Increasing the Yield of Ring Wells by User Friendly Method

H. S. Prasanna, S. C. Harshavardhan, A. R. Chaitra, P. K. Pooja, and P. Beeresha

Abstract Inadequacy of water for the irrigation purposes is being reported as the remarkable problem from the farmers. The groundwater and well systems have to be promoted where the construction of dams, reservoirs, canals, etc. alone can't serve the farmers. In this study, an attempt has been made to develop to draw water efficiently, to the ring wells situated along the bank of a river. A ring well was selected as the prototype along the river bank and the physical properties of the soil along the periphery of the well were determined to know the soil profile around the well. A model was simulated accordingly and the yield of the model was determined by conducting recuperation tests. Further, perforated laterals of two different lengths were inserted in eight radial directions alternatively at the bottom of the well, and yield was measured for various combinations of the laterals. Similarly, the recuperation tests are conducted even for the slotted laterals and compared with that of the perforated ones. The yield of the model without laterals and with laterals has been compared to know the efficiency of the model. The combination of laterals which gives the optimum yield in the model was selected and provided in the prototype. From the present study, it can be concluded that usage of laterals increases the permeability of the system and thereby increases the yield of the well without the need for increasing the cross section of the well and thus saving valuable time and money.

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1 Introduction

Agriculture sector occupies a vital portion in the overall economy of the country. About 80% of the population directly or indirectly depends on income derived from agriculture. Although agriculture is the backbone of India, it is observed, that it is extremely low in terms of annual yield of crops per acre, in relative comparison to other developing countries. Employment of scientific techniques especially in developed countries such as USA and Russia has achieved tremendous progress. Initially, machines have superseded manual labor, i.e., a larger average is brought under cultivation in more efficient manner.

In many developing countries the major contribution to the economic development, this can be supplemented through irrigation network systems. It is observed that the consumption of agricultural products is on a rising demand in many developing countries due to the magnitude of population increase, in order to meet this rising demand the respective governments made several attempts to keep the supply and demand chain in an economical order. Demand for agricultural products is generally met by rain-fed agriculture/through cultivating techniques by means of irrigation or by means of imports. Out of these, the magnitude of agricultural product output is through irrigated agricultural methods.

Irrigation increases the stability and efficiency of cropping systems and diminishes the risks of drought and desertification. An irrigation system serves as an important economic resource to provide a basis for settlements and related social amenities in areas that otherwise support sparse populations. However, the history of irrigated agriculture has not always recorded success. Some past schemes—and some very recent ones—suffered severe setbacks through silting, waterlogging, and salinization as well as social and political challenges. Some schemes proved excessively expensive. The development of irrigation can be justified from the point of view of economic necessity. Irrigation is often costly, technically complex and requires skill and experience to realize full benefits.

Supply of bulk water for irrigation is under pressure from the demands of other water-using sectors, constraints on further water resource development, and is compounded by poor maintenance of existing irrigation infrastructure. The principal sources of irrigation can be divided into Canals, Wells, Tanks, etc. The large volumes of water required for irrigation usually have to be transported over some distance to the field. For surface water, canals, and pipes can enable conveyance; in the case of groundwater, extraction is provided via tube wells. Water from rivers is extracted by constructing ring wells along the river beds. When the permeability of the soil along the river bed is more, it fetches more yield of the well. But excessive extraction of water from these ring wells also results in the subsidence of soils along the periphery of the soil, giving rise to dredging problems which is costlier for the marginal farmers who can't even afford, the increase in the size of the wells in order to get more discharge. Hence, there is a need to find a feasible solution for these problems.

In the present experimental study, an attempt has been made to solve the above-stated problems by using slotted laterals in the ring wells which gives maximum discharge from the well without increasing the diameter of the well and decreasing the problem of soil subsidence around the wells.

2 Literature Review

As it is necessary to determine the performance of each method of application of water and crop performance in each system, various methodologies have to be overviewed to develop a new one.

Al-Zuhairi et al. (2002) investigated the efficiency of using sand columns in improving soft clayey soils. Variables such as reinforcement ratio (number and cross section of sand column) and relative density of column material and their effect on the new soil system were studied. They concluded that the undrained shear strength of reinforced sample was found to be depended on both reinforcement ratio, and relative density of the sand in the column. The improvement gained was highly affected by the number of sand columns used rather than the relative density of soil in the column.

Many methods were developed in the past to recharge the existing bore-wells to supplement the magnitude of water deficit during summer seasons, i.e., Sikandar et al. (2008), Raphael (2009). Increasing the efficiency of bore-wells by Hydro-fracturing technique, Thangasala et al. (2010), Bank filtration, etc.

