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

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ABSTRACT

Surface and subsurface drainage discharge water from irrigated agriculture field is normally varies compared with the quality of the canal water supply as the drain discharge water from different locations or facilities will varied in their 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 discharge 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 plot 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 under controlled subsurface drainage system. Electrical conductivity of drain discharge water under conventional SSD varied from 3.89 to 1.24 ds/m as against 1.01 to 0.81 ds/m 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 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, NO_3-N

1. INTRODUCTION

Implementation of artificial drainage is necessary to cultivate some of the world’s most productive soils. Subsurface drain pipes are used to lower water tables, improve trafficability, prevent water-logging, decreases soil salinity and maximize yields. Subsurface drainage reduces runoff on surface, sediment losses and the contaminants attached to the sediment, such as nutrients like nitrogen and phosphorus into nala waters. However, subsurface drainage increases the losses of nitrate-nitrogen (NO_3-N) to nala waters. Research found that drainage volumes and nitrate-nitrogen losses through the drains can be substantially reduced by a practice called controlled drainage (CD) (Carstensen *et al*., 2020). 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). Controlled drainage reduces the hydraulic gradient to the drain, subsurface drainage rates and annual subsurface drainage volumes. Crop yield in canal command regions increased via subsurface drainage (SSD) by decreasing waterlogging and salinity issues. However, excessive paddy field drainage under conventional SSD is known to result in a scarcity of irrigation water at the critical growth stages of rice and also causes excessive nitrogenous fertilizers leaching. So farmers in the irrigation command area of the Tungabhadra Project (TBP) used to block the outlets of the SSD system's lateral drains. In order to solve these issues, in 2019, Karegoudar *et al*. carried out a comparative field study on clay loam soil at Agricultural Research Station (ARS), Gangavathi, over the course of four seasons in order to provide a long-lasting solution by adopting controlled drainage technique. As per practice, there was a reduction in drain discharge depth of 64.00 per cent in the case of controlled drainage over conventional drainage system, with average irrigation water saving of about 17.00 per cent. Approximately the nitrogen loss was also reduced by 50.4 per cent compared to conventional drainage. Paddy (*Oryza sativa*) 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

2.1. Experimental layout

An SSD plot experiment was conducted during *Rabi* season on a 2.8 ha area at 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) in a 1:2.5 soil water suspension and the EC thus obtained was converted to ECe (dS/m), *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).

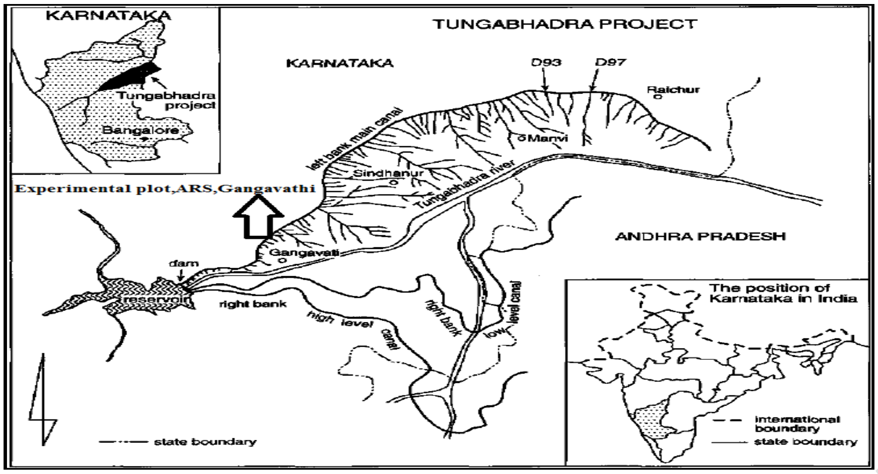

Fig. 1. Location of the TBP command area (Source: Manjunatha *et al*., 2004)

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

The groundwater table was controlled by the use of a short PVC pipe device that was integrated into a controlled SSD system and connected with a lateral drain outlet in the observation hole (Figure 2). An 80 mm diameter PVC "T" pipe with capped ends is fixed to the lateral drain pipe outlet inside the viewing hole in this setup. A riser pipe (of 0.70 m) was provided from the bottom horizontal PVC pipe through the T section in order to maintain the ideal groundwater table depth in the paddy field, which is roughly 0.3 m. Once more, a further "T" pipe is fixed to the riser pipe's top. According to Karegoudar et al. (2019), this inexpensive equipment, which consists of two PVC "T" pipes and a riser pipe, is effective in keeping the water table in paddy fields at the ideal depth.

