The Pharma Innovation Journal 2022; SP-11(4): 299-304

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(4): 299-304

www.thepharmajournal.com
Received: 04-02-2022
Accepted: 06-03-2022

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Doubling income of kinnow through solar irrigation: Comparative study in Rajasthan

NK Meena and Ram Singh, VS Meena, Sweta Singh, Rahul Kumar and Santosh Kumar

Abstract
The solar irrigation system for pumping water from underground and from other source of water for irrigation has been recognized as new initiative. This paper demonstrates apparent advantages of solar system than diesel system of irrigation in kinnow orchard in Rajasthan. Total cost of cultivation of kinnow was worked out and found to be less on solar powered than diesel powered irrigation system and the returns over the cost for solar irrigation were found to be more money-making than diesel. It was due to novelty of solar irrigation system which not need of any fuel and energy for pumping irrigation water. The solar system consuming only sun rays to create the energy for pumping the water for irrigation. Hence, study found that solar irrigation system has enhanced the returns of farm and played a partial catalyst role to enhance the income of the farm. It has not saved the fuel cost for irrigation but also enhanced the yield of the crop without interrupted the irrigation as and when needed to the crop. Therefore, the solar system has been found many fold benefits including saving of fuel costs, continuous irrigation and environment friendly which need to tapped by each of the farmers not only in the state of Rajasthan but the farmers of each of the states especially orchardists of the country for doubling of their farm income. Making a provision of incentives on solar devices may be one of the policy options to the farmers.

Keywords: Solar, diesel, kinnow, doubling income, feasibility, environment

Introduction
Horticulture is an important component of agriculture and has gained commercial tone in recent years. India's varied agro-climatic condition allows it to produce a wide variety of horticultural crops such as fruits and vegetables, tuber, plantation crops, flowers, spices and condiments etc. (Meena *et al*., 2018) [11]. According to National Horticulture Database published by National Horticulture Board, India has been produced around 98 million metric tons (MT) of fruits and 183.17 million MT of vegetables in the year 2019-20 (NHB, 2019). India's diverse climate ensures accessibility of all varieties of fruits and vegetables. Among fruits produced in India, citrus assumes importance in the horticultural economy of the country covering an area of 0.81 million hectare producing 111.47 lakh MT accounting for 12.53% of total fruit production. Among the citrus fruits, kinnow cultivation has gained impetus in addition to other due to its profitability, less loss and good market value. In India, Maharashtra, Rajasthan, Punjab, Assam, Karnataka, Madhya Pradesh, Manipur and Nagaland are the leading producers of kinnow. Many of inputs are being used for kinnow production but irrigation plays a vital role. The net irrigated area of India from 56936 thousand ha in 2001 increased to 68385 thousand ha (20.10%) in 2019-20. Out of net irrigated under canal (23.90%), tanks (2.70%), tube-wells (45.70%), other (shallow) wells (16.61%) and other sources (11.07%) of irrigation in India (GoI, 2019) [3]. To pumping the water energy requirement is meeting out through different sources *viz.*, diesel and solar irrigation system in kinnow cultivation by the farmers but continuous, sustainable, portable and uninterrupted source of irrigation remains a greater challenge to the farmer due to sky touching fuel prices on one hand and in the clean environment saga of the other. The irrigation by solar is economically viable and promising option to irrigate the crops. In the state of Rajasthan establishing the solar unit programme was started in 2008-09 with a target of 14 solar pumps. Further, in 2010-11 the target of 50 units to 500 in 2011-12, 2200 solar units in 2012-13 and to 10 thousand units in 2013-14 to cover all the 33 districts of the state (Singh *et al.*, 2017) [13]. Consequently, 29667 units of PV solar pumps have been installed in the state of Rajasthan in the year of 2014-2017, which was the highest number (Singh *et al.*, 2017) [13].

