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INFLUENCE OF SUBSURFACE TILE DRAINAGE OPERATIONAL PERFORMANCE ON NUTRIENT LOSSES UNDER SEMI-ARID ENVIRONMENT

Pir Muhammad Khan[1], Muhammad Jamal Khan[2] and Jehan Bakht[3,*]

[1]Department of Agriculture Extension Mardan, KPK Pakistan
[2]Department of Water Management, The University of Agriculture Peshawar, KPK Pakistan
[3]Institute of Biotechnology and Genetic Engineering, The University of Agriculture Peshawar, KPK Pakistan
[*]Correspondence author' s e-mail: jehanbakht@yahoo.co.uk

An appropriate designed subsurface tile drainage system plays an important role in agricultural productivity, reclamation of water logging and also minimizes nutrient losses with better crop management practices. A field study was conducted to find nutrient losses from the subsurface tile drainage system during the year 2011. The tile drainage system was installed under Swabi Salinity Control and Reclamation Project (SCARP) in July, 1997 in the North-West of Pakistan. The study area is being drained by nine subsurface tile drains spaced 100 to 150 m and length ranging from 500 to 700m at design depth of 1.5 m from the ground surface. Drainage water was collected from these tile drains on a monthly basis for the measurement of the drainable amount of macro nutrients. Ammonium, nitrate and potassium losses from unblocked and partially blocked tile drains were 90, 230, 130 g month^{-1} ha^{-1} and 110, 125 and 144 g month^{-1} ha^{-1}, respectively. Phosphorus losses were 0.53 g month^{-1} ha^{-1} from unblocked and 0.44 g month^{-1} ha^{-1} from partially blocked tile drains of the system. Our results also indicated that copper (Cu), iron (Fe) and zinc (Zn) concentrations were considerably higher in blocked (1.65, 8.28 and 1.94 mg kg^{-1}) and partially blocked (1.12, 7.49 and 1.76 mg kg^{-1}) than unblocked (1.07, 5.96 and 1.65 mg kg^{-1}) tile drains command area. In conclusion, it is recommended that over irrigation should be avoided to minimize the nutrient losses and contamination of surface and ground water resources.
Keywords: Sub-surface tile drainage system, nutrient losses, unblocked and partially blocked tile drains

INTRODUCTION

The total geographical area of Pakistan is 79.61 mha cultivated area of about 22.06 million ha and its economy mainly depends on irrigated agriculture, which is 73% of the total cultivated area. Being dominant sector of Pakistan's economy, it contributes about 24% to the country's GDP, employs 48.4% of total workforce and facilitates 70% of export revenues (MINFAL, 2013). Although, the country has a history of successful irrigation, as a results of continuous evolvement in irrigation and resulting seepage from the canal system, agricultural lands of Pakistan have suffered from the problem of water logging and salinity, one of the main threats to rural development in Pakistan. Some parts of Pakistan have alluvial deposit and consist of poorly drained soils. For improved crop production these area may be artificially drained through subsurface drainage systems. Subsurface drainage systems dispose extra water and enhance crop production; however, it also increases the leaching of nitrate nitrogen (NO_3-N) from the respective agricultural area. This leaching is mainly caused by an increase in subsurface drainage rate, which remove NO_3-N from the soil profile into the main drain (Vos *et al*., 2000; Kladivlo *et al*., 2004; Rekha *et al*., 2011). The excesses removal of NO_3-N, particularly from productive agricultural areas is recognized as a major non-point source of contamination of the water resources.

Water in a stream comes out usually from overland flow as well as generally from groundwater seepage into the bed of streams (Fetter, 2001). A portion of the groundwater is lost by the tile drains where it is available. Leveled topography and well maintained subsurface drainage systems have created difficulties in understanding the hydrology of a watershed. They have produced more problems than solutions about water and crop management in those areas (Mitchell *et al*., 2000; Pir *et al.,* 2014). Although, surface runoff occurs sometime in these highly fruitful areas (Mitchell *et al*., 2001), more questions are often upraised about the individual assistances of subsurface drainage systems and conventional base flow to total watershed nutrient loadings, and the dynamics of the N cycle in such watersheds (Dinnes *et al*., 2002; Kladivko *et al*., 2004; Rurak *et al*., 2010). A suitable water table management rules for crop production and environmental profits may be developed, if we know the answer of these questions. Neither the base flow into drainage drains in subsurface-drained watersheds areas is thoroughly understood nor has it been widely documented by field research. To calculate the influences of tile drains drainage schemes on water quality, a thought of tile drains-drained watershed hydrology, more specifically the involvement of flow and nutrient (NO_3-N) removal through tile drains and base flow from the subsurface tile drainage environment is more vital. The present study investigate the leaching of macro and micro nutrients in blocked and unblocked tile drains command area of Swabi Khyber Pukhtunkhwa (KPK), Pakistan.