3. RESULTS AND DISCUSSION

3.1. Drainage discharge changes in conventional and controlled SSD

Drainage output was gathered at the end of each treatment period during the summer. When compared to the controlled, the traditional SSD had a higher discharge or drainage water outflow (Wang et al., 2020; Pease et al., 2017). Under conventional and controlled SSD, respectively, the drain water varied from 3.66 to 0.63 mm/day and 0.73 to 0.10 mm/day with a mean value of 1.38 and 0.42 mm/day (Table 1). Figure 3 shows that the amount of discharge water in conventional SSD during the *rabi/summer* season (February–March) was higher than in controlled systems. Later, this amount of discharge water decreased. In comparison to the regulated SSD system, the conventional system constantly had a larger drain discharge, regardless of the growing season.

Table 1. Temporal variations of Drain discharge, EC, Salt removal and NO_3-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 of 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

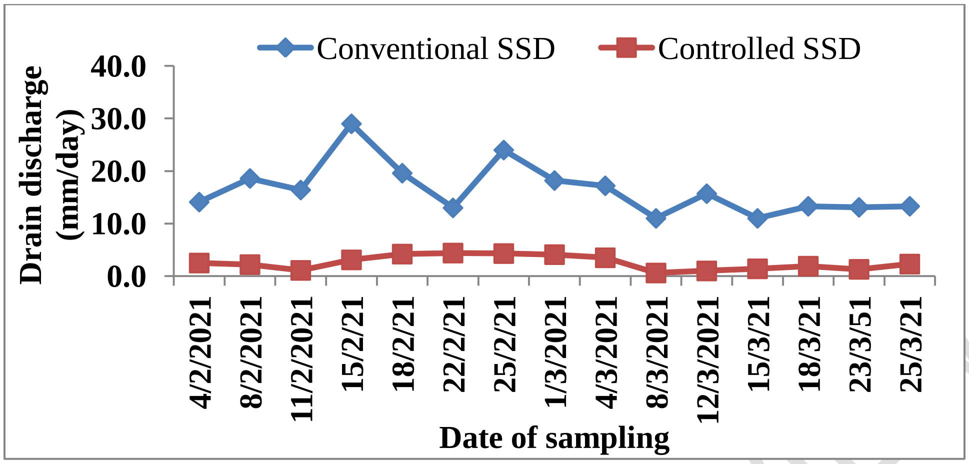

Fig. 3. Drain discharge over the growing season as influenced by 50 m lateral spacing under conventional and controlled SSD system.

3.2. Changes in drainage water salinity

Similar to discharge water salinity, which was assessed for each treatment during rabi/summer, typical SSD samples had greater salinities than controlled drainage samples. Under conventional and regulated SSD, it changed from 3.89 to 1.24 dS/m and 1.01 to 0.81 dS/m, respectively, with a mean value of 2.11 and 0.93 dS/m (Table 1). With a high flow rate of discharge under a traditional SSD system, the discharge salinity was higher. Even though the quantity of drainage discharge was significant at a later stage, the salinity level was lower than the controlled SSD, which may be because conventional SSD experienced faster reclamation (Figure 4). Monthly averages for various seasons showed that the salinity of the drainage water rose over time as the season progressed, and it was high. In the beginning, it was higher under conventional SSD than under controlled SSD. A little rise in salinity during the rabi season (February and March), which might be caused by a lack of irrigation water and mixing with poor-quality seepage water, was the only significant variation in irrigation water salinity that was noticed.