Patel et al. (2011) made an attempt to evaluate the hydraulic performance of porous pipe used as micro-irrigation lateral in sub-surface irrigation system and measured the discharge from the lateral tube and concluded that the porous pipe tested did not possess the qualities of good micro-irrigation lateral.

Sandhu et al. (2011) studied on Potential for Riverbank filtration in India and examined selected operating bank filtration sites. He elucidated additional potential RBF sites based on water problems and hydrogeologic suitability.

Mayilswami et al. (2013) studied on Guidelines for augmentation of groundwater resources under climate change in Tamil Nadu. Earlier, the ring wells were used to fetch water, now it was used to increase the water level. An age-old practice is receiving a modern twist to improve the water table in Kaniyambadi block of Vellore district. Recharge wells also known as ring wells are being built in 21 panchayats of Kaniyambadi block to improve the water table. The aim of constructing the recharge wells is to conserve rainwater and increase the water table. It is being carried out on a pilot basis in Kaniyambadi block. Water from the stream will flow into these wells. An impact study was carried out to see how this helped in improving water table for one to two years. It was found that water does not flow into the river directly. Once the groundwater level increases, water reaches the lakes in the second year and then flows into the river in the third year following three monsoons.

No studies have been reported in the documented literature regarding the increase in yield of wells using laterals.

3 Materials and Methods

A ring well located (at 12.1487400E, 76.7761970 N) along the bank of river Kabini, situated in Nagarle village, Nanjangud taluk, Mysuru district, Karnataka state, India, was selected as prototype for the present experimental study. Cylindrical galvanized pipes with threaded collars were fabricated as core cutter for sampling. In situ undisturbed and disturbed representative soil samples were brought from the site for the laboratory investigation to know the soil profile along the periphery of the well. The various laboratory tests were conducted as per relevant IS codes of practice to know the physical properties of the soils.

In situ density test [IS: 2720 (part-29)-1975] was carried out to know the field density of the fine-grained soil in four radial directions around the well. Table 1 shows the average values of In situ density of the fine-grained soil up to a depth of 1.2 m.

Specific gravity test [IS: 2720 (part-3 sec-1)-1980] was determined for both the types of soils. Free swell ratio test [IS: 2911 (part-3)-1980] was determined to the dominant clay mineralogy in the soil. Grain size analysis [IS: 3104-1965] was done as per IS code. Atterberg limits [IS: 2720 (part-5)-1985] were determined and liquid limit of the soil sample was found by both Casagrande method. Table 2 shows the characteristics of the soil that was found up to a depth of 1.2 m.

Uniformly graded sandy soil (Poorly graded soil—SP) was found to a further depth of 5.2 m and there on. The soil samples collected at different depths from the core cutter were directly transferred to the permeameter and kept for saturation. Then, the permeability test [IS: 2720 (part-17)-1986] by variable head for fine-grained soil was carried out to determine the permeability characteristics of the soil along the soil profile. Table 3 shows the values of coefficient of permeability for the soils.

Results obtained were used for the simulation of the model to estimate the yield of the prototype. The model was simulated to the field density and along with laterals of two different lengths (0.152 and 0.305 m) inserted to the well in eight radial directions in an alternative manner. Fabrication of perforated laterals for field is

Table 1 Average values of In situ density of the fine-grained soil up to a depth of 1.2 m

Soil sample	In situ density (kN/m^3)
Sample 1	17.66
Sample 2	19.75
Sample 3	20.11
Sample 4	19.52

Table 2 Characteristics of soil up to a depth of 1.2 m

Characteristics	Soil
Specific gravity	2.54
Free swell ratio	1.27
Liquid limit (%)	28
Plastic limit (%)	20
Shrinkage index (%)	18
Sand (%)	61
Silt (%)	32
Clay (%)	7
IS classification	SM

Table 3 Values of Coefficient of permeability for both the soils

Sample	Coefficient of permeability (mm/s)	
	Fine-grained soil	Sandy soil
1	1.83×10^{-5}	4.01×10^{-2}
2	4.65×10^{-6}	3.98×10^{-2}
3	7.12×10^{-6}	4.04×10^{-2}
4	9.01×10^{-7}	4.00×10^{-2}
Avg. Value	7.74×10^{-6}	4.00×10^{-2}

difficult than making slots in the laterals. Hence, the slotted laterals were preferred for field installation. Figure 1 represents the schematic diagram of the model.