MATERIALS AND METHODS

Description of Research Site: The sub-surface tile drainage system in Swabi SCARP, KPK Province, Pakistan was initiated in July 1995 and completed in June 1999. Swabi SCARP is located partly in Districts Mardan, Charsadda, Swabi and Malakand Agency and covers a total gross command area of 113,765 ha, out of which 65% is cultivable. About 80,081 ha of project area is under command of Upper Swat Canal while 5,385 ha receive irrigation supplies from Kalapani distributaries of the Lower Swat Canal. The integrated Swabi SCARP envisages remodeling of 457 km length of irrigation channels, repair of tunnel, remodeling of head works and embankments (to save the land from spilling over of the natural drainage channels in 33,603 ha), remodeling of 530 km of surface drains and installation of pipe drains in 28,340 ha. It has a designed water table depth of 1 m (3.3 feet) from the ground surface. The designed drainage rate for spacing calculations was 2 mm/d (0.0062 m/d) and the designed depth to lateral center was 1.8 m (6 ft). Sub-surface lateral tile drains depth to lateral center varied from 1.6 to 2.1 m (5.25 to 7 feet) with an average depth of about 1.85 m.

The present study was conducted at research site of Shahbaz Ghari Pilot Project area of Swabi SCARP. The research site is located Eastward from the center of Mardan city about 15 km away on Mardan-Swabi Road. Singular sub-surface tile drainage system was installed in the area and its construction was completed along with the rehabilitation of Shahbaz Ghari drain in July 1997. A little modification was made in the drainage of the research site for direct outfall into the surface drain instead of joining with collectors. Laterals at the research site were installed at 1.5 m depth from the ground surface. The length of laterals varied from 500 to 700 m. Nine laterals have been installed at site with spacing varying from 100 to 150 m. The construction of 33 observation wells has been completed at site after installation of tile drains. Water table depths data were collected from these observation wells during 1998 while in 2011 most of the observation wells were taken out by the farmers intentionally or due to farm operation, therefore 18 more observation wells were installed exactly on the same locations. Lay out of drains at site is presented in Fig. 1a.

Fluctuation in water table and drainage co-efficient: The fluctuation in water table depth, drainage co-efficient and rain fall during the study period (Jan. 2011 to Dec. 2011) is shown in Fig. 1b. The water table from the ground surface ranged from 2.09 m to 0.98 m. The water table got shallower with heavy rain fall events during monsoon period (July to September) from 1.69 m to 0.98 m. Similarly, the drainage co-efficient (q) also increased from 0.41 mm per day to 1.88 mm per day during monsoon period (July to September).

