production function was fitted to analyze the resource use efficiency of HDP apple cultivation for clonal as well as seedling rootstocks. Cobb-Douglas production function was fitted on the basis of higher value of R^2, theoretical plausibility of sign and magnitude of parameters and severity of multicollinearity. The following variables were used in order to determine the factors affecting the gross returns in clonal rootstock and seedling rootstocks of HDP apple:

$$Y = b_0 X_t^{bt} X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} X_6^{b6} X_7^{b7} X_8^{b8}$$

Log-log equation in clonal rootstock of HDP apple was as:

$$\text{Log } Y = \text{Log } b_0 + b_t \log X_t + b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_3 + b_4 \log X_4 + b_5 \log X_5 + b_6 \log X_6 + b_7 \log X_7 + b_8 \log X_8$$

Where, Y is Gross returns (₹/farm), X_t is Trellis installation cost (₹/farm) in case of clonal rootstock (material cost), X_1 is Planting material cost (₹/farm), X_2 is Drip irrigation cost (₹/farm), X_3 is Fencing cost (₹/farm), X_4 is Antihail net and shade net cost (₹/farm), X_5 is FYM cost (₹/farm), X_6 is Fertilizer cost (₹/farm), X_7 is Chemical cost (₹/farm), X_8 is Labour cost (₹/farm) and b_t,$b_1$to b_9 are the elasticity coefficients.

$$\text{Adjusted } R^2 = 1 - (1-R^2) \frac{(n-1)}{(n-k)}$$

In order to evaluate the economic rationale of resource use on different districts, the marginal value products of different resources were calculated by multiplying regression coefficient of given resources with the ratio of geometric mean of gross returns to the geometric mean of given resources. The marginal value product of a particular resource represents the expected addition to the gross returns caused by an addition of one unit of that resource while the values of other inputs are held constant. For estimation of $MVP_{xi,}$ the computational steps followed are as under:

$$MVPxi = bi \frac{\bar{Y}}{\bar{X}_1} (py)$$

RESULTS AND DISCUSSION

The present study examined the resource use efficiency in HDP apple by estimating above mentioned production function and the efficiency co-efficients. The ratio of MVPs (Marginal value products) to their respective prices in case of clonal rootstock was used to estimate the elasticity coefficients, which were found statistically efficient. The perusal of the Table 1 revealed that all the explanatory variables considered together explained about 90.20 percent to 92.80 percent of the total variations in gross returns in selected districts of Himachal Pradesh. The coefficient of multiple determination ( ) was found statistically significant at 91.10 percent in overall. It was also reported that cost of tree support system, drip irrigation system, fencing, antihail and shade net, planting material, FYM, fertilizer, chemicals and labour contributed significantly to the gross returns in clonal rootstock of HDP apple (Doda *et al.,* 5). The elasticity of various explanatory variables was discussed under following sub-heads:

It was also observed from the Table 1 that elasticity of tree support system cost was found positive in Mandi (0.15), Kullu (0.12), Shimla (0.04) and also in overall, which meant that cost of tree support system cost in these districts had positively impacted the gross returns which meant that tree support system was enhancing the production and ultimately the gross returns in clonal rootstock HDP apple. Similar was the case of fencing cost variable (X_2), elasticity values were negative (-0.05, -0.02 and -0.02) and significant which meant that although fencing around the orchard had protected the apple trees from wild animals like monkeys, but it had also caused a burden on the recovery of its cost hence, it had negatively impacted the gross returns from clonal rootstock of apple (If fencing cost increased by one percent, gross returns will decrease by 6 percent in overall). In case of drip irrigation cost (X_1), elasticity values were positive in all districts (0.53, 0.50 and 0.46) and significant which meant that

Table 1: District-wise estimates of Cobb-Douglas production function in clonal rootstock of HDP apple.

Particulars		Mandi	Kullu	Shimla	Overall
Intercept		1.53	1.33	1.48	1.39
(a) Installed systems	1. Tree support system cost (X_t)	0.15* (0.06)	0.12* (0.13)	0.04* (0.01)	0.08* (0.09)
	2. Drip irrigation cost (X_1)	0.53** (0.49)	0.50* (0.27)	0.46*** (1.19)	0.42* (0.22)
	3. Fencing cost (X_2)	-0.05* (0.20)	-0.02* (0.07)	-0.02* (0.17)	-0.06* (0.28)
	4. Antihail net and shade net cost (X_3)	0.21** (0.56)	0.29* (0.29)	0.28* (0.07)	0.30* (0.12)
(b) Inputs used	1. Planting material cost (X_4)	-0.34* (0.08)	-0.29* (0.03)	-0.16* (0.01)	-0.23* (0.07)
	2. FYM cost (X_5)	0.33* (0.09)	0.16* (0.11)	0.20* (0.20)	0.26* (0.12)
	3. Fertilizer cost (X_6)	0.17* (0.04)	0.25* (0.06)	0.09* (0.02)	0.12* (0.05)
	4. Chemical cost (X_7)	-0.08* (0.19)	-0.06* (0.05)	-0.08* (0.06)	-0.07* (0.15)
(c) Labour cost (X_8)		0.320* (0.16)	0.260* (0.06)	0.312** (0.17)	0.310* (0.14)
	Σbi	1.240	1.210	1.122	1.130
	Adj R^2	0.912	0.926	0.928	0.911