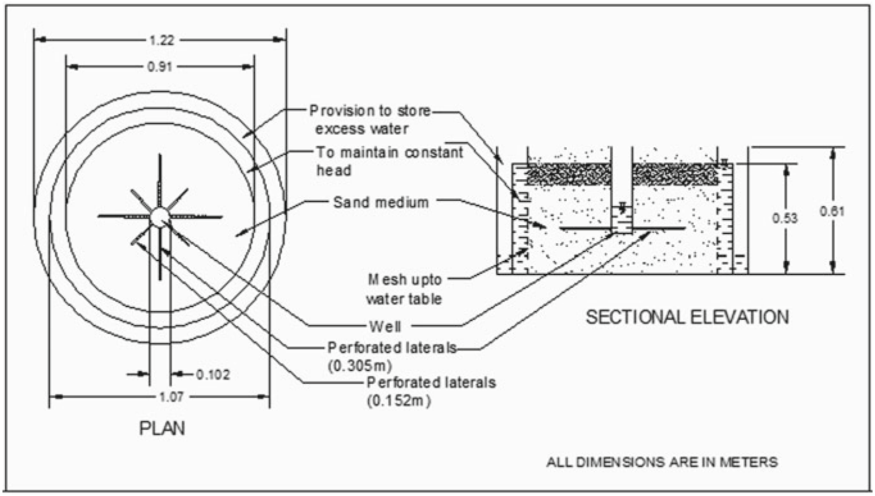

Fig. 1 Schematic diagram of model

Constant head was maintained, to measure the yield of the well by conducting recuperation test, for both the conditions. The yield was measured for the different combinations of laterals and the variation of discharge with perforated and slotted laterals were studied, respectively, and results were compared accordingly. Multilinear regression analysis was carried out to know the correlation between the discharges obtained from the slotted and perforated laterals.

Soil subsidence was found along the periphery of the well in the model during excessive discharge from the well with no laterals. When the site was investigated regarding this, the soil subsidence around the prototype was also observed. From the farmers, it was reported that during excessive discharge from the well; the soil subsidence takes place along the periphery of the well which is the major problems faced by them. Figures 2 and 3 show the subsidence in the model and prototype, respectively.

During the experimental study, the soil subsidence was reduced after the usage of laterals. Thus, providing laterals being an effective solution to reduce the soil subsidence.

Fig. 2 Subsidence in model

Fig. 3 Subsidence in prototype

4 Results and Discussions

4.1 Results of the Perforated Laterals

For the first combination of laterals, inlets of the laterals of length 0.305 m were opened and others were closed using rubber cork. For the second combination of the laterals, only the inlets of laterals of length 0.152 m were opened. For the third combination of laterals, inlets of all the 0.305 m length laterals were opened and inlets of the 0.152 m length laterals were opened one by one for different trials. For the fourth combination of laterals, inlets of all the 0.152 m length laterals were opened and inlets of the 0.305 m length laterals were opened one by one for different trials.

Tables 4, 5, 6 and 7 present the values of discharge for different no. of perforated laterals along with different combinations of laterals. Figures 4, 5, 6 and 7 represent the variation of discharge with different number of laterals.

Table 4 Values of discharge for different number of perforated laterals of length 0.305 m

Nos and length of laterals	Discharge (cm^3/s)
0	27.30
1 (0.305 m)	37.17
2 (0.305 m)	47.05
3 (0.305 m)	63.98
4 (0.305 m)	79.33

Table 5 Values of discharge for different number of perforated laterals of length 0.152 m

Nos and length of laterals	Discharge (cm^3/s)
0	27.30
1 (0.152 m)	33.08
2 (0.152 m)	37.63
3 (0.152 m)	43.04
4 (0.152 m)	48.45

Table 6 Values of discharge for different number of perforated laterals (both the lengths 0.305 m and 0.152 m)

Nos and length of laterals	Discharge (cm^3/s)
4 (0.305 m) + 1 (0.152 m)	68.35
4 (0.305 m) + 2 (0.152 m)	73.43
4 (0.305 m) + 3 (0.152 m)	65.05
4 (0.305 m) + 4 (0.152 m)	72.18

Table 7 Values of discharge for different number of perforated laterals (both the lengths 0.152 m and 0.305 m)

Nos and length of laterals	Discharge (cm^3/s)
4 (0.152 m) + 1 (0.305 m)	57.80
4 (0.152 m) + 2 (0.305 m)	69.04
4 (0.152 m) + 3 (0.305 m)	64.44
4 (0.152 m) + 4 (0.305 m)	71.43

