

Original Research Article

FEASIBILITY OF DRAIN DISCHARGE UNDER 50 M LATERAL SPACING CONTROLLED SUBSURFACE DRAINAGE IN SALINE VERTISOLS OF TBP COMMAND AREA

ABSTRACT

Surface and subsurface drainage water from irrigated agriculture is normally degraded compared with the quality of the original water (Canal water) supply as the drainage water from different locations and / or facilities will have different quality characteristics. Hence, quality assessment or feasibility studies of drain discharge both in short and long term adoption of both conventional and controlled SSD under different drain spacing is prerequisite for its reuse in crop production and efforts are being made elsewhere for reuse of drainage water in crop production. Such, feasibility studies on characterization of drain discharge from different subsurface drainage systems are lacking in TBP command area. Hence, it is proposed to conduct this experiment. A field experiment was conducted during *rabi* -2021 at Agricultural Research Station, Gangavati (Karnataka) to study the the characterization of drain discharge water for its reuse as an irrigation water. The experiment was laid out as a conventional and controlled subsurface drainage system (SSD). Among the treatments, the collected water samples from six different sampling stations revealed

that, drain discharge under conventional subsurface drainage system (SSD) varied from 3.66 to 0.63 compared to 1.38 to 0.42 mm day⁻¹ under controlled subsurface drainage system. Electrical conductivity of drain discharge water under conventional SSD varied from 3.89 to 1.24 ds m⁻¹ as against 1.01 to 0.81 ds m⁻¹ under controlled SSD respectively. While, salt output was varied from 29.0 to 11.0 under conventional compared to 16.5 to 2.5 kg ha⁻¹ under controlled SSD system. Finally, the subsurface drainage system drain water samples were not suitable for reuse as irrigation water to paddy in the R/S season as per the classification of irrigation water quality particularly for poorly drained black soils in the TBP command area.

Keywords: Subsurface drainage system, Drain water quality, Irrigation water quality, salt output, NO₃-N

1. INTRODUCTION

Artificial drainage is necessary to farm some of the world's most productive soils. Subsurface drain tubes are used to lower water tables, improve trafficability, prevent waterlogging, control soil salinity and increase yields. Subsurface drainage reduces surface runoff, sediment losses and the movement of contaminants attached to the sediment, such as nutrients like nitrogen and phosphorus, into surface waters. However, subsurface drainage increases the losses of nitrate-nitrogen (NO₃-N) to surface waters. Research has shown that drainage volumes and nitrate-nitrogen losses through the drains can be substantially reduced by a practice called Controlled Drainage (CD). This practice is also referred to as Drainage Water Management (DWM), which involves the use of a weir or an overflow device to reduce drainage rates by raising the water level in the drainage outlet (R. Wayne Skaggs and Mohamed A. Youssef, Srinivasulu *et al* 2006). CD reduces the hydraulic gradient to the drain, subsurface drainage rates and annual subsurface drainage volumes. Subsurface drainage (SSD) improves crop productivity in canal command areas suffering from waterlogging and salinity problems. However, excessive drainage of paddy fields under conventional SSD is known to cause irrigation water shortage during critical growth stages of rice and also results in excessive leaching of nitrogenous fertilizers particularly at the tail end of the irrigation command. To overcome these problems, farmers of the Tungabhadra Project (TBP) irrigation command area used to block the outlets of lateral drains of the SSD system. In order to provide a lasting solution to this problem through a controlled drainage approach, a comparative field study was conducted on clay loam soil at Agricultural Research Station (ARS), Gangavathi, over four seasons by Karegoudar *et al* in 2019. In general, there was a reduction in drain discharge depth of 64.00 per cent in the case of

controlled drainage over conventional SSD, with average irrigation water saving of about 17.00 per cent. Average nitrogen loss was also reduced by 50.4 per cent compared to conventional drainage. Paddy (*Oryza sativa*) grain yield improvement was slightly higher (from 3.84 to 5.14 t ha⁻¹) for conventional compared to controlled conditions (3.76–4.83 t ha⁻¹) reported by Karegoudar *et al* 2019.