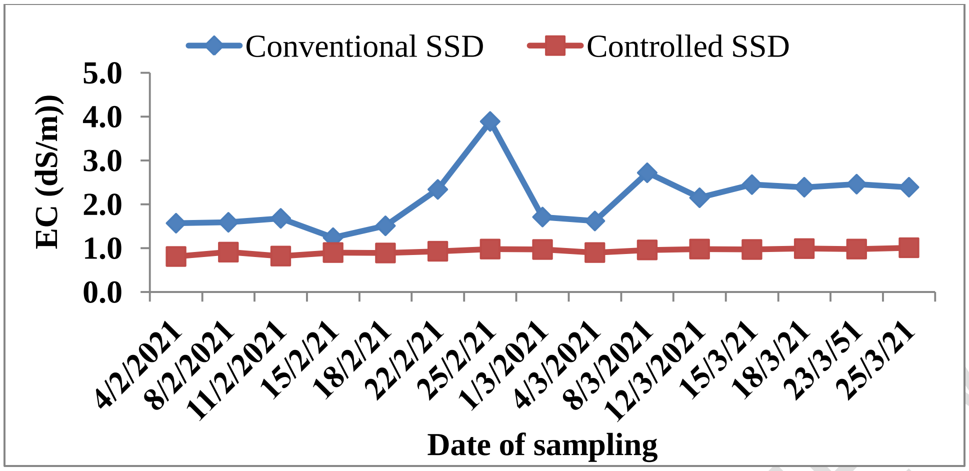

Fig. 4. Drain water salinity over the growing season as influenced by 50 m lateral spacing under conventional and controlled SSD system.

3.3. Salt output

Table 1 and Fig. 5 show the salt removal trends in the conventional and controlled drainage systems based on drainage discharge outflow and salinity. Using a Parshall flume, canal irrigation water applied to fields with conventional and controlled drainage implementation was assessed. In the rabi/summer season, the EC of the irrigation water applied ranged from 0.42 to 0.23 dS/m. The salt load in mg/l was calculated by multiplying the electrical conductivity of irrigation or drainage water by a standard factor of 640. According to the traditional drainage system, 16.5 t/ha of salt load was typically eliminated by drainage water as opposed to 2.5 t/ha under controlled drainage, demonstrating that the conventional drainage system had a quicker reclamation rate.

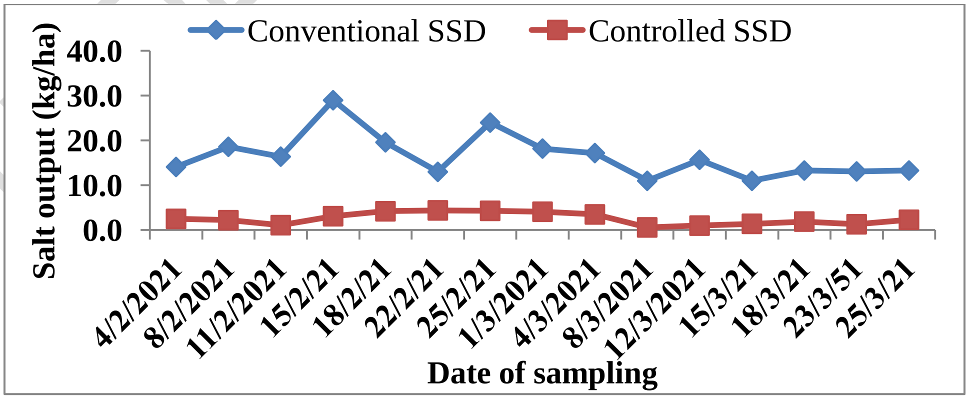

Fig. 5. Temporal variations in salt removal (kg ha^{-1}) as influenced by conventional and controlled SSD at 50 m lateral spacing during *R/S* 2020-21

3.4. Soil salinity under conventional and controlled drainage systems

Table 2 shows how the soil salinity varies for both drainage methods at the end of each season to a depth of 90 cm. According to conventional SSD, the average soil salinity decreased from 14.66 to 0.64 for depths of 0 to 15 cm, from 10.11 to 1.09 for depths of 15 to 30 cm, from 17.42 to 1.09 for depths of 30 to 60 cm, and from 16.23 to 1.06 dS/m for depths of 60 to 90 cm. The soil salinity decreased in the controlled drainage system case from 9.76 to 0.93 dS/m for 0 to 15 cm, from 16.36 to 0.96 dS/m for 15 to 30 cm, from 22.69 to 1.09 dS/m for 30 to 60 cm, and from 25.30 to 1.09 dS/m for 60 to 90 cm, respectively. The findings indicated that due of the drain water's continual flow, the traditional drainage system discharged salts more quickly and from a deeper level than the controlled drainage system. Higher starting salinity and salt deposition at lower depths as a result of blocked drainage water flow under managed SSD may be the cause of high soil salinity at lowers depths in the controlled system.

