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Effect of subsurface drainage on soil nutrients and crop yield in saline vertisol under TBP command area

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Abstract
A study was conducted to ensure the impact of subsurface drainage system on soil nutrients and crop yield in salt affected soils under the TBP command area, Karnataka. The results revealed that the analyses of soil samples from post SSD work have indicated a slight increase in soil OC content *i.e.*, 5.40, 4.31, 2.81 and 2.01 g kg^{-1}, while noticeable decrease in available N, P_2O_5, K_2O and S content of post-drainage soil samples in all the depths when compared to corresponding pre-drainage soil depths *i.e.*, 187.51, 171.39, 106.98, 80.41 kg ha^{-1} for available N, 25.48, 22.08, 19.57, 16.77 kg ha^{-1} for available P_2O_5, 365.51, 341.87, 292.86, 281.18 kg ha^{-1} for available K_2O and 36.93, 35.05, 28.79, 23.83 mg kg^{-1} for available S in 0-30, 30-60, 60-90 and 90-120 cm soil depths respectively. Similarly there was significant reduction of all the micronutrients in surface layer of post-drainage compared to corresponding pre-drainage soil samples *i.e.*, 0.43, 0.48, 0.52, 0.54 mg kg^{-1} for Zn, 0.43, 0.46, 0.50, 0.52 mg kg^{-1} for Cu, 1.23, 1.32, 1.38, 1.43 mg kg^{-1} for Fe and 3.03, 3.16, 3.35, 3.53 mg kg^{-1} for Mn for 0-30, 30-60, 60-90 and 90-120 cm. The installation of SSD system resulted in improvement of paddy yield to 4.2 t ha^{-1} compared to 3.7 t ha^{-1} before the drainage works, thus there was increase in yield by 13.27 percent.

Keywords: Subsurface drainage, soil nutrients, crop yield, saline vertisol, TBP command area

Introduction
Subsurface drainage is important to drain out excess waters and salts from low-lying waterlogged areas. In such a system, a web of porous tile pipes is buried in the soil to collect excess water from the soil and drain it out into drainage canals. The subsurface drainage system certainly lowers the water table and corrects any salinity problem if good quality water is available for effective irrigations. It is more effective than tube wells for lowering the water table and reclaiming salt-affected soils (Woltere *et al*. 1996) [7]. However, many dissolved ions including essential plant nutrients are likely to be removed from soil in drainage water. The losses of nutrients in such a system needs proper monitoring (Ochs 1987) [4] to get economically viable and sustainable output without deteriorating the soil fertility and other soil characteristics. Assessment of soil for nutrient losses is frequently required to take timely measure to protect soil resources.

The grain yields of rice were increased with the introduction of subsurface drainage system. However, because of the increased availability of irrigation water and rapid drainage, there would be substantial amount of leaching of valuable nutrients beyond the root zone that would eventually retard soil fertility and productivity if not properly replenished. It is important to note that the nutrient and salt leaching is usually high in recently installed drainage system, which decreases with time as the salt and nutrient concentrations in soil decreases (Althoff and Kleveston 1996) [1]. This study was undertaken to assess the extent of nutrients removed in soil from a subsurface drainage system in TBP command area.

Objective
To assess the effect of subsurface drainage on nutrient of saline vertisol and crop yield

Materials and Methods
The study area selected for the present study comes under the Tungabhadra command area and project site is situated at a distance of 21.0 km on Ballari to Gotur road and it is 2.00 km from the Gotur village with 15°13’93.93” N latitude and 76°92’14.43” E longitude at a elevation of 495 m above the mean sea level. A block of 80 ha area comprising of different farmers’ fields has been selected where in the subsurface drainage system was implemented during 2016. The study area falls under the Northern Dry Zone (Zone-2) of Karnataka State Agro-climatic Zones

Classification. The area is a part of semi-arid region characterized by mild winter, short monsoon and hot summer. The mean annual temperature is 27.4 °C. Summer season is very hot with temperatures rising to 42 °C or more, whereas winter season (November to February) is relatively cool and dry. The hottest months are April and May, and December is the coldest month. The average annual rainfall at Ballari rain gauge station is 550.16 mm, of which 350.6 mm occurs during June-September, which is 62.26 percent of the average annual rainfall.