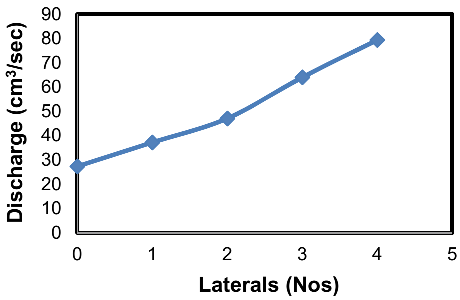

Fig. 4 Discharge curve w.r.t. number of perforated laterals (for 0.305 m laterals)

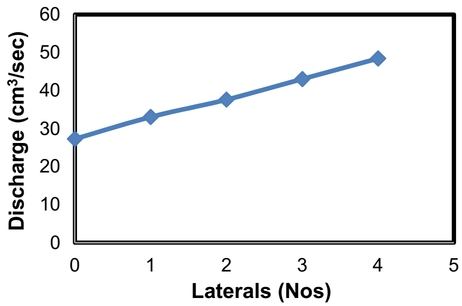

Fig. 5 Discharge curve w.r.t. number of perforated laterals (for 0.152 m laterals)

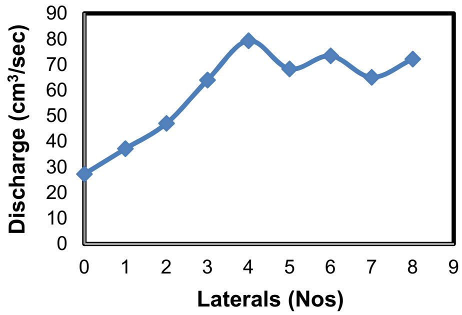

Fig. 6 Discharge curve w.r.t. number of perforated laterals (for both 0.305 m Laterals + 0.152 m Laterals)

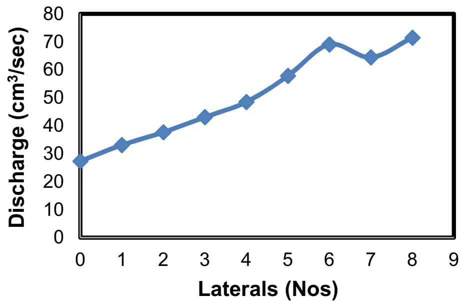

Fig. 7 Discharge curve w.r.t. number of perforated laterals (for both 0.152 m Laterals + 0.305 m Laterals)

Table 8 Values of discharge for different number of slotted laterals of length 0.305 m

Nos and length of laterals	Discharge (cm^3/s)
4 (0.305 m) + 1 (0.152 m)	70.94
4 (0.305 m) + 2 (0.152 m)	77.62
4 (0.305 m) + 3 (0.152 m)	68.68
4 (0.305 m) + 4 (0.152 m)	76.63
0	27.71
1 (0.305 m)	38.02
2 (0.305 m)	48.85
3 (0.305 m)	67.14
4 (0.305 m)	81.35

4.2 Results of the Slotted Laterals

Tables 8, 9, 10 and 11 present the values of discharge for different no. of slotted laterals along with different combinations of laterals. Figures 8, 9, 10 and 11 represent the variation of discharge with different number of laterals.

From Figs. 4 and 8, it can be observed that the discharge from the well increases with the increase in the no. of perforated and slotted laterals, respectively. Similarly

Table 9 Values of discharge for different number of slotted laterals of length 0.152 m

Nos and length of laterals	Discharge (cm^3/s)
0	27.71
1 (0.152 m)	33.83
2 (0.152 m)	38.74
3 (0.152 m)	44.78
4 (0.152 m)	49.95

Table 10 Values of discharge for different number of slotted laterals (both the lengths 0.305 and 0.152 m)

Nos and length of laterals	Discharge (cm^3/s)
4 (0.305 m) + 1 (0.152 m)	70.94
4 (0.305 m) + 2 (0.152 m)	77.62
4 (0.305 m) + 3 (0.152 m)	68.68
4 (0.305 m) + 4 (0.152 m)	76.63

Table 11 Values of discharge for different number of slotted laterals (both the lengths 0.152 and 0.305 m)

Nos and length of laterals	Discharge (cm^3/s)
4 (0.152 m) + 1 (0.305 m)	60.14
4 (0.305 m) + 2 (0.305 m)	72.69
4 (0.305 m) + 3 (0.305 m)	68.41
4 (0.305 m) + 4 (0.305 m)	80.04