Figures in parentheses are standard errors and * and ** denotes significant at 1% and 5% level of probability

proper and timely supply of water in clonal rootstocks had increased the gross returns by 32 percent in overall. Similarly, cost of antihail nets and shade nets had positive elasticity values (0.21, 0.29 and 0.28) and were significant which meant that installation of antihail nets and shade nets (X_3) had increased the gross returns in clonal rootstock of HDP apple (30 percent in overall) by protecting the fruit from external factors like hailstorms and extreme heat stress (Thakur *et al.,* 16). In case of planting material cost variable (X_1), elasticity value was negative in all districts (-0.34, -0.29 and -0.16), but was significant which meant that higher cost of planting material had negatively impacted the gross returns. In case of fertilizer cost variable (X_6), it had positive elasticity values in all the selected districts (0.17, 0.25 and 0.09) and was significant which meant that use of fertilizer had enhanced the production and quality of apple and finally the gross returns by 12 percent in overall. Similarly, in case of FYM cost variable (X_5), elasticity values were positive in all selected districts (0.33, 0.16 and 0.20), and were significant which meant that use of FYM had increased the production and gross returns in clonal rootstock. In case of chemical cost variable (X_7), elasticity values were negative in all selected districts (-0.08, -0.06 and -0.08), but were significant which meant that cost of chemicals had negative impact on the returns of HDP apple *i.e.* if we increase the cost of chemicals by one percent, it will result in decrease in gross returns by 8 percent (Singh *et al.,* 15).

Apart from these materials used, in case of labour cost variable (X_8), the elasticity value was positive in all selected districts (0.32, 0.26 and 0.31) and significant which meant that labour utilization on the orchard had really enhanced the production and hence, the gross returns in clonal rootstock of HDP apple *i.e.* one percent increase in labour cost will increase the gross returns by 31 percent in overall (Saurabh *et al.,* 13). Returns to scale which describes the output response to a proportionate simultaneous increase in all the inputs used. So, value of returns to scale was found more than one in all selected districts (1.240, 1.210, 1.122) in overall age groups of 3-10 years (Partial (1-2 years) and potential bearing stage (3-10 years)), which meant that clonal rootstock of HDP apple were generating increasing returns to scale and these findings were quite similar wis were reported by Wani *et al.* (18).

From the Table 2, it was revealed that value of resource use efficiency was over-utilized in most of the resources *e.g.* installed systems *i.e.* tree support system, drip irrigation system and fencing, whereas, antihail net and shade nets had value more than one, which meant that they were under-utilized and the reason behind their under-utilization was that these were used for only a specific duration of the year *i.e.* from flowering till the harvesting of apple fruit to protect the flowers and fruits, and after that HDP apple growers removed them till their usage in the next crop season. In case of material used, it was revealed that the resource use efficiency of FYM, fertilizer and chemicals was also over-utilized and this value was even became negative in chemicals (-0.45 in overall) which meant that the chemicals were heavily used to protect the apple trees from incidence of disease, insect-pest attack, also weedicides and so on, which had increased

Table 2: District-wise resource use efficiency in clonal rootstock of HDP apple.

Particulars		Mandi	Kullu	Shimla	Overall
(a) Installed systems	1. Tree support system cost (X_t)	0.22	0.30	0.12	0.18
	2. Drip irrigation cost (X_1)	0.84	0.97	0.83	0.8
	3. Fencing cost (X_2)	-0.04	-0.05	-0.05	-0.22
	4. Antihail net & shade net cost (X_3)	1.14	1.09	1.02	1.13
(b) Inputs used	1. Planting material cost (X_4)	-0.11	-0.10	-0.07	-0.09
	2. FYM cost (X_5)	0.96	0.67	0.48	0.67
	3. Fertilizer cost (X_6)	0.91	0.44	0.38	0.56
	4. Chemical cost (X_7)	-0.56	-0.39	-0.47	-0.45
(c) Labour cost (X_8)		0.96	0.76	0.81	0.85

the usage of various chemicals and made their use over-utilized which leads to higher cost of production. Since, it was a well-established fact from the present study that HDP apple cultivation was a labour-intensive process involving various activities on the orchard as explained in labour utilization section; so, the resource use efficiency in case of labour was over-utilized due to higher number of plants in clonal rootstock of HDP apple (Kumar, 8).