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. Losses nitrate-nitrogen through drainage water

The variability of NO_3-N loss was found to be similar in both drainage systems, as shown in Figure 6. When drain discharge was more frequent throughout the growing season, there was a higher loss. Furthermore, it is amply demonstrated that at every moment of sampling, the loss was higher under the conventional system as compared to the controlled system (Gao et al., 2018). The mean seasonal NO_3-N loss in the conventional treatment was 8.11 kg/ha compared to 2.29 kg/ha in the controlled drainage treatment (Jouni et al., 2018 and Helmers et al., 2022) (Table 1 and Fig. 6), even though there were not many differences in the mean drain discharge NO_3-N concentration (9.84 versus 9.17 mg/l) of the drainage timings. The findings demonstrated that nitrogen loss Figure 6 illustrates the variation of NO_3-N. The results revealed that the conventional drainage treatment lost three times as much nitrogen as the controlled drainage treatment, which may once more be primarily attributable to the larger drainage flow of 1.38 versus 0.42 mm/day. In the current study, the overall loss of NO_3-N for the growing season was calculated as 21.8 kg/ha under traditional SSD and 8.80 kg/ha under controlled SSD, respectively.

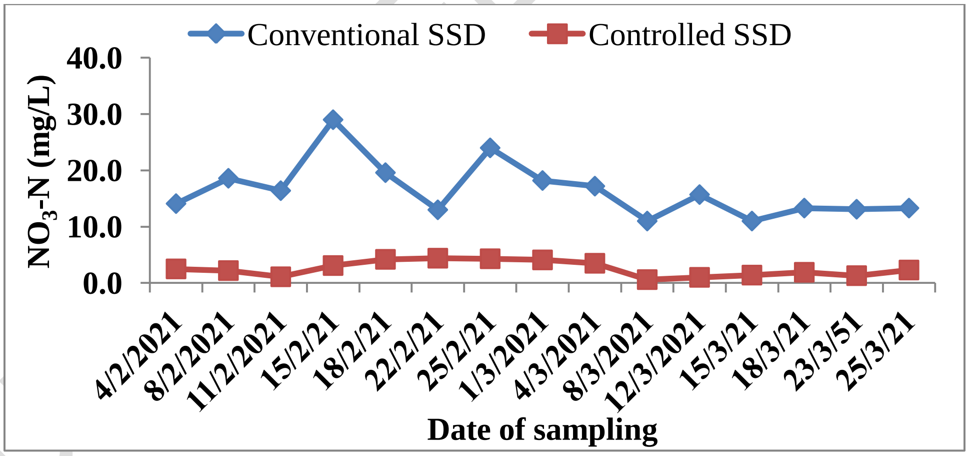

Fig. 6. Temporal variations of NO_3-N concentrations (mg L^{-1}) in drain discharge water as influenced by conventional and controlled SSD at 50 m lateral spacing during *R/S* 2020-21.

4. CONCLUSION

According to research findings from the rabi/summer season, traditional subsurface systems had a greater rate of reclamation of wet, salty soil than did controlled SSDs. However, proper drainage reduces drain damage by over 86%. Additionally, it reduces the loss of nitrogen from 8.11 and 2.29 kg/ha, conserving about 5.89 kg/ha of nitrogen and protecting water bodies downriver. In comparison to 0.42 mm/day and 0.93 dS/m under controlled drainage, the average drain flow and salinity of the drainage water under conventional drainage were 1.38 mm/day and 2.11 dS/m, respectively. According to the salt balancing analysis, during traditional drainage, salt was removed by drainage as opposed to 16.2 and 2.5 t/ha under the controlled drainage system, respectively. It's possible that the controlled drainage system's slower rate of restoration is related to Compared to a traditional system, the drainage coefficient was lower, which indicated salt collection at shallower depths. According to the results of the savings in nitrogen and irrigation water, CD seemed to be a more environmentally friendly technology and could be applied to a broader area at the TBP irrigation command area.

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