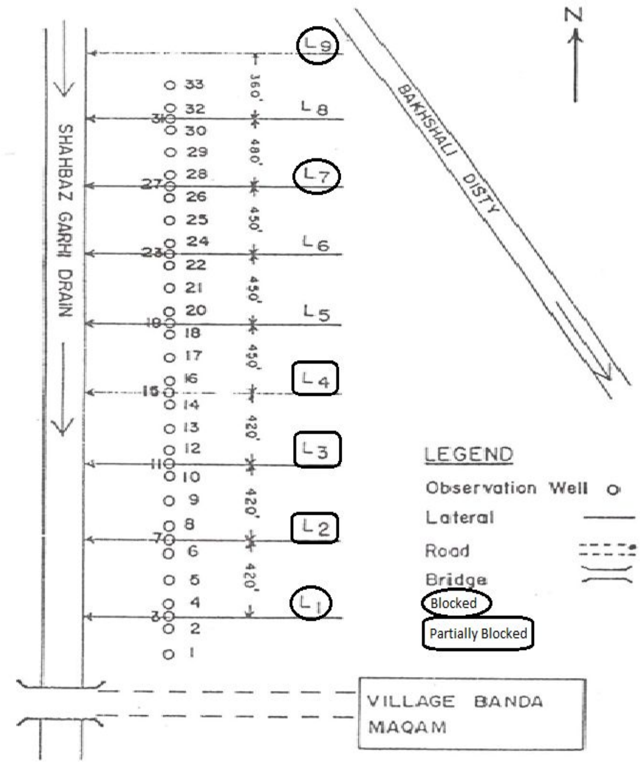

Figure 1a. A lay out map of the subsurface tile drains at site 1-A

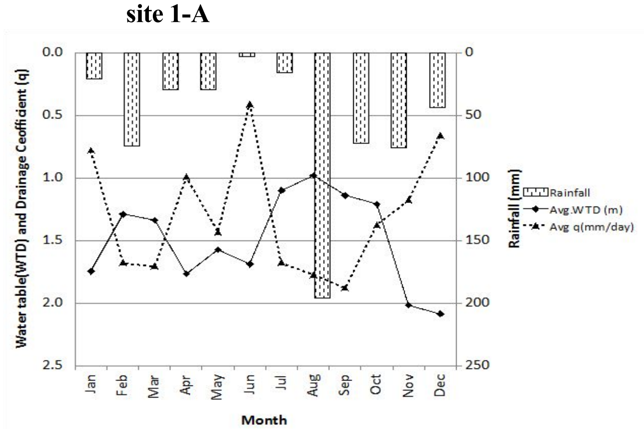

Figure 1b. Fluctuation in water table and drainage co-efficient

NPK concentration in grain and plant tissue samples of major crops: Grain and plant tissue samples were collected from selected fields of major crops (wheat, maize, rice and sugarcane) in each blocked, partially blocked and unblocked subsurface tile drains command area at the time of maturity. The collected samples were used for the determination of NPK from grains and plant tissues of all major crops. The NPK in plant tissue was determined as described in Jones and Steyn (1973).

Soil samples collection: For various physico-chemical characteristics of the soil as influenced by depths, six (6) samples from each tile service area were collected at different soil depths with 30 cm interval respectively. In this way 54 samples from the whole research site were collected and put in labeled plastic bags for two times in a season (winter or summer), usually at the start and end of the season. The collected samples were analyzed for macro and micro nutrients in the laboratory. Amonium-N and NO_3^--N was determined by Kjeldahl method (Beathgen and Alley, 1989). Phosphorus and potassium were determined according to the methods of Ashworth and Mrazek (1995). Micro-nutrients were determined as described by Isaac and Kerber (1971).

Statistical Analysis: Analysis of variance techniques (ANOVA) was used for the interpretation of data using a simple factorial design based on the number of variables in the study. Statistical analysis were performed using Statistix 8.1 computer programme. The effects of various variable factors were differentiated by using Least Significant Difference (LSD) test (Steel *et al*., 1997).

RESULTS AND DISCUSSIONS

There were significant ($p<0.05$) differences in grain N and K content of all the three major crops. In case of P, maize grain had higher P (0.32%) than wheat (0.22%) and rice (0.24%) crops (Table 1).

Table 1. NPK in grains and plant tissues of wheat, maize, rice and sugar cane.

Crop	N	P	K
		Grain (%)	
Wheat	1.35 b	0.22 b	0.43 a
Maize	1.73 a	0.32 a	0.34 c
Rice	1.21 c	0.24 b	0.39 b
		Plant tissue (%)	
Wheat	0.31 d	0.038 a	1.52 a
Maize	0.40 bc	0.032 b	1.28 b
Rice	0.44 a	0.039 a	1.48 a
Sugarcane 1st year	0.43 ab	0.034 ab	1.47 a
Sugarcane 2nd year	0.39 c	0.037 ab	1.50 a

Means followed by different letters are statistically significant at P<0.05

Nitrogen content in maize grain was significantly ($p<0.05$) higher than rice and wheat crops grown in blocked, partially blocked and unblocked tile drains command area which showed that maize was more exhaustive crop for N than wheat and rice crops (Table 2). Nitrogen percentage was also significantly ($p<0.05$) higher in the grains of wheat and maize (1.55 and 2.13%, respectively) crops grown in unblocked tile drains command area than the rest of two tile drains area due to a better N uptake environment in the root zone. A reverse trend was noted in N content of rice grain as its concentration was higher (1.40%) in crops grown in blocked tile drains command area as compared to unblocked (0.97%) tile drains command area. The probable reason could be that as rice is a water loving crop and grow well under ponded condition. The mean N percentage (1.55%) of all the three crops grown in unblocked tile drains command area was significantly ($p<0.05$) higher than the rest of the tile drains area. Non significant ($p<0.05$) differences were recorded in the mean grain N percentage of all crops grown under blocked and partially blocked tile drains command area.

Table 2. NPK in grain of different crops grown at the study area

Crop	Tile drains Status			Mean
		Nitrogen (N %)		
Block	**Blocked**	**Partially Blocked**	**Unblocked**	
Wheat	1.18 f	1.31 df	1.55 b	1.35 b
Maize	1.44 c	1.63 b	2.13 a	1.73 a
Rice	1.40 cd	1.27 ef	0.97 g	1.21 c
Mean	**1.34 b**	**1.41 b**	**1.55 a**	
		Phosphorus (P %)		
Wheat	0.17 d	0.20 c	0.30 b	0.22 b
Maize	0.18 c	0.30 b	0.47 a	0.32 a
Rice	0.42 a	0.19 c	0.11 d	0.24 b
Mean	**0.26 b**	**0.23 b**	**0.29 a**	
		Potassium (K %)		
Wheat	0.33 e	0.43 bc	0.54 a	0.43 a
Maize	0.22 f	0.35de	0.45 b	0.34 c
Rice	0.52 a	0.39 cd	0.25 f	0.39 b
Mean	**0.36 b**	**0.39 a**	**0.42 a**	