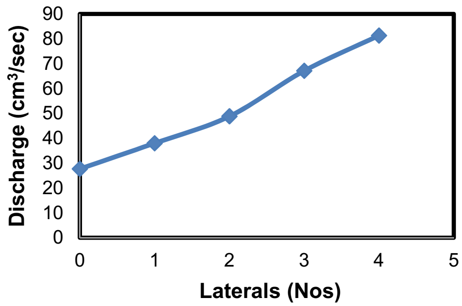

Fig. 8 Discharge curve w.r.t. number of slotted laterals (for 0.305 m laterals)

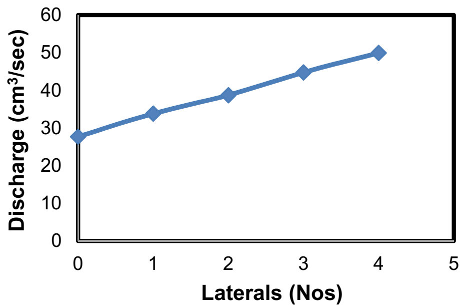

Fig. 9 Discharge curve w.r.t. number of slotted laterals (for 0.152 m laterals)

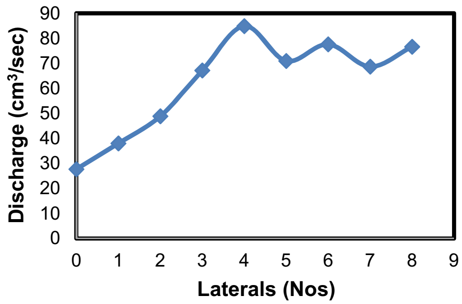

Fig. 10 Discharge curve w.r.t. number of slotted laterals (for both 0.305 m Laterals + 0.152 m Laterals)

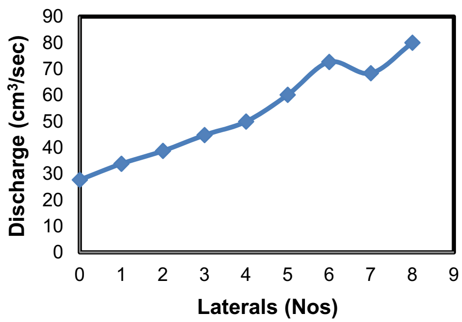

Fig. 11 Discharge curve w.r.t. number of slotted laterals (for both 0.152 m Laterals + 0.305 m Laterals)

from Figs. 5 and 9, it can be observed that there is an increase in the discharge from the well with the increase in the no. of perforated and slotted laterals, respectively.

From Figs. 6 and 10, it can be observed that discharge for the laterals of 0.305 m length is maximum (with 4 no. of laterals) than for the laterals of 0.152 m length.

From Figs. 7 and 11, representing the combination of 0.305 m laterals and 0.152 m laterals, it is observed that discharge is maximum for four large laterals and usage of 8 laterals would be uneconomical. It is observed that discharge is maximum for the combination of 4 no. of 0.152 m & 2 no. of 0.305 m laterals.

Even though 6 laterals gives the maximum discharge but it is less than the discharge obtained by providing 4 laterals (Figs. 7 and 11).

Thus, the yield obtained by the maximum discharge from 4 no. of 0.305 m laterals is considered to be the optimum one in both perforated and slotted laterals. From the yield comparison between optimum no. of laterals and no laterals, it is observed that the yield of the well is increased by 190.57% for perforated laterals and 193.58% for slotted laterals.

4.3 Correlation of Discharge Slotted with Discharge Perforated

Making perforations in the laterals used for installing in the field were found to be difficult than making slots. Hence, slotted laterals were preferred for both model and field installation and experiments are conducted on both perforated and slotted laterals in the model to know the correlation between them and their efficiency is checked.

Figure 12 represents the correlation of discharge obtained for slotted and perforated laterals (for the combination of 0.305 m laterals). Figure 13 represents the

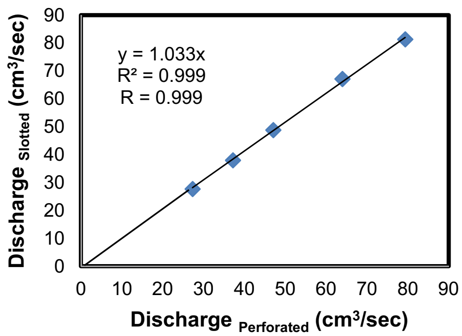

Fig. 12 Correlation of Discharge obtained for slotted and perforated laterals (for the combination of 0.305 m laterals)