Since the state of Rajasthan is rich in renewable energy resources, especially wind and solar for irrigation. In respect to solar the state of Rajasthan is blessed highest numbers of sunny days (325) which produces of 6-7 kWh/m^2 per day solar radiation on earth (Lal *et al.*, 2013) [10]. In future the state is planning to enhance the photo voltaic (PV) units with its 7.5-10.0 hp (Singh *et al.*, 2017) [13]. Mostly the PV solar units have been established in farmers' farm to pump out the irrigation water particularly in orchard crops. Among the orchard crops *kinnow crop* has been recognized as major crop in the state. The PV solar system improved yields of crops and enlarged profits (IRENA, 2015) [7]. The state of Rajasthan, *kinnow* fruit crop covered 8.8 thousand ha, 189.48 thousand MT and 21.48 MT per ha area, production and yield, respectively in the year 2016-17 (GoR, 2016) [5]. Hence, the state of Rajasthan made a lot progress for establishing the solar units but still it needs its publicity of its novelty of manifold benefits to the adopters. Therefore, this paper is in backdrop of above facts for PV solar units to assess the benefits of Irrigation for doubling of farmers' income through PV solar units compared to traditional irrigation in Kinnow orchard of Rajasthan.

Material and Methods

The site for present investigation was in Sri-Ganganager block of Sri-Ganganagar and Khajuvala block of Bikaner districts of Rajasthan state as highest number of solar units were installed to irrigate the kinnow orchard in these blocks under districts. For investigating the apparent impact of solar energy compared to diesel irrigation system a total of 200 kinnow growers were selected and categorized into two groups *viz.*, irrigation system of solar (160 adopters) and diesel (40 Non-solar-adopters) from both the districts under investigation (Table 1).

Table 1: Selection of Solar adopter and non-adopter under irrigation system

(Number)							
Block	**Village**	**Respondents under irrigation system**				**Total**	
		Solar (Adopter)		**Diesel (Solar Non-adopter)**			
Sri-Ganganagar		**TR**	**SR**	**TR**	**SR**	**TR**	**SR**
	11Q	30	23	15	5	45	28
	13Q	35	27	12	4	47	31
	15-Z	21	16	16	6	37	22
	9-Q	18	14	12	5	30	19
Sub total		104	80	55	20	159	100
Khajuvala	17 KYD	36	28	9	4	45	37
	6 PHM	23	18	16	7	39	25
	7 PHM	23	18	10	4	33	22
	3 KYD	20	16	12	5	32	21
Sub total		102	80	47	20	149	100
Total		206	160	102	40	308	200

Source: Field Survey

Note: TR- Total Respondents, SR- Selected Respondents
Note: Q, Z, KYD and PHM are minor/distributors of Gang Canal and 11, 13, 15, 9,17,6,7 and 3 are number of mori (hole) and Village situated at 11, 13, 15, 9,17,6,7 and 3 number mori of Q, Z, KYD and PHM Minor known as 11Q, 13Q,15Z,9Z, 17KYD, 6PHM,7PHMand 3KYD Village.
fixed costs like cost of solar pump, cost of diesel pump, cost of well or tube well construction, cost of pond (diggi) construction, cost of drip system, depreciation of tools and implements, interest accrued on fixed cost, salvage and rental value of assets and land, respectively, life span of solar, electric and diesel pump, establishment cost of kinnow orchard, cost of seedlings, plant protection, manures and fertilizers, training or pruning, intercultural operation, gap filling, irrigation, harvesting of kinnow and cost of ward and watch and others like repair and maintenance cost of the systems like, diesel, solar system, drip system, tube-well and pond (diggi) were collected for the crop year of 2015-18 (Consecutive three years) from selected solar adopters and non-adopters.

Analytical Framework

The data were analyzed to draw an apparent inferences of impact of solar irrigation system over traditional system (diesel) by applying standard techniques like cost concepts (GoI, 1979) [4].

Cost A1

i) Value of hired human labour
ii) Value of hired bullock labour
iii) Value of owned bullock labour
iv) Value of owned machinery labour
v) Value of hired machinery charges
vi) Value of seedlings
vii) Value of insecticides and pesticides
viii) Value of manure (owned and purchased)
ix) Value of fertilizer
x) Depreciation on farm implements
xi) Irrigation charges
xii) Land revenue, assets, cesses and other taxes
xiii) Interest on working capital
xiv) Miscellaneous expenses (Artisans etc.)

Cost A2: Cost A2 + rent paid for leased in land

Cost B: Cost A2 + rental value of owned land (net of land revenue) & interest on
Owned fixed capital (excluding land)

Cost C: Cost B + imputed value of family labour

Returns Analyses

Gross Farm income (GFI) = Value of product
Farm business income = GFI – Cost A2
Family level income = GFI − Cost B
Net farm income = GFI – Cost C
Farm investment income = Farm business income – Wages of family labour
Net returns over variable cost = GFI – Total variable cost

Economic Feasibility

To examine the economic feasibility of kinnow orchard with solar and diesel irrigation system while studying the economics of kinnow three indicators were used *viz*. Net Present Value (NPV), Benefit Cost ratio (BCR) and Pay Back Period (PBP).