Means followed by different letters are statistically significant at P<0.05

The NPK contents of wheat and maize grain increased from crops grown in blocked to unblocked tile drains command area, while in rice crop a reverse trend was observed as its percentage decreased from blocked to unblocked tile drains command area due to its ecology for shallow water table. It is clear from Table 2 that P uptake of wheat and maize crops was higher (0.30 and 0.47%, respectively) in area under good drainage system having proper aeration in the root zone, while rice roots require no aeration and grow well under ponded or submerged condition, therefore its percentage was two times higher (282%) than crops grown in unblocked tile drains command area. The same pattern was observed for grain K content as previously recorded for P. Its percentage was relatively higher in wheat (0.43) than maize (0.34) and rice (0.39) crops grown in the study area. Non significant ($p<0.05$) variations were found in the mean

K concentrations of all crops grown on partially blocked and unblocked tile drains command areas, while its mean percentage was significantly ($p<0.05$) lower in crops grown on blocked tile drains command area. Significant ($p<0.05$) differences were observed in the N concentration of plant tissue of all crops (Table 3).

Table 3. NPK in plant tissue of different crops grown at the study area.

Crop	Tile drains Status			Mean
	Nitrogen (N%)			
	Blocked	**Partially Blocked**	**Unblocked**	
Wheat	0.25 i	0.29 hi	0.40def	0.31 d
Maize	0.30 hi	0.39 ef	0.53 b	0.40bc
Rice	0.59 a	0.44 de	0.30 gh	0.44 a
Sugarcane 1st year	0.49bc	0.44 de	0.37 f	0.43 ab
Sugarcane 2nd year	0.44 cd	0.38 f	0.35 fg	0.39 c
Mean	**0.41 a**	**0.39 b**	**0.39 b**	
	Phosphorus (P%)			
Wheat	0.02 e	0.03 c	0.06 a	0.038 a
Maize	0.02 c	0.03 cd	0.05 b	0.032 b
Rice	0.06 a	0.04 c	0.02 de	0.039 a
Sugarcane 1st year	0.05 ab	0.03 c	0.02 e	0.034 ab
Sugarcane 2nd year	0.05 ab	0.03 c	0.02 de	0.037ab
Mean	**0.041 a**	**0.033 b**	**0.033 b**	
	Potassium (K%)			
Wheat	1.34 cde	1.51 b	1.70 a	1.52 a
Maize	1.14 f	1.24 ef	1.45bc	1.28 b
Rice	1.72 a	1.40 bcd	1.31 de	1.48 a
Sugarcane 1st year	1.70 a	1.46 b	1.26 e	1.47 a
Sugarcane 2nd year	1.77 a	1.46 b	1.28 e	1.50 a
Mean	**1.53 a**	**1.41 b**	**1.40 b**	

Means followed by different letters are statistically significant at $P<0.05$

Nitrogen percentage was the highest for rice followed by maize and sugarcane. The mean N contents were non-significant ($p>0.05$) in plant tissues of different crops grown in partially blocked and unblocked tile drains command area of the system, however, had significantly ($p<0.05$) higher percentage under blocked tile drains command area due to its increasing trend in sugarcane crop from unblocked to blocked tile drains command areas of the system. The NPK concentration in plant tissues of wheat and maize crops increased with improvement in drainage from blocked to unblocked tile drains command area, while on the other hand it decreased for rice, sugarcane 1st and 2nd year crops. The reason may be that wheat and especially maize crop were highly susceptible to water logging and requires proper aeration in the root zone, while on the other hand rice and sugarcane crops can uptake nutrients even under shallower water table conditions. These results agree with the findings of Choudhury *et al*. (2000) and Saifullah *et al*. (2002) who observed similar trends for rice and wheat crops respectively. Significantly ($p<0.5$) higher percentage of NPK was found in plant tissues collected from the command area of blocked sub-surface tile drainage system. However, an average N, P and K percentages were non-significant ($p>0.05$) in plant tissues of different crops grown on partially blocked and unblocked tile drains command area respectively. The overall mean K percentages of almost all crops plant tissues were non-significant, except for maize crop. The NPK in plant tissues of wheat and maize crops were considerably higher than rice and sugarcane grown in unblocked tile drains command area (Table 3). Similar NPK percentages in grain and plant tissues of maize, wheat and rice were also reported by Ranjha *et al*. (2002), Hussaini *et al*. (2008), and Ghaffar *et al*. (1999).

Depth wise macro nutrients concentration in soil of blocked and unblocked tile drain service area: Figure 2 shows the total N percentage in blocked, partially blocked and unblocked tile drains command area at different depths of soil from the ground surface.