Collection and preparation of soil samples for chemical analysis

In order to carry out systematic studies, the sampling points were identified on a grid size of 50 m × 50 m in the study area (9 points). The soil samples were collected at different depths of 0-30, 30-60, 60-90 and 90-120 cm from each grid points during 2016 before the installation of subsurface drainage. The post subsurface drainage soil samples were collected after the harvest of first crop *i.e.*, during 2017. However, care was taken to keep the soil sampling points as same as those of pre-drainage points using GPS. The soil samples were air dried in the shade, ground with wooden pestle and mortar and passed through 2 mm sieve. Samples were preserved in polyethylene bags for further nutrient analysis. The comparison of soil parameters of pre SSD and post SSD soil samples was carried out by using paired t-test and impact of SSD was assessed.

Chemical parameters of soil samples

Sl. No.	Parameter	Method	Reference
1.	Organic carbon (%)	Wet oxidation method	Walkley and Black (1934) [11]
2.	Available N (kg ha^{-1})	Alkaline potassium permanganate method	Subbaiah and Asija (1956) [10]
3.	Available P (kg ha^{-1})	Olsen's method	Jackson (1973) [8]
4.	Available K (kg ha^{-1})	Neutral normal ammonium acetate method	Jackson (1973) [8]
5.	Available S (kg ha^{-1})	Turbidometric method	Jackson (1973) [8]
6.	Available Zn, Fe, Cu & Mn (mg kg^{-1})	DTPA extractant method	Lindsay and Norvell (1978) [9]

Result and Discussion

The analysis of pre and post-drainage soil samples were also used for the estimation of soil organic carbon (g kg^{-1}), available N, P_2O_5, K_2O (kg ha^{-1}) and sulphur (mg kg^{-1}) and the results are presented in the Table 1. In general, among pre-drainage soil samples the OC values ranged from 1.52 to 4.52 g kg^{-1}, available N values ranged from 70.44 to 268.80 kg ha^{-1}, available P_2O_5 values ranged from 6.70 to 40.11 kg ha^{-1}, available K_2O values ranged from 238.83 to 523.04 kg ha^{-1} and available sulphur values ranged from 20.46 to 49.76 kg ha^{-1} irrespective of soil depths. The mean values of OC, N, P_2O_5, K_2O and S of pre-drainage soil samples were 4.35, 4.06, 2.50, 1.93 g kg^{-1} for OC, 223.04, 192.56, 128.37, 89.25 kg ha^{-1} for N, 31.06, 26.93, 22.46, 17.66 kg ha^{-1} for P_2O_5, 380.67, 358.96, 303.54, 286.80 kg ha^{-1} for K_2O and 44.58, 39.89, 31.13, 26.62 mg kg^{-1} for S in 0-30, 30-60, 60-90 and 90-120 cm soil depths respectively, showing a noticeable decrease with increasing in soil depth (Table 1a).

On the other hand, in the case of post SSD soil samples, in general the OC values ranged from 1.38 to 5.85 g kg^{-1}, the available N values ranged from 63.46 to 260.25 kg ha^{-1}, the available P_2O_5 values ranged from 10.38 to 33.49 kg ha^{-1}, the available K_2O values ranged 234.15 to 413.48 kg ha^{-1} and the available S values ranged from 17.36 to 40.76 mg kg^{-1} irrespective of soil depths. The analyses of soil samples from post SSD work have indicated a slight increase in soil OC content *i.e.*, 5.40, 4.31, 2.81 and 2.01 g kg^{-1}, while noticeable decrease in available N, P_2O_5, K_2O and S content of post-drainage soil samples in all the depths when compared to corresponding pre-drainage soil depths *i.e.*, 187.51, 171.39, 106.98, 80.41 kg ha^{-1} for available N, 25.48, 22.08, 19.57, 16.77 kg ha^{-1} for available P_2O_5, 365.51, 341.87, 292.86, 281.18 kg ha^{-1} for available K_2O and 36.93, 35.05, 28.79, 23.83 mg kg^{-1} for available S in 0-30, 30-60, 60-90 and 90-120 cm soil depths respectively (Table 1b).