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY

2.1. Experimental layout

An SSD field experiment was carried out during *Rabi* season on a 2.8 ha area at the Agricultural Research Station (ARS), Gangavathi (15° 27' 14.1" N, 76° 32' 06.12" E) in Karnataka, India (Figure 1). The soils of the experimental site were predominantly of clay loam with weathered calcareous parent material locally known as *murrum* at a depth of about 1.0 m. Hydraulic conductivity was measured using the augur-hole method (Van Beers, 1965). It was between 0.0503 and 0.092 m day⁻¹ at 1.0 m depth. In order to assess the impact of the conventional and controlled drainage on the ground/perched water level, 16 PVC observation wells were installed at mid spacing and at two positions, *viz.*, at one-third length of the lateral and at two-thirds distances of the lateral length in a 10 cm diameter hole to a depth of 1 m. The PVC pipes with perforations all over the pipe periphery were lowered into the augured hole and the space around filled with sand and gravel. The water level in the above-mentioned observation wells was monitored at three day intervals (Figure 2). Also soil samples up to a depth of 90 cm, with 15 cm increments, were taken from each treatment at each sampling time to understand the effect of drainage treatments (conventional and controlled) on soil salinity (Karegoudar *et al.* 2019). Soil sampling was done in a zigzag fashion using GPS at the start and end of each crop-growing season, and soil samples were analyzed for initial soil pH and soil salinity (EC, dS m⁻¹) in a 1:2.5 soil water suspension and the EC thus obtained was converted to EC_e (dS m⁻¹), *i.e.*, EC of saturation paste extract was multiplied by a conversion factor of 2.66 which was worked out for these soils at ARS, Gangavathi (personal communication). The pH and EC of water samples was determined by using glass electrode and conductivity meter (Jackson, 1973).

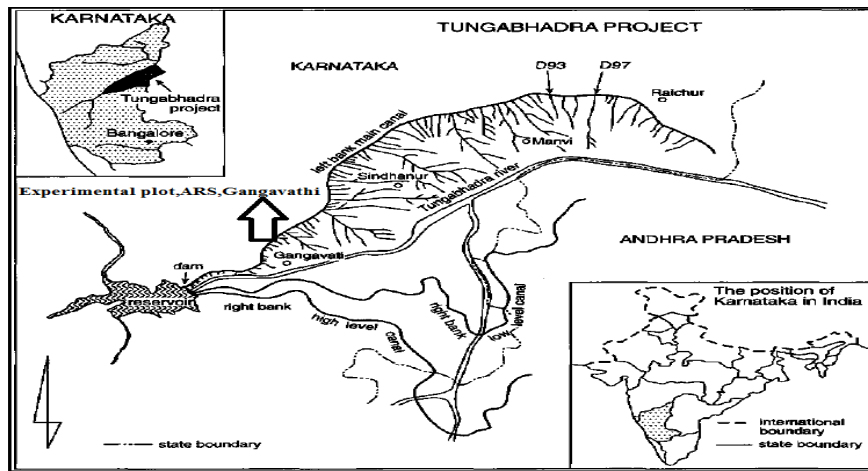


Fig. 1. Location of the TBP command area (Source: Manjunatha *et al.*, 2004)



Fig. 2. A view of Conventional and Controlled SSD systems imposed at 50 m lateral spacing at Agricultural Research Station, Gangavathi.

3. RESULTS AND DISCUSSION

3.1. Temporal changes in drainage discharge

The drain discharge was collected from the outlet of the each treatment rabi/summer season. The drain discharge or drainage water outflow was higher in the case of conventional SSD compared to the controlled drainage system. The drain discharge varied from 3.66 to 0.63 mm day⁻¹ and 0.73 to 0.10 mm day⁻¹ with a mean value of 1.38 and 0.42 mm day⁻¹ under conventional and controlled SSD respectively (Table 1). During *rabi*/summer season (February–March) revealed that drain discharge was higher in conventional SSD as compared to controlled SSD systems (Figure 3) and declined later on. Irrespective of season, conventional SSD consistently had a higher drain discharge compared to controlled SSD.

Table 1. Temporal variations of Drain discharge, EC, Salt removal and NO₃-N concentrations (mg L⁻¹) in drain discharge water as influenced by conventional and controlled SSD at 50 m lateral spacing during R/S 2020-21.