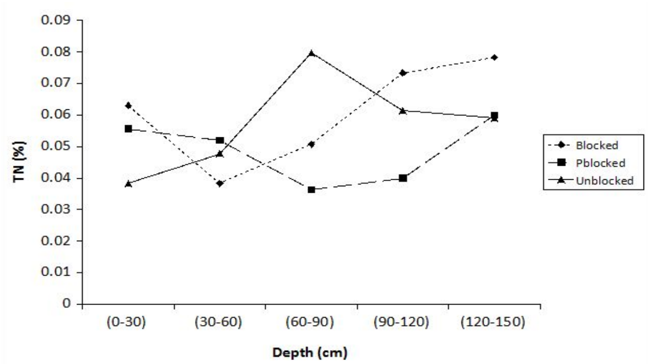

Figure 2. Depth wise variation in soil TN in blocked and unblocked tile drains command area.

The total N percentage occurred in the range of 0.04 to 0.08% in 0-150 cm depth of soil in blocked, partially blocked and unblocked tile drains command area, respectively. The difference in total N percentage was non-significant ($p>0.05$) between 60-120 cm depth from the ground surface, while it was significantly ($p<0.05$) different between 0-30, 30-60 and 120-150 cm depths from the ground surface. The total N (TN) in un-blocked sub-surface tile drainage system showed an increasing trend from surface layer (0-30 cm) to mid layer (60-90 cm) and then decreased in deeper layer (120-150 cm). In general total N percentage showed an increasing trend from surface layer

(0-30 cm) to deeper layer (120-150 cm). Similar pattern of total N was observed in partially. The highest average N percentage of 0.066% was recorded in 120-150 cm from the ground surface in blocked, partially blocked and unblocked tile drains command area, which decreased to 0.052% from the ground surface. The percent N in soil of blocked tile drains command area was 0.06% in 0-30 cm depth from the ground surface, which was reduced to 0.04% in 30-60 cm and increased again in 60-150 cm depth from the ground surface. The same changes were recorded in unblocked tile drains command area along with an abrupt increase to 0.08% in the range of 60-90 cm depth, while a decreasing trend was noted in 0-90 cm range and increased again in the range of 90-150 cm from the ground surface in partially blocked tile drains command area.

The data indicated in Figs. 3 and 4 clearly suggested that the concentration of ammonium (NH_4^+) and NO_3^- in the soil increased in ascending order from blocked to the partially blocked and finally to the unblocked tile drains command area. The mean NH_4^+ concentrations decreased from 13.09 to 10.24 mg kg^{-1} with increase in depth from the ground surface. Higher concentration of NH_4^+ was observed in the first layer of 0-30 cm depth of soil from the ground surface due to the application of nitrogenous fertilizers and farm yard manure (FYM). The concentration in the unblocked tile drains command area was higher than blocked and partially blocked tile drains command area. The reason may be due to higher rates of nitrification in unblocked and de-nitrification in blocked tile drains command area. Nitrification of NH_4–N to NO_3 was the lowest under flooded condition (Zia *et al*., 2001). De-nitrification is a microbial process that takes place mostly under anaerobic (waterlogged) conditions, and is highly sensitive to temperature and the redox potential. Drainage limited de-nitrification to about 65% of losses from un-drained soil (Colbourn and Dowdell, 1984). With descent a general decrease in the mean NO_3^- concentration below 60 cm depth of soil from the ground surface was noted. This decrease in macronutrients concentrations with increase in depth from the ground surface was also reported by Memon *et al*. (2001), Samreen *et al*. (2003) and Dang *et al*. (2007).

The data suggested that NH_4^+ and NO_3^- concentrations were higher (11.46 and 10.38 mg kg^{-1}) up to a depth of 60 cm. Significant ($p<0.05$) differences occurred between 0-30, 30-60 and 60-90 cm depth from the ground surface, while these differences were non-significant ($p>0.05$) in 90-120 120-150 cm depths. The concentrations of both NH_4^+ and NO_3^- decreased to 10.95 and 8.94 mg kg^{-1} below 60-90 cm and 90-150 cm depths, respectively and from the ground surface, it became almost constant (Figs. 3 and 4). Singh *et al*. (2007) reported a gradual increase in NO_3^- accumulation in 0-30 cm layer from the ground surface. Nitrate concentrations were significantly different in the range of 0-60 and 60-150 cm from the ground surface, while within these two ranges its concentration was non-significant. The higher concentrations of NH_4^+ and NO_3^- in the top 0-60 cm range may be the result of nitrogenous fertilizers, FYM application and incorporation of crop residues into the soil. Similar result was also reported by Samreen *et al*. (2003).