The comparative analyses of soil OC, N, P_2O_5, K_2O and S of pre and post-drainage soil samples using paired t test is given in Table 2. The analyses results revealed that the OC content of post-drainage soil samples significantly increased in surface soil layers whereas available soil N, P_2O_5, K_2O and S had significantly reduced in all the soil depths when compared to corresponding depths of pre-drainage soil samples with the exception of 9-120 cm for P_2O_5 and K_2O, while 60-90 and 90-120 cm for S were non-significant.

The SSD positively impacted the organic carbon (OC) of post-surface soil samples significantly while sub surface soil sample non-significantly. The higher OC content of post-drainage soil samples was due to the normal growth of the crops after installation of subsurface drainage system and crop residues have contributed to the more OC content in post-drainage soil samples. Similar results were reported by Anand (2003) [2].

The analysis results of post-drainage soil samples have recorded lower available soil primary nutrients and sulphur than that of the pre-drainage soil samples in all the corresponding depths. The loss of nutrients in post-drainage soil samples was due to leaching of nutrients through SSD along with water. Similar observations were also reported by Padalkar *et al.* (2012) [5].

Micronutrients (mg kg^{-1})

The data on zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn) of pre-drainage and post-drainage soil samples are presented in Table 3. In general, among the pre-drainage soil samples the Zn values ranged from 0.24 to 1.17 mg kg^{-1}, the Cu values ranged from 0.10 to 0.84 mg kg^{-1}, the Fe values ranged from 1.19 to 1.97 mg kg^{-1} and the Mn values ranged from 2.58 to 3.71 mg kg^{-1} irrespective of soil depths. The results revealed that the mean micronutrients of pre-drainage soil samples were 1.04, 0.83, 0.64, 0.42 mg kg^{-1} for Zn, 0.71, 0.55, 0.38, 0.26 mg kg^{-1} for Cu, 1.81, 1.63, 1.54, 1.37 mg kg^{-1} for Fe and 3.48, 3.27, 3.06, 2.82 mg kg^{-1} for Mn respectively for 0-30, 30-60, 60-90 and 90-120 cm soil depths respectively, all the micronutrients showed a slight decrease with increasing in soil depths (Table 3a).

On the other hand, in the case of post SSD soil samples, in general the Zn values ranged from 0.29 to 0.82 mg kg^{-1}, the Cu values ranged from 0.18 to 0.83 mg kg^{-1}, the Fe values ranged from 1.01 to 1.74 mg kg^{-1} and the Mn values ranged from 2.40 to 3.91 mg kg^{-1} irrespective of soil depths and results indicated a increase of micronutrients with the increase in soil depths *i.e.*, 0.43, 0.48, 0.52, 0.54 mg kg^{-1} for Zn , 0.43, 0.46, 0.50, 0.52 mg kg^{-1} for Cu, 1.23, 1.32, 1.38, 1.43 mg kg^{-1} for Fe and 3.03, 3.16, 3.35, 3.53 mg kg^{-1} for Mn for 0-30, 30-60, 60-90 and 90-120 cm soil depths respectively in post-drainage soil samples (Table 3b).

The comparative analysis of micronutrients content of pre and post-drainage soil samples using paired t test is presented in Table 4. The results revealed that there was significant reduction of all the micronutrients in surface layer of post-drainage soil samples, whereas the change in micronutrient concentrations were non-significant in lower depths of post-drainage soil samples.