Date sampling	50 m lateral spacing							
	Drain discharge (mm day ⁻¹)		EC (dS m ⁻¹)		Salt removal (kg ha ⁻¹)		NO ₃ -N (mg L ⁻¹)	
	Conv.	Cont.	Conv.	Cont.	Conv.	Cont.	Conv.	Cont.
04/2/2021	1.41	0.48	6.41	4.98	14.1	2.5	7.44	8.06
08/2/2021	1.83	0.38	6.05	4.53	18.6	2.2	8.68	12.90
11/2/2021	1.52	0.20	5.94	4.57	16.4	1.1	13.64	12.40
15/2/2021	3.66	0.54	6.02	4.58	29.0	3.1	9.92	13.14
18/2/2021	2.03	0.73	6.11	4.90	19.6	4.2	9.92	6.20
22/2/2021	0.87	0.73	6.14	5.10	13.0	4.4	14.90	9.92
25/2/2021	0.96	0.68	6.19	4.78	24.0	4.3	10.54	9.30
01/3/2021	1.66	0.65	6.25	5.18	18.2	4.1	12.40	9.92
04/3/2021	1.66	0.61	6.32	5.45	17.2	3.5	8.68	8.68
08/3/2021	0.63	0.10	6.64	6.21	11.0	0.6	12.40	11.04
12/3/2021	1.14	0.17	6.35	5.73	15.7	1.0	9.92	8.06
15/3/2021	0.70	0.23	6.26	5.56	11.0	1.4	4.96	11.16
18/3/2021	0.87	0.30	6.18	5.64	13.3	1.9	6.20	6.20
23/3/2021	0.83	0.20	6.12	5.71	13.1	1.3	6.20	5.58
25/3/2021	0.87	0.35	6.28	5.95	13.3	2.3	11.78	4.96
Maximum	3.66	0.73	6.64	6.21	29.0	4.4	14.90	13.14
Minimum	0.63	0.10	5.94	4.53	11.0	0.6	4.96	4.96
Average	1.38	0.42	6.22	5.26	16.5	2.5	9.84	9.17

Note: Conv: Conventional SSD Cont: Controlled SSD

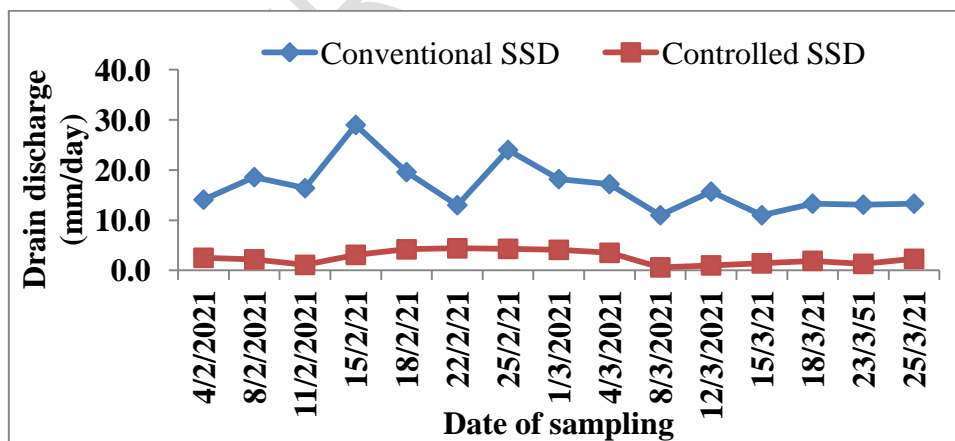


Fig. 3. Drain discharge over the growing season as influenced by 50 m lateral spacing under conventional and controlled SSD system.

3.2. Temporal changes in drainage water salinity

Similarly, drainage water salinity was measured for each treatment during *rabi/summer* season and was higher in the case of conventional SSD compared to the controlled drainage system. It varied from 3.89 to 1.24 dS m⁻¹ and 1.01 to 0.81 dS m⁻¹ with a mean value of 2.11 and 0.93 dS m⁻¹ under conventional and controlled SSD, respectively (Table 1). The salinity of the effluent was high with a high flow rate under conventional SSD. Though the drainage effluent volume was high at a later stage, the salinity level was lower than the corresponding controlled SSD which could be due to faster reclamation under conventional SSD (Figure 4). Monthly averages for different seasons revealed that temporally the drainage water salinity increased as the season advanced, and it was higher in the initial years under conventional compared to controlled SSD. Not much variation in irrigation water salinity was observed except for a slight increase during the *rabi* season (February and March) which could be due to a shortage of irrigation water and mixing with seepage water of poor quality.