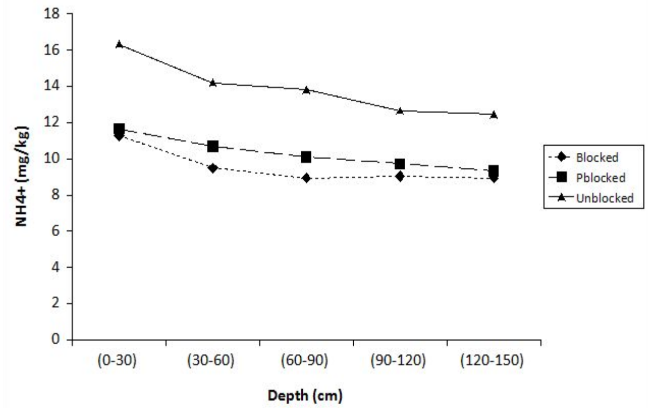

Figure 3. Depth wise variations in soil ammonium (NH_4) in blocked and unblocked tile drains command area.

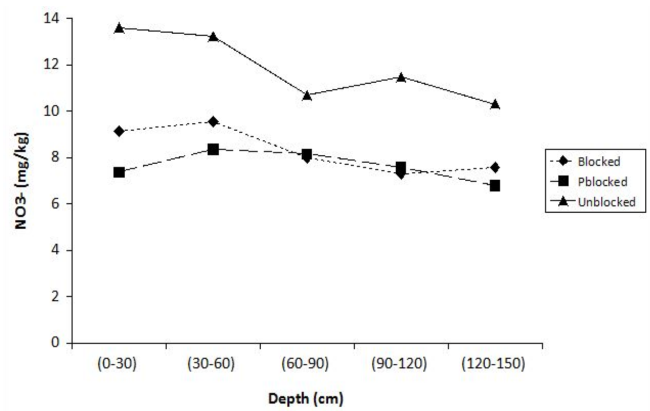

Figure 4. Depth wise variation in soil nitrate (NO_3) in blocked and unblocked tile drains command area.

Phosphorus concentrations were higher in 30-60 and 120-150 cm from the ground surface with non-significant ($p>0.05$) differences between the two layers (Fig. 5). The relatively lower concentration of P in the upper soil layer (0-30 cm) may be due to crop uptake, leaching and losses in drainage water, while its higher concentration in middle layer (30-60 cm) may be the creation of hardpan and unused of deep ploughing. The higher concentration of P in 120-150 cm from the ground surface may be the result of its accumulation in that zone. Phosphorus concentration was higher in blocked tile drains than partially blocked and unblocked tile drains command area due to its partial and continuous losses with drainage water. Potassium concentration was significantly ($p<0.05$) different in all soil layers from the ground surface (Fig. 6).

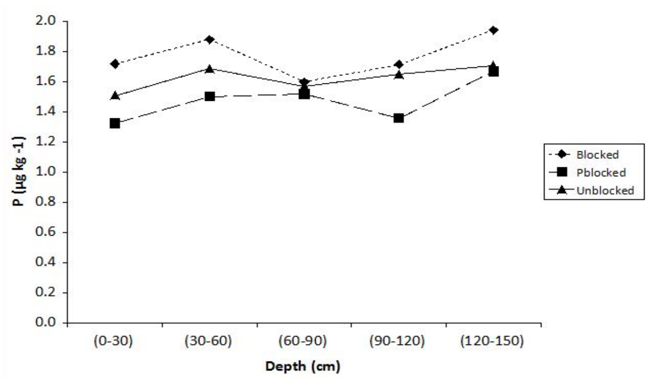

Figure 5. Depth wise variations in soil phosphorus (P) in blocked and unblocked tile drains command area.

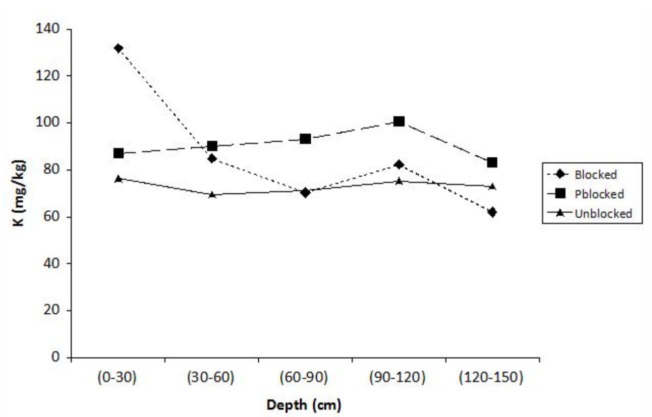

Figure 6. Depth wise variations in soil potassium (K) in blocked and unblocked tile drains command area.