Net present value (NPV)

$$NPV = \sum_{i=1}^{n} \frac{Yn}{(1+r)^n} - C$$

Where,

Y_n = Net cash inflows in the n^{th} year

r = Discount rate

C = Initial cost of investment

n = Economic life of the kinnow orchard.

NPV of the project should be accepted if its value is positive, and reject if its value is negative. If the NPV is zero, it is a matter of indifference.

Benefit cost ratio (BCR)

Benefit-cost ratio (BCR) is the ratio discounted net benefits to the initial investments. The BCR has been worked out as

$$BCR = \frac{\text{Gross present value of income}}{\text{Gross present value of costs}}$$

Results and Discussion

Establishment Cost (Solar V/s Diesel System)

Kinnow cultivation is a capital-intensive enterprise. The initial cost (1 to 3 years) of a kinnow orchard under diesel and solar irrigation system consists of the preparation of land and layout, digging and filling of pits, plant materials (seedlings), fencing, cost of pond (diggi) construction, cost of drip system and cost of tube-well construction etc. are presented in [Table-2].

The total establishment cost of kinnow orchard with solar irrigation system was found to be of ₹ 444323 per ha of which maximum was contributed by pond construction (51.26%) followed by cost of solar system (23.99%), tube-well construction (15.91%) and least were observed in preparation of land and layout (0.79%) followed by digging and filling of pits (1.47%) (Table 1). Whereas, the total establishment cost of a kinnow orchard with diesel irrigation was estimated of ₹ 362646 per ha of which highest share was contributed by pond (diggi) construction (62.80%) which was followed by tube-well (19.49%), cost of diesel system (6.89%), drip irrigation system (3.16%), fencing (2.56%), planting material (2.33%), digging and filling of pit (1.81%) and preparation of land and layout (0.95%). Hence, the initial cost has been observed more for solar than traditional irrigation system, but it was apparent that the structure of solar was long lasting than other.

Table 2: Establishment cost of kinnow under different irrigation system

Components	Solar		Diesel	
	Cost (₹/ha)	Percent	Cost (₹/ha)	Percent
Preparation of land and layout	3518	0.79	3450	0.95
Digging and filling of pit	6553	1.47	6553	1.81
Planting materials	8347	1.88	8467	2.33
Permanent fencing	9245	2.08	9288	2.56
Pond/diggi construction	227743	51.26	227743	62.80
Drip establishment	11625	2.62	11448	3.16
Tube-well construction	70697	15.91	70697	19.49
Cost of irrigation system	106595	23.99	25000	6.89
Total	444323	100	362646	100

Source: Field Survey

Operational Cost with (Solar V/s Diesel System)

Table-2 reveals that total operational cost of kinnow orchard with solar system were estimated of ₹ 461505 per ha. The major share of investment in operational cost was found to be on watch and ward (55.25%) followed by picking (13.78%), training and pruning (7.66%), manures (7.48%), intercultural operations (5.93%), plant protection (5.36%) and fertilizers (4.93%). The major share of investment in operational cost of kinnow orchard with diesel irrigation system was found to be on fuel charge (77.16%) followed by watch and ward (16.11%), picking (3.90%), training & pruning (2.25%), manures (2.20%), intercultural operation (1.77%) plant protection (1.58%) and fertilizer (1.34). The results were in conformity of findings of Bhat *et al.* (2011), Kumar *et al.* (2017) and Kaur and Singla (2016) in Jammu, Haryana and Punjab states, respectively. The analysis of operational cost with solar and diesel irrigation system in kinnow has shown that apart from watch and ward; the cost of picking, fuel has played a vital role. Contrary to solar system; diesel powered pump need fuel to generate energy to pump the water to orchard. Therefore, solar system has saved cost of fuel and added returns of the farmers.