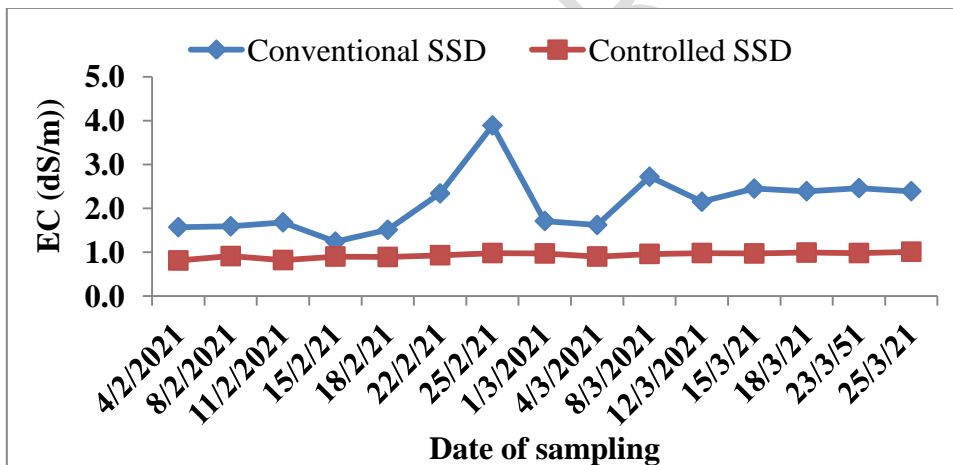


Fig. 4. Drain water salinity over the growing season as influenced by 50 m lateral spacing under conventional and controlled SSD system.

3.3. Seasonal salt output

On the basis of drainage water outflow and salinity, salt removal patterns for the conventional and controlled drainage systems are presented in Table 1 and Fig. 5. Irrigation water applied to conventional and controlled drainage fields was measured with a Parshall flume and electrical conductivity (EC) of irrigation water applied varied from 0.42 to 0.23 dS m⁻¹ in *rabi/summer* season. The EC of irrigation

or drainage water was multiplied by a standard factor of 640 to get the salt load in mg L^{-1} . In the case of the conventional drainage system, on average, 16.5 t ha^{-1} salt load was removed through drainage water compared to 2.5 t ha^{-1} under controlled drainage respectively, indicating that the rate of reclamation was faster in the conventional than the controlled drainage system.

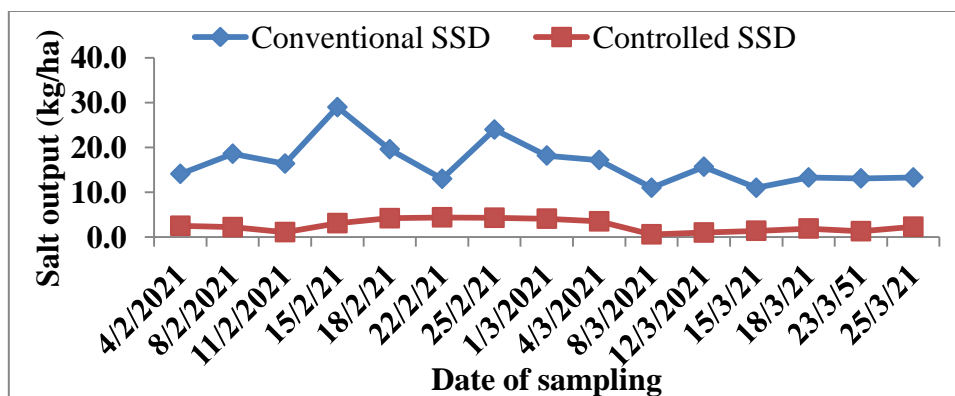


Fig. 5. Temporal variations in salt removal (kg ha^{-1}) as influenced by conventional and controlled SSD at 50 m lateral spacing during R/S 2020-21

3.4. Temporal changes in soil salinity under conventional and controlled drainage systems

Soil salinity changes to a depth of 90 cm at the end of the each growing season under conventional and controlled drainage systems are shown in Table 2. The mean soil salinity under conventional SSD was reduced from 14.66 to 0.64 for 0–15 cm, from 10.11 to 1.09 for 15–30 cm, from 17.42 to 1.09 for 30–60 cm and from 16.23 to 1.06 dS m^{-1} for 60–90 cm, respectively. In the case of the controlled drainage system, the soil salinity reduced from 9.76 to 0.93 dS m^{-1} for 0–15 cm, from 16.36 to 0.96 dS m^{-1} for 15–30 cm, from 22.69 to 1.09 dS m^{-1} for 30–60 cm and from 25.30 to 1.09 dS m^{-1} for 60–90 cm, respectively. The results indicated that due to the continuous flow of drain water, removal of dissolved salts through drainage effluent was faster as well as from a greater depth in conventional SSD than in the controlled drainage system. Higher soil salinity at lower depth in the controlled system might also be attributed to higher levels of initial salinity and build-up of salts at lower depths due to blockage of drainage water flow under controlled SSD.