Potassium concentration was higher in the top 0-30 cm layer below which, it decreased to a depth of 90 cm and increased again in the range of 90-120 cm depth due to its slight accumulation in that zone. Its concentration decreased from 98.42 to 72.66 mg kg^{-1} when moved from top (0-30 cm) to bottom layer (120-150 cm) of the soil from the ground surface. Similar trend was also observed by Khan and Bhatti (2000) and Jobbagy and Jakson (2001). Most of the farmers of the study area were reluctant to apply P and K fertilizers as they were poor and uneducated. Its concentration was almost higher in partially blocked than blocked and unblocked tile drains command area, except in the first layer (0-30 cm) of blocked tile drains command in which the concentration was the highest (131.88 mg kg^{-1}) from the rest of two tile drains command areas. An increasing trend was recorded in partially blocked tile drains from 87.05 to 100.60 mg kg^{-1} in 0-120 cm depth from the ground surface, below which it decreased to 83.15 mg kg^{-1} in the range of 120-150 cm from the ground surface. In unblocked tile drains command area its concentration was higher (76.34 mg kg^{-1}) in 0-30 cm depth from the ground surface which decreased to 69.37 mg kg^{-1} in the second layer (30-60 cm) of the soil profile. An increasing trend from 69.37 to 75.26 mg kg^{-1} was observed in 30-120 cm depth from the ground surface in unblocked tile drains command area below which it decreased slightly in 120-150 cm depth from the ground surface. Memon *et al*. (2001) reported that nutrients concentration such as phosphorus and potassium which are strongly cycled by plants were higher in the top soil (upper 20 cm).

Ammonium and nitrate (NH_4^+ and NO_3^-) ***concentrations in soil:*** Soil NH_4^+ and NO_3^- concentrations were significantly ($p<0.05$) higher (45.49 and 42.72%) in unblocked tile drains than blocked tile drains command area (Table 4). Similarly, their concentrations were non-significant ($p>0.05$) in partially blocked and blocked tile drains command area. The reason may be due to higher rate of nitrification in unblocked and de-nitrification in blocked tile drains command area. Similar findings are also reported by Randall and Goss (2008). Nitrification of NH_4–N to NO_3 was the lowest under flooded condition (Zia *et al*., 2001; Dinnes *et al*., 2002). De-nitrification is a microbial process that takes place mostly under anaerobic (waterlogged) conditions, and is highly sensitive to temperature and the redox potential. Drainage limited de-nitrification to about 65% of losses from un-drained soil (Colbourn and Dowdell, 1984).

Table 4. Primary macro nutrient concentrations in blocked, partially blocked and unblocked tile drains command area

	Tile drains Status		
Obs. No	**Blocked**	**Partially Blocked**	**Unblocked**
		NH_4^+ (mg kg^{-1})	
1	8.4	9.68	13.53
2	9.95	10.38	13.77
3	10.27	10.85	14.35
Mean	**9.54 b**	**10.30 b**	**13.88 a**
		NO_3^- (mg kg^{-1})	
1	8.4	7.12	12.25
2	7.67	7	11.9
3	8.87	8.87	11.43
Mean	**8.31 b**	**7.66 b**	**11.86 a**

Means followed by different letters are statistically significant at P<0.05

Depth wise micro nutrients concentration in soil: Copper concentration in blocked tile drains command area was significantly ($p<0.05$) higher than partially blocked and unblocked tile drains command area (Table 5).

Table 5. Micro nutrient concentrations in blocked, partially blocked and unblocked tile drains command area

Depth	Drainage			
	Blocked	Partially blocked	Unblocked	Mean
		Cu^{2+} (mg kg^{-1})		
(0-30)	1.91	1.36	1.32	1.53 a
(30-60)	1.69	1.06	1.03	1.26 b
(60-90)	1.63	1.05	1.08	1.26 b
(90-120)	1.56	0.98	0.91	1.15 c
(120-150)	1.46	1.13	0.99	1.19 c
	1.65 a	1.12 b	1.07 b	
		Fe^{3+} (mg kg^{-1})		
(0-30)	8.56	8.87	7.78	8.40 a
(30-60)	8.31	8.56	6.19	7.69 b
(60-90)	8.79	6.05	5.38	6.74 c
(90-120)	8.13	7.33	5.19	6.88 c
(120-150)	7.60	6.64	5.26	6.50 d
	8.28 a	7.49 a	5.96 a	
		Zn^{2+} (mg kg^{-1})		
(0-30)	0.23	0.20	0.18	0.20 a
(30-60)	0.17	0.17	0.18	0.17 b
(60-90)	0.23	0.17	0.14	0.18 b
(90-120)	0.15	0.16	0.14	0.15 c
(120-150)	0.19	0.18	0.18	0.18 b
	0.194 a	0.176 a	0.164 a	
		Mn^{4+} (mg kg^{-1})		
(0-30)	4.08	4.96	4.17	4.40 a
(30-60)	2.90	4.11	2.98	3.33 b
(60-90)	3.17	3.53	3.47	3.39 b
(90-120)	3.09	3.91	2.77	3.26 b
(120-150)	2.90	3.90	3.44	3.42 b
	3.23 a	4.08 a	3.37 a	