Table 3: Operational cost of kinnow orchard with solar and diesel irrigation system

	Solar		Diesel	
Particulars	Cost (₹/ha)	Percent	Cost (₹/ha)	Percent
Intercultural operations	27366	5.93	27993	1.77
Training & pruning	35340	7.66	35619	2.25
Manures	34534	7.48	34801	2.20
Fertilizers	20912	4.53	21193	1.34
Fuel charge	-	-	1221119	77.16
Plant protection	24744	5.36	24988	1.58
Watch & ward	255000	55.25	255000	16.11
Picking	63609	13.78	61778	3.90

Total cost (for 1 to 17 years)	461505	100	1582491	100

Source: Field Survey

Table 4: Cost of cultivation of Kinnow orchard using cost concepts for 17 years (₹/ha)

	Solar		Diesel	
Particulars	**Cost**	**Percent**	**Cost**	**Percent**
Hired labour	46750	3.14	9795	0.35
Machine labour	10298	0.69	46500	1.66
Seedlings	8347	0.56	8467	0.30
Protection measures	24744	1.66	24988	0.89
Manures	34534	2.32	34801	1.24
Fertilizers	20912	1.40	21193	0.76
Depreciation	244800	16.43	314840	11.24
Irrigation	-	-	1121119	40.03
Total variable cost	390385	26.20	1581703	56.47
Interest on working capital	15616	1.05	3270	2.26
Cost A1	406001	27.24	1644973	2.26
Rent paid for leased-in land	-	-	-	-
Cost A2	406001	27.24	1644973	58.73
Rental value of owned land	435761	29.24	602344	21.50
Interest on owned FC	528751	35.48	431545	15.41
Cost B	1370513	91.96	2678862	95.64
Family labour	119750	8.04	122100	4.36
Cost C	1490263	100	2800962	100

Source: Field Survey

The total cost of cultivation with solar system excluding family labour was calculated to be ₹1370513 per hectare and total cost of cultivation including family labour was of ₹ 490213 per hectare. The results of item wise and concept wise costs of kinnow with solar system (Table 4) indicated that overall per ha cost A_1, cost A_2, cost B and cost C were ₹ 406001, ₹406001, ₹1370513 and ₹1490213,respectively. Similarly,

The cost A_1 was estimated to be of ₹1644973 per ha. The charge of fuel has been proved to be largest item of cost A_1 across the years of orchard. Cost A_2 was similar to cost A_1 under the diesel irrigation system across the years. Cost B has been estimated to be of ₹2678862 per ha (95.74%) to the total cost. The imputed family labour was ₹122100 per ha which has contributed of 4.36 per cent. The cost C was calculated to be of ₹2800962 per ha. Results were in conformity of Meena *et al*. (2018) [11], Chiphang and Roy (2018), Kumar *et al.* (2017) and Kaur and Singla (2016). Hence, cost A_1, cost A_2, cost B and cost C were found less of solar system orchards than the diesel system orchards.

Returns from Kinnow (Solar Vs Diesel System)

The total productivity of kinnow orchard with solar irrigation was estimated to be of 428 MT per ha of which total gross farm income has been estimated of ₹5137920 per ha. The per hectare farm business income, family labour income, net farm income, farm investment income and net returns over variable cost were estimated of ₹4731919, ₹3767403, ₹3647653, ₹ 4612165 and ₹4747535, respectively. Whereas, the productivity of kinnow orchard with diesel irrigation system was estimated of 425 MT per ha. The total gross farm income was observed to be of ₹5104128 per ha, Similarly, per hectare income of farm business, family labour, net farm, farm investment, and net returns over variable cost has been observed and estimated of income ₹3459155, ₹2425266, ₹ 2303166, ₹3337055 and ₹3522425. Hence, the yield of kinnow orchard with solar irrigation has harvested higher yield than the farm with diesel irrigation system. As the soil of Rajasthan state is sandy in nature which needs regular irrigation to maintain the high fertility and productivity of the farm. The diesel system of irrigation becoming costly and farmers were very conservative for the use of diesel, which has hampered the regular application of irrigation of the kinnow orchards. Consequently, it reduced the yield of the orchard with traditional irrigation system. Hence, kinnow farm with solar has harvested more yield and saved the fuel costs (Singh *et al*., 2016) [14], (Kumar *et al*., 2017) [9] and Chiphang and Roy (2018) [2].