Table 2. Soil salinity as influenced by conventional and controlled SSD at 50 m lateral spacing

Statistics	Soil ECe (dS m ⁻¹)							
	0-15 cm		15-30 cm		30-60 cm		60-90 cm	
	Conv.	Cont.	Conv.	Cont.	Conv.	Cont.	Conv.	Cont.
	Before transplanting (Summer 2020)							
Maximum	14.66	9.76	10.11	16.36	17.42	22.69	16.23	25.30
Minimum	0.64	0.93	1.09	0.96	1.09	1.09	1.06	1.09
Average	2.74	2.60	2.51	4.05	5.42	8.58	4.67	11.26
After harvest (R/S 2020-21)								
Maximum	4.23	6.04	9.47	12.50	20.00	23.57	18.22	25.56
Minimum	1.09	1.22	1.01	1.57	1.12	1.70	1.48	8.67
Average	2.32	2.42	2.41	3.68	4.32	10.41	5.20	14.22

3.5. Nitrate-nitrogen loss through drainage water

As showed in Figure 6, the temporal variability of NO₃-N loss appeared to be similar in both drainage systems. The loss was higher whenever the drainage discharge was more during the cropping season. Further, it is clearly showed that the loss was more under the conventional compared to the controlled system at any point of observation. Though there was not much variation in the mean drain discharge NO₃-N concentration (9.84 versus 9.17 mg L⁻¹) of the drainage events, the average seasonal NO₃-N loss in the conventional treatment was 8.11 kg ha⁻¹ compared to 2.29 kg ha⁻¹ in the controlled drainage treatment (Table 1 and Fig. 6). The data indicated that nitrogen loss in the conventional drainage treatment was thrice the controlled drainage treatment which might again be related mainly to its higher drain discharge of 1.38 versus 0.42 mm day⁻¹. The total loss of NO₃-N for the growing season in the present study was worked out as 21.8 and 8.80 kg ha⁻¹ under conventional and controlled SSD, respectively.

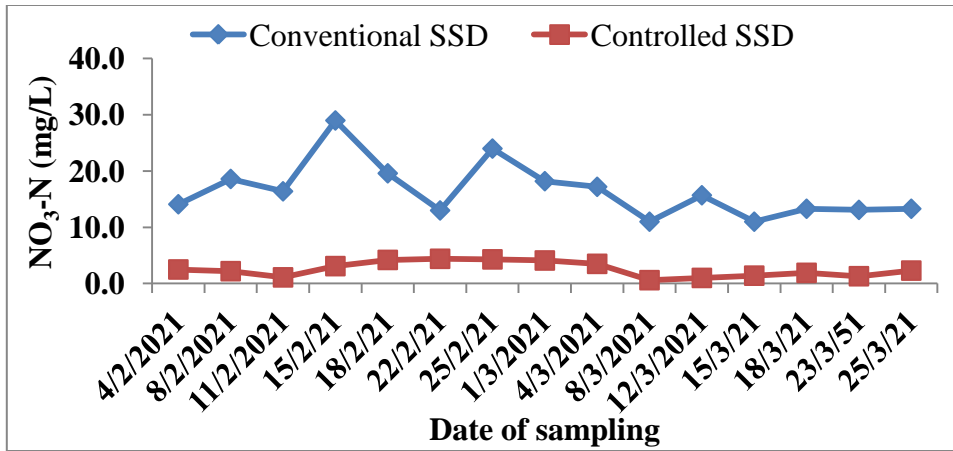


Fig. 6. Temporal variations of $\text{NO}_3\text{-N}$ concentrations (mg L^{-1}) in drain discharge water as influenced by conventional and controlled SSD at 50 m lateral spacing during R/S 2020-21.

4. CONCLUSION

The data of the rabi/summer season revealed that the rate of reclamation of waterlogged saline soil was faster in the case of conventional drainage compared to controlled drainage. However, controlled drainage reduced around 86 % of drainage water. It also reduced nitrogen loss from 8.11 and 2.29 kg ha^{-1} , saving around 5.89 kg ha^{-1} of nitrogen and preserving downstream water bodies. The average drain discharge and salinity of the drainage water under conventional drainage were 1.38 mm day^{-1} and 2.11 dS m^{-1} , respectively, compared to 0.42 mm day^{-1} and 0.93 dS m^{-1} under controlled drainage. As per the salt balance study, salt removed through drainage under conventional drainage against 16.2 and 2.5 t ha^{-1} , respectively, under the controlled drainage system. The slower rate of reclamation under the controlled drainage system may be due to the reduced drainage coefficient compared to be conventional system, resulting in accumulation of salts at lower depths. Considering savings of irrigation water and nitrogen, controlled drainage appeared to be a more environmental friendly practice and could be propagated on a large scale in the TBP irrigation command area.

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