The analysis results of post-drainage soil samples have recorded lower micronutrients than that of the pre-drainage soil samples in all the corresponding depths. Pre-drainage soil samples contain more available micronutrients in surface layer because of more organic carbon content in surface layer whereas in post-drainage soil samples the micronutrient concentration was generally greater at deeper than at the shallower depths. These results indicated that intensive leaching of water in these soils has caused downward movement of micronutrients nutrients to the deeper soil depth. Similar results were reported by Hamir *et al.* (2013) [3].

Studies on crop performance

The performance of subsurface drainage works installed in Gotur village, Ballari district was studied by monitoring the crop yield in the selected study area. The crop yield of the study area before and after the installation of drainage system is shown in Table 5. The results of the drainage work positively impacted by improving the land conditions. After the installation of the SSD system, the post-drainage yield increased to 42.50 q ha^{-1} as compared to pre-drainage yield of 37.62 q ha^{-1}, which meant an increase of 13.27 percent.

The installation of SSD system resulted in improvement of paddy yield to 4.2 t ha^{-1} compared to 3.7 t ha^{-1} before the drainage works, thus there was increase in yield by 13.27 percent (Fig.1). However, it was the first year after the installation of the SSDs, the yield could be expected to improve considerably during the succeeding seasons with appropriate and better cropping and irrigation management practices. Increase in grain yield due to subsurface drainage was reported in previous studies of Patil *et al.* (2016)

Table 1: Impact of SSD on organic carbon and available nutrients recorded in soil samples collected from different sampling points

Soil depth (cm)	OC (g/Kg)			N (Kg/ha)			P_2O_5 (Kg/ha)			K_2O (Kg/ha)			S (mg/kg)		
	a) Pre-drainage														
	Min	Max.	Mean.	Min	Max.	Mean.	Min	Max.	Mean.	Min.	Max.	Mean	Min.	Max.	Mean
0-30	4.10	4.52	4.35	176.34	268.80	223.04	23.22	40.11	31.06	312.57	523.04	380.67	39.78	49.76	44.58
30-60	3.74	4.31	4.06	168.42	210.42	192.56	18.91	39.40	26.93	336.82	400.56	358.96	35.37	46.73	39.89
60-90	2.17	3.04	2.50	112.28	140.28	128.37	16.99	26.03	22.46	258.45	334.46	303.54	26.31	38.46	31.13
90-120	1.52	2.31	1.93	70.44	119.75	89.25	6.70	25.94	17.66	238.83	323.18	286.80	20.46	33.86	26.62
b) Post-drainage															
0-30	4.95	5.85	5.40	160.45	205.86	187.51	18.30	33.49	25.48	320.16	413.48	365.51	29.71	40.67	36.93
30-60	4.07	4.58	4.31	120.34	260.25	171.39	14.49	27.91	22.08	320.78	381.48	341.87	27.82	38.46	35.05
60-90	2.33	3.53	2.81	93.57	116.90	106.98	13.46	25.73	19.57	246.30	328.10	292.86	21.38	33.89	28.79
90-120	1.38	2.65	2.01	63.46	107.88	80.41	10.38	21.39	16.77	234.15	316.84	281.18	17.36	28.04	23.83

Tables 2: Comparison of soil organic carbon and available nutrients of pre-drainage and post-drainage soil samples using paired t-test

Soil depth (cm)	OC		N		P_2O_5		K_2O		S	
	t_{cal}	t_{cri}	t_{cal}	t_{cri}	t_{cal}	t_{cri}	t_{cal}	t_{cri}	t_{cal}	t_{cri}
0-30	-9.60*	1.86*	8.26*	1.86*	5.03*	1.86*	3.83*	1.86*	14.53*	1.86*
30-60	-4.30*		7.06*		3.38*		2.91*		8.64*	
60-90	-1.69		5.12*		2.28*		2.67*		1.78	
90-120	-0.47		2.34*		0.80		1.12		1.49	