Table 5: Return from kinnow orchard with solar and diesel irrigation system (₹/ha)

Particulars	Solar	Diesel
Productivity (MT/ha)	428	425
Gross farm income	5137920	5104128
Farm Business Income	4731919	3459155
Family Labour Income	3767403	2425266
Net Farm Income	3647653	2303166
Farm Invest Income	4612165	3337055
Net Returns over Variable Cost	4747535	3522425
Source: Field Survey		

Economic Feasibility of Kinnow orchard (Solar and Diesel System)

The costs and return estimates were discounted at an annual rate of interest of 12 per cent for the medium term investment for each year (Table 7 and 8). Comparative returns under solar irrigation orchard estimated to be higher side than the diesel irrigation system due to the merit of solar system which supplies energy to pump water un-interrupted as the water is required to maintain fertility of soils in Rajasthan at regular and continuous basis (Meena *et al.*, 2018, [11] Hossain *et al.*, 2015 and Singh *et al*, 2017) [13]. The Net Present Value (NPV) of diesel and solar irrigation estimated to be of ₹349214, ₹ 842521, respectively in kinnow orchard. The Benefit Cost Ratio has been estimated to be at higher (2.36) than diesel (1.31) irrigation system (Khan *et al.*, 2013).

Table 6: Economic feasibility analysis of different irrigation system

Feasibility Indicators	Irrigation Systems	
	Solar	Diesel
Net Present Value (₹)	842521	349214
Pay-back period (Year)	7.1	8.7
B:C Ratio	2.36	1.31

The pay-back period also found to be in positive side. Hence, the analysis of different economic indicators showed the solar powered irrigation system as more economically feasible than the diesel system of irrigation. The higher return in solar system proved the merit of solar system under orchard has been irrigated without using any fuel which saved huge amount of operational cost. Consequently, returns of solar irrigated orchard increased compared to diesel irrigation system (Meena *et al.*, 2018, [11] Singh *et al.*, 2016 [14] and Kaur and Singla, 2016) [8].

Table 7: Cash flow analysis of kinnow orchard with diesel irrigation system

Year	Cost	Return	Discounted cost at 12% discounted rate	Discounted benefit at 12% discounted rate	Discounted net return at 12% discounted rate
1	142291	0	127046	0	-127046
2	136088	0	108489	0	-108489
3	135914	0	96741	0	-96741
4	141961	153600	90219	97616	7397
5	151114	172800	85746	98051	12305
6	159746	192000	80932	97273	16341
7	174056	245760	78734	111169	32435
8	174536	303360	70492	122522	52030
9	174177	376320	62810	135705	72895
10	175187	384000	56405	123638	67232
11	175339	433920	50406	124742	74336
12	176069	430080	45192	110391	65198
13	176615	464640	40476	106483	66008
14	176881	480000	36193	98218	62024
15	176942	483840	32327	88396	56069
16	177012	491520	28874	80178	51303
17	177034	492288	25784	71699	45915
Total	2800960	5104128	1116866	1466080	349214

Table 8: Cash flow analysis of kinnow orchard with solar irrigation system

Year	Cost	Return	Discounted cost at 12% discounted rate	Discounted benefit at 12% discounted rate	Discounted net return at 12% discounted rate
1	93237	0	83248	0	-83248
2	80969	0	64548	0	-64548
3	80175	0	57067	0	-57067
4	81591	145920	51853	92735	40882
5	83747	153600	47520	87157	39637
6	85749	180480	43443	91437	47994
7	87527	253440	39593	114643	75051
8	87306	307200	35261	124073	88812
9	87830	345600	31673	124627	92954
10	88549	384000	28510	123638	95127
11	89092	445440	25612	128053	102441
12	89935	456960	23084	117290	94206
13	90843	476160	20819	109124	88305
14	91136	480000	18648	98218	79569
15	91647	499200	16744	91202	74458
16	90528	503040	14767	82057	67290
17	90402	506880	13167	73824	60658
Total	1490262	5137920	615555	1458077	842521

Conclusion

The solar irrigation system was only long lasting, portable, sustainable, eco-friendly, economically feasible and viable device for irrigation. The analysis of cost of cultivation has proved that solar irrigation system has enhanced the economic returns of kinnow farm and played a partial catalyst role to enhance the income of the farm. The income and profitability of the solar system need to realize through state extension system. Hence, adoption of solar irrigation system is instrumental for doubling of farmers' income in general and especially for kinnow growers. Therefore, provision of incentives on solar devices should be made to the farmers.

Acknowledgements

The authors are grateful to Ministry of Human Resource, Govt. of India, New Delhi for financial assistance under the scheme of National Fellowship for Higher Education (NFHE) for Ph.D. research from which this paper has been prepared. Authors are also thankful to the Central Agricultural University, Imphal, Manipur, India to facilitate and implement this research.

Submission Declaration and Verification

The work described has not been published previously elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copy right holder.

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