Means followed by different letters are statistically significant at P<0.05

The concentration of copper (Cu) in soil decreased with an increase in depth from the ground surface. The higher concentration of Cu was noted in the first 0-30 cm layer of soil from the ground surface due to incorporation of crop residues and application of FYM in 0-30 cm range of soil. These results agree with Jaing *et al.* (2009). Iron (Fe) is another important micro-nutrient and like Cu, its deficiency would also adversely affect crop productivity of the area. Iron concentration was significantly ($p<0.05$) lower in unblock tile drains than block and partial block tile drains command area as shown in Table 5 which may be due to its losses with continuous drainage from the system. Similarly, partially blocked tile drains command area had lower concentration of Fe than blocked tile drains command area due to partial drainage. These tile drains showed a negative aspect of sub surface tile drains drainage system installed in the study area. Iron concentration of soil in unblock tile drains command area decreased down the soil in a systematic pattern up to a depth of 60-90 cm range below which it became constant. However, Fe concentration in soil of blocked tile drains command was almost the same with a little decrease below 90 cm depth from the ground surface. Similar trend was also observed in soil of partial blocked tile drains command area except with an abrupt down in 60-90 cm range. The mean concentration of Fe decreased from 8.40 to 6.50 mg kg^{-1} with increased in depth from top (0-30 cm) to bottom (120-150 cm) layer of the soil from the ground surface. Similar results are also reported by Jaing *et al*. (2009).

Table 5 shows the manganese (Mn) concentrations in blocked, partially blocked and unblocked tile drains command area at different depths of soil from the ground surface. Manganese concentrations in the soil of all tile drains command areas were higher in 0-30 cm depth from the ground surface. Each tile drains behaved differently below 30 cm depth, however, non-significant ($p>0.05$) variations were observed in soil of all tile drains command areas. Manganese concentrations were slightly higher in all depths of partially blocked tile drains command than the remaining tile drains but this difference was non-significant statistically. Farman and Bhatti (2000) reported similar concentration for the soil profile of Malakand Agrncy KPK. Like other micro nutrients the main sources of Mn were also FYM, irrigation water and crop residue incorporation into the soil as the farmers of the study area were poor and uneducated. With an increase in depth from ground surface a striking decrease was observed in zinc (Zn) concentration of all tile drains command area, however, in 120-150 cm it increased slightly due to a little accumulation in that zone (Table 5). A sudden increase was also noted in the 60-90 cm range of blocked tile drains command area. Like other micro nutrients, highest concentrations of Zn were recorded in the first layer (0-30 cm) from the ground surface in soil of all tile drains command area. Zinc was found almost deficit throughout the soil profile and its concentration was less than 0.50 mg kg^{-1}. From these results it can be concluded that the concentrations of Cu, Fe, Mn and Zn were higher in the range of 0-30 cm depth of soil. The higher concentration of micro nutrients in the top (0-30 cm) layer may be the result of FYM application and incorporation of crop residues in the top (0-30 cm) layer of the soil. These micro nutrients decreased below 30 cm from the ground surface and in the range of 90-150 cm depth; their concentrations became almost constant. Similar results were also reported by Jiang *et al*. (2009) and Gul *et al*. (2013).

Micro nutrients in blocked and unblocked tile drains command area :Our results indicated that the mean values of Cu, Fe and Zn were considerably higher in blocked (1.65, 8.28 and 1.94 mg kg^{-1}) and partially blocked (1.12, 7.49 and 1.76 mg kg^{-1}) than unblocked (1.07, 5.96 and 1.65 mg kg^{-1}) tile drains command area (Table 5). There could be two reasons for this trend. Firstly, due to higher uptake by the crops as the root zone environment for the crop uptake was more favorable in partially blocked and unblocked tile drains command area as compared to blocked tile drains command area because of good drainage system. Secondly, due to continuous drainage from unblocked and partial drainage from partially blocked tile drains, a substantial amount of these micro nutrients might be lost through the system continuously with drainage water. Zinc was found deficit in all soils of the drainage system. Farmers of the area were not applying micro-nutrients into their fields. The main sources of micro-nutrients were FYM, crop residue and irrigation water. Similar micronutrients values were reported by Iqbal *et al*. (1987), and Khattak and Parveen (1987) for the soils of Peshawar, Mardan and other parts of the Pakistan.

Conclusion: Highest percentages of NPK were observed in wheat and maize grains as well as in plant tissue in un-blocked tile drain command area as compared to blocked. No significant differences were observed in NPK concentration in different soil layers (0-150 cm). Significantly higher concentration of ammonium and nitrate in soil was found in un-block sub-surface tile drain compared to partially blocked and block sub-surface command area. The concentration of Cu, Zn, Fe and Mn in soil decreased with an increase in depth from the ground surface.

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