Table 3: Effect of SSD on DTPA-extractable micronutrients (mg kg^{-1}) recorded in soil samples collected from different sampling points

Soil depth (cm)	Zn			Cu			Fe			Mn		
	a) Pre-drainage											
	Min	Max.	Mean.	Min	Max.	Mean.	Min	Max.	Mean.	Min.	Max.	Mean
0-30	0.87	1.17	1.04	0.58	0.84	0.71	1.57	1.97	1.81	3.19	3.71	3.48
30-60	0.68	1.08	0.83	0.38	0.76	0.55	1.41	1.77	1.63	3.01	3.51	3.27
60-90	0.44	0.86	0.64	0.19	0.54	0.38	1.33	1.67	1.54	2.83	3.34	3.06
90-120	0.24	0.61	0.42	0.10	0.42	0.26	1.19	1.50	1.37	2.58	3.10	2.82
b) Post-drainage												
0-30	0.36	0.48	0.43	0.25	0.61	0.43	1.01	1.35	1.23	2.40	3.34	3.03
30-60	0.29	0.60	0.48	0.28	0.64	0.46	1.10	1.46	1.32	2.52	3.54	3.16
60-90	0.30	0.66	0.52	0.18	0.76	0.50	1.18	1.50	1.38	2.98	3.60	3.35
90-120	0.32	0.82	0.54	0.19	0.83	0.52	1.20	1.74	1.43	3.21	3.91	3.53

Table 4: Comparison of DTPA-extractable micronutrients of pre-drainage and post-drainage soil samples using paired t-test

Soil depth (cm)	Zn		Cu		Fe		Mn	
	t_{cal}	t_{cri}	t_{cal}	t_{cri}	t_{cal}	t_{cri}	t_{cal}	t_{cri}
0-30	34.18*	1.86*	15.69*	1.86*	64.99*	1.86*	4.39*	1.86*
30-60	11.38*		7.96*		44.12*		0.95	
60-90	3.33*		-3.59*		39.01*		-11.17*	
90-120	-5.64*		-5.61*		-0.81		-33.66*	

Table 5: Crop yield of study area before and after the installation of subsurface drainage system

Sl. No.	Crop	Before installation of SSD		After installation of SSD		Percent Change
		Area (ha)	Yield (q ha^{-1})	Area (ha)	Yield (q ha^{-1})	Yield
1	Paddy	80	37.62	80	42.50	13.27

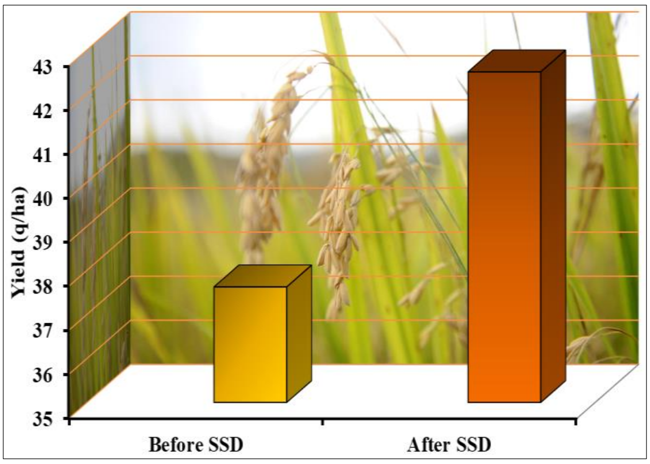

Fig 1: Comparison of paddy yield during pre-drainage and post-drainage SSD at Gotur, Ballari (Tq)

Conclusion

The installation of SSD system resulted in improvement of paddy yield by 13.27 percent and increase in soil organic carbon content in surface soil depths; however, there is decline in values of primary and micronutrients in post SSD soils due to leaching. However, it was the first year after the installation of the SSDs; the yield could be expected to improve considerably during the succeeding seasons with appropriate and better cropping and irrigation management practices.

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