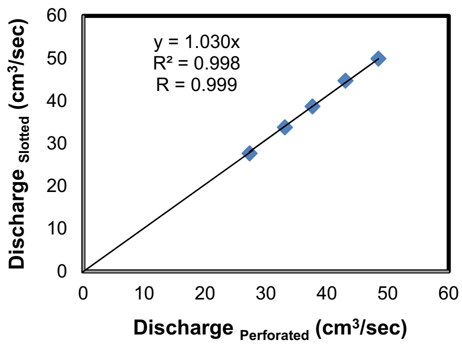

Fig. 13 Correlation of Discharge obtained for slotted and perforated laterals (for the combination of 0.152 m laterals)

correlation of discharge obtained for slotted and perforated laterals (for the combination of 0.152 m laterals). Figure 14 represents the correlation of discharge obtained for slotted and perforated laterals (for the combination of 0.305 m + 0.152 m laterals). Figure 15 represents the correlation of discharge obtained for slotted and perforated laterals (for the combination of 0.152 m + 0.305 m laterals). Figure 16 represents the correlation of discharge obtained for slotted and perforated laterals irrespective of the combination of laterals.

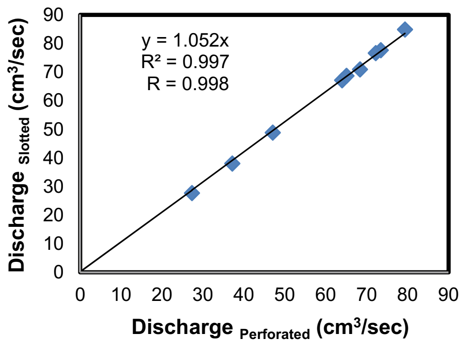

Fig. 14 Correlation of Discharge obtained for slotted and perforated laterals (for the combination of 0.305 m + 0.152 m laterals)

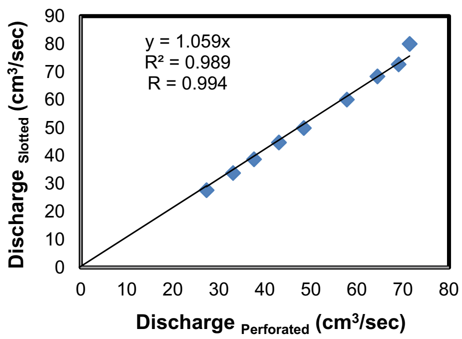

Fig. 15 Correlation of Discharge obtained for slotted and perforated laterals (for the combination of 0.152 m + 0.305 m laterals)

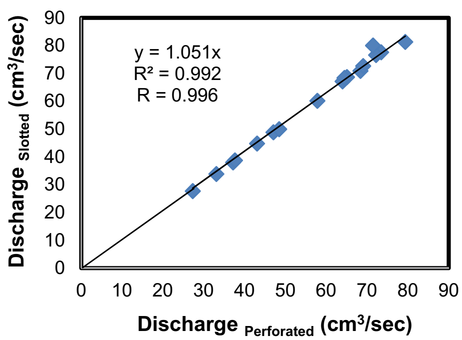

Fig. 16 Correlation of Discharge obtained for slotted and perforated laterals irrespective of the combination of laterals

From the above figures, it can be observed that the discharge obtained from the slotted laterals can be effectively correlated with the discharge obtained from the perforated laterals with coefficient of correlation of 0.99.

5 Conclusions

In the present experimental study on increasing the yield of the well-using laterals, following are the important conclusions made from the results and observations:

- It can be concluded that the discharge from the well can be increased by providing the laterals which influences the permeability of the soil. Thus, the yield of the well can be increased without increasing the cross-sectional area of the well.
- Even though, all the combinations of laterals result in the increase in the yield of well, the combination of 4 no. of 0.305 m laterals gives the maximum yield of the well in both slotted and perforated laterals.
- From the regression analysis, it can be concluded that the discharge obtained from the slotted laterals can be effectively correlated with the discharge obtained from the perforated laterals with coefficient of correlation of 0.99.
- It is also observed that the provision of laterals also prevents subsidence of the soil mass around the periphery of the well, thus, reducing the problems of dredging of soil from the well.
- As the usage of laterals is more economical than increasing the size of the well to increase the yield, this method greatly helps the marginal farmers and hence to the society at large.
- Due to its simplicity and maximum efficiency, this technology can be considered as user friendly.

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