The perusal of Table 3 revealed that all the explanatory variables considered together in seedling rootstock explained about 92.90 percent to 93.60 percent of total variations in gross returns in selected districts of Himachal Pradesh. The coefficient of multiple determination (was found statistically significant at 93.8 percent in overall. It was also reported that cost of drip irrigation system, fencing, antihail and shade net, planting material, FYM, fertilizer, chemicals and labour contributed significantly to the gross returns in seedling rootstock of HDP apple. Apart from these materials used, in case of labour cost variable (X_8), the elasticity value was negative in overall (-0.21), but significant which meant that labour utilization on the orchard had really enhanced the production but negatively impacted the gross returns in seedling rootstock of HDP apple due to more investment on labour for operations like training and pruning as seedling rootstocks had tendency to grow fast due to non-availability of dwarfing rootstock as in clonal rootstocks. The value of returns to scale was found more than one in all selected districts (1.14, 1.13, 1.12) in overall age groups of 3-7 years (Partial (1-2 years) and potential bearing stage (3-7 years)), which meant that seedling rootstock of HDP apple were generating increasing returns to scale.

From the Table 4, it was revealed that the value of resource use efficiency was over-utilized in all the resources *e.g.* installed systems *i.e.* drip irrigation system, fencing, antihail net and shade nets, and the reason behind their overutilization was that these were used completely around the orchard due to closer

Table 3: District-wise estimates of Cobb-Douglas production function in seedling rootstock of HDP apple.

Particulars		Mandi	Kullu	Shimla	Overall
Intercept		-1.42	1.04	-2.01	-1.26
(a) Installed systems	1. Drip irrigation cost (X_1)	0.78** (0.40)	1.11*** (1.01)	1.40** (2.01)	1.25* (0.20)
	2. Fencing cost (X_2)	-0.14** (1.21)	-0.13* (0.68)	-0.33* (2.43)	-0.27* (0.12)
	3. Antihail net and shade net cost (X_3)	-0.27* (0.22)	-0.19** (0.28)	-0.34*** (1.84)	-0.30* (0.15)
(b) Inputs used	1. Planting material (X_4)	0.47*** (1.75)	0.54** (0.59)	0.62** (1.49)	0.67** (1.11)
	2. FYM cost (X_5)	0.81* (0.12)	0.32** (1.18)	0.66** (1.04)	0.67* (0.21)
	3. Fertilizer cost (X_6)	-0.11** (0.85)	-0.08** (1.18)	-0.46* (0.48)	-0.36* (0.38)
	4. Chemical cost (X_7)	-0.29** (0.85)	-0.21* (0.87)	-0.28** (1.56)	-0.22* (0.16)
(c) Labour cost (X_8)		-0.11** (1.48)	-0.23* (0.16)	-0.15** (0.90)	-0.21* (0.06)
	Σbi	1.140	1.130	1.120	1.130
	Adj R^2	0.929	0.933	0.936	0.938

Figures in parentheses are standard errors and *, **&*** denotes significant at 1%, 5% and 10% level of probability

Table 4: District-wise resource use efficiency in seedling rootstock of HDP apple.

Particulars		Mandi	Kullu	Shimla	Overall
a. Installed systems	1. Drip irrigation cost (X_1)	0.51	0.66	0.49	0.48
	2. Fencing cost (X_2)	-0.20	-0.23	-0.22	-0.21
	3. Antihail net & shade net cost (X_3)	-0.06	-0.29	-0.13	-0.15
b. Inputs used	1. Planting material cost (X_4)	0.87	0.94	0.66	1.19
	2. FYM cost (X_5)	0.59	0.53	0.35	0.49
	3. Fertilizer cost (X_6)	-0.05	-0.09	-0.06	-0.02
	4. Chemical cost (X_7)	-0.17	-0.14	-0.11	-0.13
c. Labour cost (X_8)		-0.18	-0.08	-0.21	-0.14

spacing of seedling rootstocks. In case of material used, it was revealed that resource use efficiency of FYM, fertilizer and chemicals was also over-utilized and this value was even became negative in fertilizers and chemicals (-0.36 and -0.22 in overall).

The above results led us to the conclusion that HDP apple has emerged as a advanced technology based solution involving better use of land, water, sunlight, and labour, easier management for pruning, spraying, and harvesting due to smaller trees and better canopy and it is also ideal for drip irrigation, fertigation, and mechanization. HDP apple cultivation is a labour-intensive process (Nyorak *et al.,* 9). Clonal rootstock or seedling rootstock involving various activities on the orchard like training and pruning, maintenance of tree basins, use of antihail nets, FYM, fertilizers and plant protection chemicals, timely irrigation and so on; so, the resource use efficiency in case of labour was over-utilized and due to higher number of plants in seedling rootstock of HDP apple which require continuous training and pruning due to higher vegetative growth which also increases the labour cost of the training and pruning in them. So, we have concluded that these HDP apple orchards containing clonal and seedling rootstocks are highly efficient due to their higher returns and lower payback periods (3-4 years (Wani *et al.,* 18), and has emerged as a key adaptation to climate change impacts like heavy snowfall, and has been making apple cultivation viable and profitable for marginal farmers. But, the excessive pesticidal use in HDP apple is a major concern as it causing harmful effects on human health. So, there is a great need for those government policies which can control the use of these chemicals like switching towards natural farming which can also help in reducing environmental pollution and improving our surrounding ecosystem.

AUTHORS' CONTRIBUTION

Conceptualization of research, designing of materials and methods, execution of surveys, analysis of data and interpretation and preparartion of manuscript (SR and SS).

DECLARATION

The authors declare that there is no conflict of interest.

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